



HAL
open science

Modélisation d'un système de maîtrise des risques liées à la sous-traitance : Un cas dans l'industrie Française Nucléaire

Diana Paola Moreno Alarcon

► To cite this version:

Diana Paola Moreno Alarcon. Modélisation d'un système de maîtrise des risques liées à la sous-traitance : Un cas dans l'industrie Française Nucléaire. Business administration. Université Paris sciences et lettres, 2021. English. NNT : 2021UPSLM075 . tel-04043162

HAL Id: tel-04043162

<https://pastel.hal.science/tel-04043162>

Submitted on 23 Mar 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



THÈSE DE DOCTORAT
DE L'UNIVERSITÉ PSL

Préparée à MINES ParisTech

**Modeling of Subcontracting-related Risk Management Control System:
A Case Study in the French Nuclear Industry**

**Modélisation d'un Système de Maîtrise des Risques liées à la Sous-
traitance : Un Cas dans l'Industrie Française Nucléaire**

Soutenue par

**Diana Paola MORENO
ALARCON**

Le 15 décembre 2021

Ecole doctorale n° 621

**ED Ingénierie des Systèmes,
Matériaux, Mécanique,
Energétique**

Spécialité

**Sciences et Génie des
Activités à Risque**

Composition du jury :

Jean-Philippe DENIS Professeur, Université Paris Sud / Paris Saclay	Président
Marc BIDAN Professeur, Université de Nantes	<i>Rapporteur</i>
Aziza LAGUECIR Professeur, EDHEC	<i>Rapporteur</i>
Edward H. POWLEY Associate Professor, Naval Postgraduate School	<i>Examineur</i>
Jean-François VAUTIER Docteur, CEA	<i>Examineur</i>
Aude DEVILLE Professeur, IAE Nice - Université Côte d'Azur	<i>Directrice de thèse</i>
Franck GUARNIERI Professeur, Mines ParisTech PSL	<i>Directeur de thèse</i>

Acknowledgements

I would like to extend my sincere appreciation to the following people who provided invaluable support throughout this long journey toward the completion of this Ph.D. thesis. Your unwavering support, encouragement and dedication were a huge contribution to the drive to pursue and complete this research project. As a result, it is with great pleasure that I acknowledge each of your roles.

First of all, I would like to thank Franck Guarnieri, my Ph.D. Director at the Crisis and Risk Research Centre (CRC) of Mines ParisTech PSL for his insight, advice, and for always finding time, despite his busy schedule, to address my queries or concerns. A special thanks to Aude Deville, for her role as my Director both during my Masters of Research in Management Science (M.Rsg) and during the Ph.D. She was instrumental in educating me and imparting her knowledge of the Research world which allowed me not only to access this Ph.D. but also made a lasting impression.

I would also like to express my sincere gratitude to the Director of Nuclear Safety and Security (*Directeur de la Sécurité et de la Sûreté Nucléaire, DSSN*) at the French Alternative Energies and Atomic Energy Commission (*Commissariat à l'énergie atomique et aux énergies alternatives, CEA*) who, like his predecessor, made this thesis possible. Thank you to the CEA personnel including the Facility Managers, Middle Managers and subcontractors who graciously participated in the study. In particular, I have the highest gratitude for my Industrial Tutor, Dr. Jean-Francois Vautier, whose patience, motivation, continuous support and immense knowledge in Safety and Human and Organizational Factors (HOF) at the CEA proved to be invaluable through every step of this project. I am also grateful to Guillaume Hernandez, Human Factor expert at the CEA, for his kindness and valuable input on Human Factors in the Nuclear Industry throughout these years.

I would like to thank the President of the Jury Pr. Jean-Philippe Denis, as well as Jury members Pr. Aziza Laguecir and Pr. Marc Bidan for taking the time to read and evaluate this dissertation, as well as to Dr. Jean-François Vautier and Pr. Edward H. Powley for their participation in the Jury.

This thesis has also benefited from the suggestions and contributions of the participants from the following seminars, conferences and workshops:

- EDEN Doctoral Seminar on Qualitative Methods in Business Research, May 9-12, 2016, Brussels
- 37th Congress of the Francophone Accounting Association (AFC), May 18-20, 2016, Clermont-Ferrand
- Barrier Based Risk Management Event, September 19-20, 2016, Amsterdam
- EDEN Doctoral Seminar on Case Studies in Business and Management, November 21-25, 2016, Helsinki
- 33rd European Accounting Association (EAA) Doctoral Colloquium, May 6-12, 2017, Valencia
- 38th Congress of the Francophone Accounting Association (AFC), May 29-31, 2017, Poitiers
- 39th Congress of the Francophone Accounting Association (AFC), May 15-17, 2018, Nantes
- 2nd French-Anglo Seminar of the Nuclear Energy Society (SFEN), October 17, 2018, Paris
- 11th Institute for Risk Management (IMdR) Young Engineers and Researchers' Day, March 15, 2019, Paris
- 11th Management Control Association (MCA) Doctoral Symposium, June 25-26, 2019, London

- 10th International Conference on Applied Human Factors and Ergonomics (AHFE), July 24-28, 2019, Washington DC
- 29th European Safety and Reliability (ESREL) Conference, September 22-26, 2019, Hanover
- 12th Annual CEA Human and Organizational Factor (HOF) Day at the French Alternative Energies and Atomic Energy Commission (CEA), November 5, 2019, Marcoule

Additionally, I would like to extend my gratitude to my colleagues both at Mines ParisTech and at the French Civil Aviation University (*École Nationale de l'Aviation Civile, ENAC*) for your encouragements and institutional support.

I gratefully acknowledge our family friend Daryl Ward for his support and second generation of thesis editorial assistance.

I would also like to evoke an enormous thank-you to my close friends for their immense love, patience, and unwavering support throughout this arduous journey. You know who you are and how grateful I am to each of you.

Finally, I thank my family and parents, especially my mom, Dr. Melva Alarcon Zuluaga, who unselfishly offered guidance every step of the way, motivated me towards the conclusion of this work, and dedicated herself to ensuring its success.

Diana Paola MORENO ALARCON

Table of Contents

Acknowledgements	1
Table of Contents	3
List of Figures	7
List of Tables	9
Acronyms and Abbreviations	10
<i>Introduction générale (Résumé en Français)</i>	11
<i>General Introduction</i>	19
1. Theoretical Foundations	22
1.1. Management Control System (MCS) Literature	22
1.2. Risk and Enterprise Risk Management (ERM) Literature	23
1.3. Inter-organizational Relationship (IOR) Control Literature	25
2. Research Question(s)	26
3. Theoretical Framework of the Research	28
3.1. General Systems Theory	28
3.2. Contingency Theory	28
4. Methodology	29
5. The purpose of the thesis and the contributions	30
6. Thesis Structure	32
<i>Chapitre 1 –Revue de la littérature (Résumé en Français)</i>	35
<i>Chapter 1 – Literature Review</i>	39
1. General Systems Theory	39
1.1. Systems Thinking	41
1.2. Emergence, Hierarchy, Communication and Control in Systems Theory	42
1.3. Managing Safety and Accidents from a Systems Theory Approach	44
1.4. Systems Approach and Systems Theory in the Nuclear Industry	45
1.5. Systems Theory in Organizations and Management Control	46
1.6. Ago-antagonistic Systems (AAS)	48
1.6.1. Characteristics of Ago-antagonistic Systems	49
1.6.2. Strategies to Balance Ago-antagonistic Pairs	50
2. Management Control Systems (MCS)	50
2.1. Central Concepts in Management Control Systems	51
2.2. Evolution of Traditional Management Control System Theories	52
2.3. Typology of Management Control Systems	53
2.4. Simons' (1995) Levers of Control (LOC) Framework	55
2.4.1. Dynamic Interplay of Forces between the Four LOC	57
2.5. Malmi and Brown's (2008) MCS as a Package	58

2.6.	Formal and Informal Controls	61
2.6.1.	Complementary nature of Formal and Informal Controls	63
3.	<i>Risk and the Management of Risk of Inter-Organizational Relationships (IOR)</i>	64
3.1.	Risks of Subcontracting	65
3.2.	The Control of Risk and the Risk of Control	66
3.2.1.	The Control of Risk: Organizational Design for Optimal Risk Management	66
3.2.2.	The risk of control: Diminished Flexibility to respond to unexpected environmental changes	67
3.3.	Enterprise Risk Management (ERM)	68
3.4.	Risk Management: Use of MCS to Advert and Mitigate Risk in IOR	70
4.	<i>Contingency Theory Framework of Management Control Systems (MCS) and Enterprise Risk Management (ERM)</i>	73
4.1.	Contingency Theory	74
4.2.	Development of Contingency Variables in MCS and in ERM Literature	75
4.3.	Contingency Frameworks in MCS Literature	76
4.3.1.	Otley's (1980) Contingency Variable Framework	76
4.3.2.	Chenhall (2003; 2006) Contingency Framework	78
4.4.	Contingency Framework for ERM Literature	82
4.4.1.	Nedaei et al's., (2015) Contingency Model of Enterprise Risk Management	83
4.4.2.	Safety Culture as a Contingent Variable in ERM	86
4.5.	Fit of Contingency Variables in MCS and ERM	88
	<i>Conclusion of Chapter 1</i>	91
	<i>Chapitre 2 - Conception et méthodologie de la recherche (Résumé en Français)</i>	95
	<i>Chapter 2 - Research Design and Methodology</i>	99
1.	<i>Theoretical Framework, Paradigm Choices and Research Approach</i>	100
1.1.	Justification of the Theoretical Framework	100
1.2.	Research Paradigms and Epistemological Assumptions of the Research Study	102
1.3.	Research Approach	106
1.4.	Research Process	110
1.4.1.	Systemic Combining	110
1.4.2.	The Model-centered Process	115
2.	<i>Analysis of the System for Model Construction</i>	120
2.1.	The empirical Setting: The CEA	120
2.2.	Use of a Case Study and Case Selection Strategies	122
2.2.1.	Case Selection Characteristics	124
2.3.	Data Collection Methods	126
2.4.	Data Analysis Methods	132
3.	<i>Formalization of the model</i>	134
3.1.	Formalization of the Initial Model at Facility A	134
3.1.1.	Immersion at Facility A	134
3.1.2.	Emergent Themes from Phases 2-5 and Phase 6	135
3.1.3.	Theoretical Concepts that contributed to the Initial Model (Phases 1-6)	136
3.1.4.	Modelization of the Initial MCS and Risk Model and Complementary MCS Analogy	137
3.2.	Formalization of the Developed Model from Facility B	138

3.2.1. Immersion at Facility B	138
3.2.2. Emergent Themes from Phases 7-8	139
3.2.3. Theoretical Concepts that contributed to the Developed Model (Phases 1-8)	139
3.2.4. Modelization of the Developed MCS, Risk and Leadership Model and Complementary Ago-antagonistic Analogy	140
4. Validation of Model in Situ (in the field)	141
4.1 Authentication and Validation of the Initial Model	142
4.1.1 Authentication of the Initial Model at Facility A (Phase 6)	142
4.1.2. Validation of the Initial Model at Facility B (Phase 7-8)	142
4.2. Authentication and Validation of the Developed Model	143
4.2.1 Authentication of the Developed Model at Facility B (Phase 7-8)	143
4.2.2 Validation of the Developed Model at Facility A (Phase 6*)	143
4.3. Potential Validation of the Developed Model at Facility E and other CEA Facilities with quasi-integration	144
4.3.1. Presentation of the Developed Model at Facility E (Phase 9, Phase 9*)	144
4.3.2. Presentation of the Developed Model at the CEA's 12 th Annual Human and Organizational Factors (HOF) Day in 2019	145
4.4. Quality of Research and Methodological Reflections	145
Conclusion of Chapter 2	148
Chapitre 3 - Résultats empiriques (Résumé en Français)	150
Chapter 3 – Empirical Results	155
1. The use of MCS to Avert and Mitigate Subcontracting related risks at the CEA	158
1.1. Subcontracting related risks at the CEA	158
1.2. Identification of 24 MCS common to Facility A, Facility B and Facility E	162
1.3. A new definition: Appropriation of the MCS in the Industrial Context	167
1.4. Identification of control-risk couplings at the CEA	167
1.4.1. Control- Risk Coupling 1: Social Control – Relational Risk, Performance Risk and Compliance and Regulatory Risk	167
1.4.2. Control Risk Coupling 2: Behavior Controls and Social Control used to avert and mitigate relational risks	168
1.4.3. Control- Risk Coupling 3: Output Controls & social controls used to mitigate performance risk	169
1.5. Effectiveness of MCS in preventing or detecting subcontracting related risks.	171
Summary of the Results for Section 1	173
2. Characteristics of the CEA's MCS	174
2.1. Analysis of the 24 MCS according to 12 defining characteristics	175
2.2. Towards new definitions: Description of MCS as Preventive and Detective Controls	180
2.3. The temporal aspect of averting an event	181
2.4. Implications of Ago-antagonistic Systems (AAS) in Risk and Safety Management	182
2.4.1. Contrasting Preference of Ago-antagonistic Poles at Facility A, Facility B, and Facility E.	184
2.4.2. Examples of Re-balancing of Facility B's Ago-antagonistic Poles	185
2.5. Categorization of the 24 MCS into the 6 cluster groups: Preventive CS, Detective CS, Preventive CC, Detective CC, Preventive CR, Detective CR	187
2.6. The Control Cycle: Towards an integrated Cycle of four clusters of controls	188
2.7. Synchronous Interactive MCS, Synchronous Auto controls, and Asynchronous MCS in the CEA	191

2.8. Relay Control Couples (bis controls): An immediate or nearly immediate sequence of Preventive and Detective Behaviour Controls _____	198
Summary of the Results for Section 2 _____	200
3. Impact of Contingent Variants on the use of MCS and leadership style in Facility A, Facility B and Facility E. _____	202
3.1 External Environment and Information Asymmetry _____	203
3.2. Technology: Work Processes and Interdependencies within and between System levels _____	205
3.3. Organisational Structure/ Managerial Configuration and System level Interactions _____	207
3.4. Size and Ratio of Middle Managers and CEA Managers to Subcontractors _____	211
3.5. Strategies and Methods to Achieve Results and Safety Objectives _____	214
3.6. Implication of CEA Managers in Promoting Safety Culture _____	221
Summary of the Results for Section 3 _____	230
<i>Conclusion of Chapter 3</i> _____	235
<i>Chapitre 4 - Discussion (Résumé en Français)</i> _____	237
<i>Chapter 4 – Discussion</i> _____	243
1. Managerial Implications _____	246
1.1. Managerial Implications for the CEA _____	246
1.2. Managerial Implications for the Directorate of Nuclear Safety and Security (DSSN) _____	248
1.3. Managerial Implications for Managers (CEA Managers/ Middle Managers) at the Facilities at the CEA _____	250
2. Academic Contributions _____	255
2.1. Contributions to Management Control Systems (MCS) Literature _____	255
2.2. Contributions to Enterprise Risk Management (ERM) Literature _____	263
3. Limitations and Suggestions for Future Research _____	269
3.1. Limitations of the Research _____	269
3.2. Avenues for Further Research _____	271
3.2.1. Short-term Research Interest _____	272
3.2.2. Medium-term Future Research Interests _____	272
3.2.3. Long-term Future Research Interests _____	272
<i>Conclusion (Résumé en Français)</i> _____	274
<i>Conclusion</i> _____	280
<i>Bibliography</i> _____	286
<i>Appendices</i> _____	299
Appendix A: Data collection _____	299
Appendix B: Interview Guide _____	302
Appendix C: Additional information on the Epistemological Assumptions of the Thesis _____	304
Appendix D: Conference Paper 1 _____	306
Appendix E: Conference Paper 2 _____	307

List of Figures

Figure 1. Properties of vertical quasi-integration (specialization subcontracting) at the CEA (Adapted from Holmes (1986) typology of subcontracting relationships)	20
Figure 2. The Research Question at the Heart of the Theoretical Foundations and the Empirical Applications	27
Figure 3. Layout of the Thesis.....	34
Figure 4. The three classifications of Systems Adapted from Leveson, 2011 (who adapted their Figure from An Introduction to General Systems Thinking [John Wiley, 1975]).....	41
Figure 5. A Standard Control Loop (from Leveson, 2011).....	44
Figure 6. Physiological Model: after the suppression of y (adrenalectomy), x (vasopressin) increases. The addition of Y (adrenocortical therapy) led x to return to its initial value (adapted from Bernard-Weil, 1975).....	48
Figure 7. Ago-antagonistic Model of an Ago-antagonistic couple (Moreno Alarcon et al., 2019) adapted from (Bernard-Weil, 2002, 2003a).....	49
Figure 8. Simons' Four Levers of Control [adapted from Simons, 1995. pg. 7]	56
Figure 9. Management Control Systems Package (from Malmi and Brown 2008, p.291)	61
Figure 10. Recapitulative diagram of the Typology of Control	63
Figure 11. Recapitulative diagram of the Task Characteristics in each type of control	64
Figure 12. Recapitulative Diagram of the Uses of Controls to Mitigate Subcontracting-related Risks.....	72
Figure 13. Common Characteristics of Previous Contingency Studies (Otley, 1980)	77
Figure 14. Otley's (1980) Contingency Framework for Studying Context	78
Figure 15. Nedaei et al. (2015) Contingency Model of Enterprise Risk Management	84
Figure 16. Classification of Organizational theories according to the dynamics and the granularity of the research objective (Adapted from Lemaire, 2013, original source: Rojot, 2003 and Plane, 2012).....	101
Figure 17. Philosophical and Methodological Continuum of this Study that is underpinned by a Critical Realist Paradigm (Adapted from Burrell and Morgan, 1982).	105
Figure 18. Comparison of the deductive (blue), inductive (yellow) and abductive (red) research processes (adapted from Kovács and Spens (2006)).....	108
Figure 19. The abductive research process.....	109
Figure 20. The two processes and four factors of Systemic Combining.....	111
Figure 21. The model centered approach [Adapted from Pave (1990) in Guarneri (1995), Pave (1990) in Van Wassenhove (2004), and Pave (2006)].	118
Figure 22. Single case-study at the CEA, with three Embedded Case Units (Facility A, Facility B, and Facility E) each with three levels of analysis (CEA Managers, Middle Managers and Subcontractors).	123
Figure 23. Levels of Control and characteristics of the three Facilities of the CEA (Facility A, Facility B, and Facility E).	125
Figure 24. The nine data collection and the nine data analysis phases of the research.	127
Figure 25. Coding example concerning a Co-activity meeting.	133
Figure 26. Stages in the formalization of the Initial Model (Phase 1-6) and the Developed Model (Phase 1-8).	134
Figure 27. Conceptual model from Phases 2-5 at Facility A, detailing the emergent themes of risk, control and trust.	136
Figure 28. Levels of Control from INSAG-10 Defense in Depth and France's Decree from February 7, 2012.....	136
Figure 29. Categorization of a Task according to its Twelve Dimensions of Control.	137
Figure 30. MCS Analogy: Controls during Automotive Driving Activities (as a complement to the Initial (Facility A) Model).....	138

Figure 31. Control and Leadership Analogy: Balance through Ago-Antagonistic Systems (as a complement to the Developed (Facility A and Facility B) Model.	140
Figure 32. Overview of the research	156
Figure 33. Components of the three sections of Chapter 3	157
Figure 34. Definition of the three Subcontracting Related Risks in the Industrial Context	162
Figure 35. Definition of Social Control (CS), Behavior Control (CC) and Output Control (CR) in the French Nuclear Context.....	167
Figure 36. Twelve Characteristics of the 24 MCS used at Facility A, Facility B and Facility E.....	176
Figure 37. Proposed definition of the nature of the MCS as Preventive and Detective Controls following the analysis of 24 MCS at the CEA.....	180
Figure 38. Temporal distribution of an event and the functionality of MCS as preventive and detective controls in averting or detecting the event.	181
Figure 39. Distribution of MCS according to the type of control and the temporal aspect of the task	188
Figure 40. The cycle of control	191
Figure 41. Number of Controls used at each Facility.....	197
Figure 42. Number and percentage of non-interactive controls, inter-organizational controls, and intra-organizational controls at Facility A, Facility B and Facility E	206
Figure 43. Organizational Structure and decentralized or centralized control of Facilities A, B and E ..	208
Figure 44. Ratio of Personnel at the Subcontractor, Middle Management and CEA Management Level in the three Facilities	214
Figure 45. Leadership Factors associated with the changes that altered the balance of Prevention & Detection	216
Figure 46. Predominant type of control and leadership style of Facility A, Facility B and Facility E. ...	218
Figure 47. Types of Controls and their interaction with the five Empowerment Leadership Factors.....	219
Figure 48. Comparison of the predominant choice of controls amongst the daily sequence of controls of the control cycle and the fit of these MCS with the distinct leadership styles of Facility A, Facility B , and Facility E	220
Figure 49. Relationship between all of the Contingent Variables and their effects on leadership style ..	221
Figure 50. Relationship between all of the Contingent Variables in Facility A and their effects on Facility A's leadership style	223
Figure 51. Relationship between all of the Contingent Variables in Facility B and their effects on Facility B's leadership style	225
Figure 52. Relationship between all of the Contingent Variables in Facility E and their effects on Facility E's leadership style.....	226
Figure 53. Distribution of 24 MCS in Facility A according to the system level that conducts the control	227
Figure 54. Distribution of 24 MCS in Facility B according to the system level that conducts the control and the Empowerment Leadership Factors as the motivation for changes made to 3 Social Controls....	228
Figure 55. Distribution of 24 MCS in Facility E according to the system level that conducts the control and the Empowerment Leadership Factors as the motivation of a new social control created to re-enforce communication between the CEA and the subcontractors	229
Figure 56. Recommendations on how to deal with Ago-antagonistic Imbalances at the CEA Facilities	254
Figure 57. Applying Preventive and Detective Controls, defined in this study's Risk Management Strategy, to Simons' (1995) Levers of Control (LOC) Framework [Adapted from Simons' (1995)].	258
Figure 58. Proactive and Reactive/ Adaptive Controls for Safety 1 and for Safety 2 at the CEA Facilities	268

List of Tables

Table 1. Mechanistic and Organic Forms of Control (source: Chenhall 2003; 2006)	54
Table 2. Elements of the Research Design	99
Table 3. Basic Beliefs of Positivism, Post-Positivism and Interpretivist/ Constructivist (Adapted from Guba and Lincoln, 1994).....	104
Table 4. Overview of Deduction, Induction and Abduction. (Adapted from Danermark et al., 2005)....	107
Table 5. Six sources of Evidence Adapted from Yin (2009. P 103-120)	127
Table 6. Interviews conducted broken-down into the Levels of Analysis.	129
Table 7. Key Elements of the 9 phases of the Data Collection Process at Pilot Study, Facility A, B and E	130
Table 8. Strategies used in the study to achieve Lincoln and Guba (1985)'s four criteria of trustworthiness (or reliability).	146
Table 9. Recapitulation of the English and French terms used in this chapter, their acronyms and designated colour.....	158
Table 10. Categorization of the 24 MCS identified in both facilities A and B into formal and informal controls.....	163
Table 11. Summary of the Risks and the types of controls used to mitigate these risks.....	170
Table 12. Description of the nature (preventive or detective) and the frequency (low or high) of the 24 MCS at the CEA.....	179
Table 13. Contrasting Characteristics of MCS as preventive controls and detective controls.....	181
Table 14. Eight Characteristics of Control as an Ago-antagonistic System (AAS).....	182
Table 15. Distribution of the 24 MCS according to either their preventive or detective nature.	187
Table 16. Level of Control, Type of Interaction and System levels involved in the MCS at the CEA....	196
Table 17. Overview of the types of interactions (non-interactive; intra-organizational interactive, inter-organizational interactive) during the controls used at the CEA.....	197
Table 18. Size of Staff at each level in Facility A, B and E.....	213
Table 19. Use of MCS and Leadership Style at CEA Facilities based on their six Contingent Variables.....	234
Table 20. Brief Overview of the answers to the four Sub-Research Questions	244
Table 21. Overview of Safety I and Safety II in relation to this study (Adapted from Hollnagel 2013, p.26)	268

Acronyms and Abbreviations

AA	<i>Ago-antagoniste</i> Ago-antagonist
AAS	<i>System Ago-antagoniste</i> Ago-antagonistic System
ASN	<i>Autorité de sûreté nucléaire</i> French Nuclear Safety Authority
ASND	<i>Autorité de Sûreté Nucléaire de Défense</i> French Defense Nuclear Safety Authority
CC	<i>Contrôle Comportemental</i> Behaviour Control
CR	<i>Contrôle par les Résultats</i> Output Control
CS	<i>Contrôle Social</i> Social Control
CEA	<i>Commissariat à l'énergie atomique et aux énergies alternatives</i> French Alternative Energies and Atomic Energy Commission
CQSE	<i>Cellule Qualité Sécurité Environnement</i> Environment Quality Occupational Safety Unit
CSMN	<i>Cellule Sûreté Matière Nucleaire</i> Nuclear Safety and Nuclear Material Unit
CSNSQ	<i>Cellule de Sûreté Nucléaire, Sécurité et Qualité</i> Nuclear Safety, Occupational Safety and Quality Unit
DSSN	<i>Direction de la Sécurité et de la Sûreté Nucléaire</i> Directorate of Nuclear Safety and Security
ELM	<i>Modèle de leadership par responsabilisation</i> Empowerment Leadership Model
Facility A	<i>Installation de conditionnement et d'entreposage de déchets radioactifs</i> Packaging and Radioactive Waste Storage Facility
Facility B	<i>Installation de conditionnement des déchets radioactifs solides</i> Solid Radioactive Waste Packaging Facility
Facility E	<i>Installation d'entreposage de déchets radioactifs</i> Radioactive Waste Storage Facility
HOF	<i>Facteurs Organisationnels et Humains</i> Human and Organizational Factors
H and OS	<i>Sécurité du travail</i> Health and Occupational Safety
INSTN	<i>Institut national des sciences et techniques nucléaires</i> National Institute for Nuclear Science and Technology
IOR	<i>Relations inter-organisationnelles</i> Inter-organizational Relationships
OTI	<i>Opérateur Technique Industriel</i> Subcontractor or Technical Industrial Operator
MCS	<i>Systèmes de Contrôle de Gestion</i> Management Control Systems
RCI	<i>Responsable de contrat d'installation</i> Responsible for the Contract of the Facility
RNC	<i>Risque de non-conformité</i> Compliance and Regulatory Risk
RO	<i>Research Objective</i> Objective de Recherche
RR	<i>Risque Relationnel</i> Relational Risk
S3N	<i>Support en Sécurité et Sûreté Nucléaire</i> Nuclear Safety and Occupational Safety Support Department

Introduction générale (Résumé en Français)

Implications empiriques

Depuis le début des années 1990, la sous-traitance a connu une croissance considérable dans les secteurs public et privé (Langfield-Smith et Smith, 2003b) en raison de l'afflux de la mondialisation et des développements technologiques. Cette croissance a entraîné une vague de nouvelles formes organisationnelles qui s'éloignent de la configuration bureaucratique traditionnelle pour adopter une forme plus flexible. Ce mouvement a été accentué par la croissance de la sous-traitance, qui présente des avantages stratégiques et économiques avérés, notamment des économies de coûts, la flexibilité, des conseils d'experts externes et la capacité de se concentrer sur les pratiques commerciales essentielles de l'organisation tout en améliorant les services grâce à la sous-traitance (Smith et al., 2005). Par conséquent, la sous-traitance devient la pratique commerciale plutôt que l'exception rare, mais elle peut exposer les deux parties à un grand risque (Das et Teng 1999, 2001), car chaque partie peut avoir des agendas différents qui pourraient conduire à une exploitation opportuniste (Langfield-Smith et Smith, 2003). Ce risque est exacerbé par la distance organisationnelle entre deux entités distinctes de la relation contractant-sous-traitant. Cependant, malgré son vaste développement, la littérature de gestion n'a que récemment commencé à étudier les pratiques de sous-traitance, les avantages, les risques et les implications du contrôle sur la sous-traitance. Le Commissariat à l'énergie atomique et aux énergies alternatives (CEA), est une organisation industrielle et un acteur important de la filière nucléaire française. Le CEA est une agence gouvernementale française et un organisme public créé en octobre 1945 par le Général de Gaulle. Avec neuf centres de recherche répartis sur le territoire français, le CEA est un leader dans la recherche, le développement et l'innovation des énergies nucléaires et alternatives. Le CEA a un statut particulier, qui le classe comme un établissement public à caractère industriel et commercial aussi appelé EPIC (*Etablissement Public à Caractère Industriel et Commercial*).

Plusieurs chercheurs (Chaillou, 1977, Holmes, 1986 ; Watanabe, 1971; 1972) ont classé plusieurs types de relations de sous-traitance allant d'une relation entre le contractant et le sous-traitant sans intérêts mutuels, lorsque le contractant fabrique le même produit que le sous-traitant, à avec intérêts mutuels lorsque les entreprises fabriquent un composant que le contractant ne peut pas obtenir facilement.

Nous nous intéressons à la deuxième de ces catégories, car le CEA emploie un style particulier de sous-traitance d'intérêt mutuel connu sous le nom de **sous-traitance de spécialisation** - une intégration verticale définie pour la première fois par Houssiaux en 1957 comme une **quasi-intégration** - et aujourd'hui appelée "**quasi-intégration verticale**". Dans cette relation, le sous-traitant contrôle la méthode de production et le processus de travail et le CEA assume la responsabilité du processus global de production.

D'une manière générale, la structure du marché de ce type de produits ou services sous-traités est *oligopolistique avec quelques acteurs* (Holmes, 1986) ou *monopolistique (pas de concurrents)* (Holmes,

1986) lorsque l'entreprise sous-traitante est le seul producteur de pièces ou services sous-traités pendant la période contractuelle. En fait, la production de produits ou de services, est entièrement réalisée par l'entreprise sous-traitante dans le cadre d'une seule unité d'affaires sous-traitant-sous-traitant sans transformation ultérieure (Blois, 1972). Par conséquent, le sous-traitant produit un composant ou un service spécialisé que le contractant ne peut pas obtenir facilement (*spécialisation*), ce qui donne lieu à une relation complémentaire et interdépendante à long terme fondée sur l'intérêt mutuel (Baudry, 2013 ; Houssiaux, 1957a, 1957b). La nature de cette affiliation établit une codépendance, car le contractant dépend des connaissances spécialisées fournies par le sous-traitant et le sous-traitant dépend du contractant pour gérer sa production (Larsson, 1999).

Holmes (1986) différencie encore la *spécialisation (quasi-intégration verticale)* des deux autres typologies par trois questions clés :

1. Quel est le degré de contrôle du processus de production ?
2. Quel type de marché est disponible pour le produit sous-traité ?
3. Le contractant fabrique-t-il lui-même la pièce sous-traitée ?

Le graphique 1 (cf. la figure 1 dans le texte en anglais) détaille les réponses possibles aux trois questions de Holmes (1986), puis applique cette typologie théorique à gauche au contexte empirique du CEA à droite. L'utilisation par le CEA de la sous-traitance verticale de quasi-intégration détaillée ci-dessus est également résumée dans ce graphique.

Le CEA exploite plusieurs installations en quasi-intégration. Malgré les aspects positifs de la quasi-intégration, comme tout type de sous-traitance, cette pratique comporte de nombreux **risques**. De plus, l'évolution historique du CEA, les implications juridiques de sa quasi-intégration et la différence d'expérience au sein des entreprises de sous-traitance nouvellement créées qu'il emploie augmentent encore le niveau d'exposition au risque du CEA. En fait, le CEA est considéré comme une organisation industrielle à haut risque car il exerce des activités liées au nucléaire considérées comme des activités à risque par les autorités nucléaires françaises.

En outre, le "*délit de marchandage*" (articles L8231 du Code civil - Code du travail), est le plus grand risque de sous-traitance en France et figure dans la législation depuis 1848. Cette loi est également détaillée dans la directive européenne 2008/104/CE contractant. Le CEA doit éviter d'indiquer comment la production doit être réalisée et ne pas intervenir dans la programmation ou le licenciement des sous-traitants afin d'éviter d'être requalifié en employeur direct et de risquer un "*délit de marchandage*". De tels comportements illicites sont punis par la loi de peines de prison et d'amendes¹, en conséquence, le personnel sous-traitant d'un contractant doit rester sous l'autorité de son employeur (l'entreprise sous-traitante) et non sous l'autorité de l'entreprise contractante. Le contractant est obligé de contrôler les sous-traitants sans s'adresser directement à eux, mais uniquement au chef de projet de l'entreprise sous-traitante². Cette

¹ Le "*délit de marchandage*" est passible de 2 ans de prison et de 150 000 euros d'amende, ainsi que d'une interdiction de recourir à des sous-traitants pendant 2 à 10 ans.

² Selon la page 109 du rapport de la mission parlementaire publié le ³⁰ juin 2011 sur la sûreté nucléaire suite à la catastrophe de Fukushima, la sous-traitance présente des difficultés juridiques : L'activité du sous-traitant est soumise

dynamique hiérarchique imposée par cette loi crée un obstacle supplémentaire pour le CEA dans le contrôle et la gestion de ses sous-traitants dans une industrie déjà à haut risque, laissant les installations du CEA plus sujettes aux erreurs. Le besoin de systèmes de contrôle efficaces est d'autant plus essentiel que le CEA est l'entité de la relation contractant-sous-traitant qui est légalement responsable.

Le CEA met en œuvre des procédures de contrôle et de surveillance pour assurer le bon fonctionnement des installations, notamment des inspections quotidiennes sur le terrain, des rondes quotidiennes et des procédures de contrôle mensuel. Ainsi, le CEA vise à mettre en place un système de surveillance qui s'adapte, évolue et assure la sûreté des installations nucléaires tout en respectant la réglementation spécifique de chaque site. Par ailleurs, les sites et installations nucléaires en France sont contrôlés, pour le compte de l'Etat, par l'*Autorité de sûreté nucléaire (ASN)*, autorité administrative indépendante créée par la "*Loi relative à la transparence et à la sécurité en matière nucléaire (Loi TSN 2006-686)*" du 13 juin 2006. L'ASN a pour mission de réglementer la sûreté nucléaire et la radioprotection des travailleurs du nucléaire, des patients en médecine nucléaire, du public et de l'environnement face aux risques des installations nucléaires.

Les systèmes de contrôle de gestion tels que les contrats et les procédures aident à contrôler certaines tâches et procédures, mais tout ne peut pas être détaillé dans ces contrôles formels, ce qui oblige les managers à favoriser une relation forte entre le contractant et le sous-traitant³. Face à ces insatisfactions, le CEA cherche à mieux comprendre ses interactions avec ses sous-traitants et proposer ensuite des évolutions et des axes d'amélioration concernant les méthodes de management spécifiques pour contrôler et encadrer les sous-traitants. Cette thèse s'inscrit dans ces propositions et a été financée par le CEA pour proposer un modèle de contrôle des sous-traitants au sein des installations nucléaires tout en prévenant et en atténuant les risques liés à la sous-traitance. Les modèles théoriques actuels de contrôle de gestion proposés dans la littérature des sciences de gestion sont détaillés dans la section suivante.

Fondements théoriques

Les fondements théoriques de la thèse se situent à l'intersection de trois thèmes principaux de la comptabilité de gestion : Le système de contrôle de gestion, le risque et la gestion des risques, et le contrôle inter-organisationnel. Plus précisément, cette thèse s'intéresse aux contrôles utilisés par les managers (Systèmes de Contrôle de Gestion, SCG) sur les sous-traitants (Contrôle de Relations Inter-organisationnel,

à un contrôle par le contractant, ce qui ajoute une tâche supplémentaire au contractant d'assurer l'inspection de l'entreprise sous-traitante. En même temps, le personnel de l'entreprise contractante, affecté au contrôle de l'entreprise sous-traitante, n'a en principe pas le droit de parler directement au personnel du sous-traitant, mais seulement à la direction de l'entreprise sous-traitante.

³ Les éléments d'une relation forte entre le contractant et le sous-traitant, tels que la confiance, ont été identifiés dans l'ensemble du cadre empirique. Cependant, cette thèse ne se concentre pas sur la notion de confiance, et s'intéresse plutôt à d'autres éléments, dont le leadership en matière de sécurité, qui contribuent à réduire la distance entre le contractant et le sous-traitant. Par conséquent, toute observation ou résultat concernant la confiance sera examiné sous l'angle du leadership en matière de sécurité et de ses effets simultanés avec les systèmes de contrôle de gestion sur la réduction des risques.

RIO) pour prévenir et atténuer les risques liés à la sous-traitance (Gestion des Risques d'Entreprise, GRE) dans un contexte où la temporalité de ces contrôles est cruciale pour assurer la sûreté nucléaire.

Question(s) de recherche

Les questions de recherche de cette thèse sont à l'intersection des Implications Empiriques et des Fondements Théoriques, toutes deux détaillées ci-dessus. La sous-traitance dans le secteur nucléaire français présente un contexte intéressant pour étudier la recherche sur le contrôle de gestion et la gestion des risques pour un certain nombre de raisons. *Premièrement*, la France dépend de l'énergie nucléaire pour 75% de son énergie électrique, mais l'énergie nucléaire dans le monde a connu plusieurs catastrophes et accidents au niveau international qui ont eu un fort impact sociétal. *Deuxièmement*, la France est l'un des leaders mondiaux en matière d'avancées nucléaires et de technologie nucléaire. *Troisièmement*, le secteur nucléaire est à l'avant-garde de la gestion des risques et de la sécurité et, par conséquent, l'industrie nucléaire est devenue la référence pour les autres industries à haut risque. *Quatrièmement*, il y a eu très peu d'études en matière de recherche sur le contrôle de gestion et la gestion des risques dans le secteur nucléaire français, et encore moins avec une perspective in-situ permettant un accès direct aux acteurs et aux procédures de gestion quotidiennes. Dans ce contexte, l'industrie nucléaire française est un cadre important pour étudier l'aversion au risque et les questions liées à la sous-traitance au niveau managérial.

La figure 2 (cf. texte en anglais) corrobore davantage la principale question de recherche au cœur des Fondements Théoriques et des Implications Empiriques. A la lumière du cadre empirique qui nous indique que le CEA n'est pas en mesure de surveiller et d'observer ses sous-traitants à tout moment, et compte tenu des éléments contextuels de la littérature qui indiquent que les contrôles de gestion ne sont pas suffisants pour garantir des comportements optimaux en matière de sécurité de la part des sous-traitants.

Cette recherche vise à explorer : ***Comment le CEA conçoit-il des systèmes de contrôle de gestion (SCG) capables de prévenir et d'atténuer efficacement les risques de sous-traitance associés à la quasi-intégration, dans le contexte des caractéristiques spécifiques de ses installations nucléaires ?***

Pour répondre à cette question, quatre sous-questions se posent. Plus précisément :

Comment les SCG employés par les Managers du CEA (vis-à-vis des sous-traitants) évitent-ils et atténuent-ils les risques ?

Comment les managers du CEA équilibrent-ils le SCG "en tant que paquet" pour éviter et atténuer les risques et les événements liés à la sous-traitance ?

Quelle dimension est mise en œuvre pour orchestrer le SCG précédent pour améliorer les comportements de sécurité au CEA ?

Quelle(s) approche(s) de mise en œuvre du SCG, à la suite d'un quasi-événement ou d'un événement mineur, permet(tent) contrôles de se soutenir et de se renforcer mutuellement "en tant que paquet" ?

L'objectif de la thèse et les contributions

Cette thèse s'inscrit dans une démarche descriptive et globale visant à comprendre les procédures de maîtrise et les interactions entre les acteurs des Installations Nucléaires pour améliorer la collaboration et réduire les risques liés à la sous-traitance. Plus précisément, cette recherche propose une nouvelle approche de la gestion des risques et de la sécurité, basée sur la Systémique, qui applique les principes du *Modèle de Leadership par Responsabilisation* (ELM) (Arnold et al., 2000) pour développer et surmonter les limites des *Systèmes de Contrôle de Gestion* (SCG). Elle combine une approche systémique du SCG avec une approche systémique du leadership en matière de sécurité, par le biais d'un modèle Ago-Antagoniste.

D'un point de vue théorique, les résultats contribuent à enrichir les connaissances dans le domaine de la littérature sur le contrôle de gestion inter-organisationnel et la contingence, dans le cas très spécifique de trois installations nucléaires du CEA qui sous-traitent un pourcentage de leur travail mais ont des configurations managériales différentes. Cette relation inter-organisationnelle présente des avantages stratégiques et économiques, mais expose les parties à des risques liés à la sous-traitance, qui peuvent avoir un impact sur la sûreté nucléaire et la sécurité au travail. En fait, ces risques sont accentués par la distance organisationnelle entre les deux entités de la relation contractant-sous-traitant, ce qui démontre l'importance des interactions entre les managers du CEA, les managers du sous-traitant (managers dits intermédiaires) et le personnel sur le terrain du sous-traitant. Les managers de l'entreprise sous-traitante supervisent les sous-traitants dans leurs tâches quotidiennes.

En plus de contribuer au domaine du contrôle des Relations Inter-Organisationnel (RIO), des systèmes de contrôle de gestion (SCG) et de la gestion des risques d'entreprise (GRE), cette thèse apporte également des contributions académiques transversales au domaine de la science de la sécurité et aux facteurs organisationnels et humains (FOH). Plus précisément, cette recherche contribue académiquement à :

- La littérature GRE, en décrivant deux types de contrôle utilisés dans la gestion des risques (contrôle de prévention et contrôle de détection) et en illustrant comment l'aspect temporel de ces contrôles détermine leur capacité à prévenir et/ou détecter les risques qui, s'ils ne sont pas détectés, peuvent conduire à des événements.
- La littérature SCG, en relayant les contrôles de prévention et de détection aux leviers de contrôle (LOC) de Simons (1995, 2013), et en proposant une méthode pour équilibrer ces forces antagonistes. De plus, cette recherche illustre comment les styles de leadership favorisent la sécurité en aidant à surmonter les limites des systèmes de contrôle de gestion.
- La littérature sur les contingences du SCG (et de la GRE), en montrant comment les préférences en matière de contrôle et les styles de leadership dépendent des facteurs de contingence de l'organisation (*environnement externe, technologie, structure organisationnelle, taille et ratio, stratégie et culture*) et s'y adaptent.
- La littérature sur le RIO en montrant les effets du style de leadership des managers de la sous-traitance et leur implication et promotion de la culture de sécurité.

- La littérature de la science de la sécurité et du HOF en utilisant la pensée systémique et les systèmes ago-antagonistes pour définir et modéliser les contrôles de prévention et de détection afin de montrer leur rôle en combinaison avec le leadership en matière de sécurité pour renforcer les pratiques de sécurité et de gestion des risques.

D'un point de vue pratique, la recherche permet de formuler des suggestions pour améliorer le contrôle managérial des sous-traitants. Les suggestions formulées sont destinées aux acteurs managériaux du processus de gestion des risques : le Chef d'Installation (ou RCI) et les ingénieurs du CEA qui supervisent l'installation (ingénieurs de sécurité d'installation, ingénieurs de sûreté nucléaire), tout en tenant compte simultanément du rôle et de l'impact des managers des entreprises sous-traitantes (Middle Managers) dans la mise en œuvre de ces suggestions. La recherche fournit une série de modèles systémiques de l'approche de gestion utilisée au CEA pour éviter et atténuer les risques liés à la sous-traitance, à la lumière de la théorie des contingences et de la théorie des systèmes, qui mettent en évidence les facteurs de contingence et la nature ago-antagoniste des pratiques de gestion des risques.

Plus précisément, cette recherche apporte une contribution pratique en :

- identifiant le cycle de contrôle commun aux trois installations nucléaires et classer les différents contrôles en fonction de l'aspect temporel des contrôles (par rapport à la tâche) et de la position de l'acteur qui effectue la tâche.
- identifiant les aspects ago-antagonistes des contrôles et montrer comment équilibrer les contrôles ago-antagonistes pour une meilleure prévention et atténuation des risques et des événements potentiels liés à la sous-traitance.
- proposant un système rigoureux de directives de gestion des contrôles, adapté aux particularités et aux spécificités de l'industrie nucléaire, une industrie qui maintient un niveau d'excellence en matière de sécurité.

Enfin, ces contributions managériales s'alignent sur les appels lancés par l'Agence internationale de l'énergie atomique (AIEA) à la suite de trois accidents nucléaires majeurs : Three Mile Island en 1979, Tchernobyl en 1986 et Fukushima Daiichi en 2011. Plus précisément, l'AIEA souligne l'importance des facteurs organisationnels et humains dans la sûreté nucléaire, appelle à des pratiques de leadership efficaces considérées comme des "leviers de changement" pour la culture de sûreté et accentue la nécessité de compléter les approches traditionnelles de la sûreté par une approche systémique.

Structure de la thèse

La construction d'un modèle explicatif (*cognitif*) illustre les mécanismes interactifs fondamentaux du contrôle inter-organisationnel dans l'industrie nucléaire. Ce contrôle inter-organisationnel, sous-tendu par la pensée systémique, est organisé autour des thèmes suivants : la prévention et la détection des risques ou des événements, la nature du contrôle qui dépend de l'installation nucléaire (basée sur sa configuration managériale), les aspects temporels et la nature du SCG et leur efficacité pour éviter et atténuer les

événements et, enfin, les stratégies managériales (leadership, outils systémiques pour équilibrer) qui, combinées au SCG en tant que paquet, interagissent dans un système complexe pour renforcer les performances de sécurité.

La structure de la thèse est détaillée dans la Figure 3 (cf. texte en anglais), en distinguant les thèmes de cette analyse dans le processus de construction du modèle cognitif explicatif - risque - gestion contrôle - stratégies, et les contributions théoriques (Systèmes ago-antagonistes et équilibre des contrôles) et pratiques (Leadership de sécurité, Middle Management).

Cette thèse est organisée en quatre chapitres :

Le chapitre 1 présente le cadre théorique de la pensée systémique et de la théorie de la contingence ainsi que l'analyse documentaire des théories existantes sur les systèmes de contrôle de gestion, notamment les leviers de contrôle de Simons, les paquets SCG et l'utilisation du contrôle inter-organisationnel dans la gestion des risques. Ce chapitre nous permet de situer l'étude dans la littérature existante en discutant les études des systèmes de contrôle de gestion qui ont mis en œuvre la théorie des systèmes et la théorie de la contingence.

Le chapitre 2 présente le cadre méthodologique de la recherche, y compris la conception et les méthodes de recherche de la thèse, en se concentrant particulièrement sur la stratégie de conception, le cadre de recherche, la collecte des données et les méthodes d'analyse. Plus précisément, lors de la conception du modèle SCG, l'objectif du modèle est d'abord discuté et le système (CEA) où le modèle sera appliqué est analysé, présentant ainsi le contexte du secteur nucléaire. Ensuite, le modèle est formalisé et présenté en utilisant le langage de modélisation adapté, y compris l'utilisation de métaphores liées à la conduite ou au contrôle d'une automobile. Plus précisément, le *modèle initial* est recadré et affiné dans la première installation nucléaire, reconçu et formalisé dans le *modèle développé* dans la deuxième installation une fois les composants manquants identifiés, et enfin réévalué et validé dans la première installation nucléaire. Les résultats obtenus dans la troisième installation nucléaire n'invalident pas le modèle.

Le chapitre 3 présente deux études de cas approfondies sur la façon dont les managers mettent en œuvre le SCG dans trois installations nucléaires qui ont des activités sous-traitées similaires et qui sont situées dans deux centres CEA différents, ce qui donne lieu à des configurations organisationnelles et managériales différentes et à des styles de leadership contrastés. L'objectif du chapitre 3 est de différencier les caractéristiques de chaque installation nucléaire et de déterminer les types de SCG utilisés dans la gestion des risques. Plus précisément, ce chapitre détaille : la prévention et la détection des risques ou des événements, leur nature ago-antagoniste, la nature du contrôle spécifique à la configuration managériale de chaque installation nucléaire, les aspects temporels et la nature des SCG et leur efficacité pour éviter et atténuer les événements et, enfin, les stratégies managériales, y compris le leadership et les outils systémiques mis en œuvre en combinaison avec les SCG en tant que paquet pour rééquilibrer et renforcer la sécurité. Les résultats de ce chapitre servent donc à enrichir l'analyse comparative entre les différentes caractéristiques des trois installations nucléaires et leurs effets sur les contrôles managériaux à travers une étude de cas intégrée.

Le chapitre 4 présente la discussion des résultats et expose les contributions tant académiques que managériales. Premièrement, il détaille l'utilisation des systèmes ago-antagonistes, l'outil de modélisation systémique, pour identifier les déséquilibres et rééquilibrer les systèmes de contrôle de gestion. Deuxièmement, les styles de leadership, leur mise en œuvre dans les pratiques de contrôle de gestion et leurs effets sur la régulation des procédures de sécurité par la responsabilisation des employés pour améliorer les performances de sécurité sont discutés. Enfin, l'impact d'une forte présence de l'encadrement intermédiaire et ses effets sur la réduction de la distance entre les contractants et les sous-traitants sont également discutés.

La conclusion résume les résultats, discute des limites et des contributions de l'étude, et suggère des pistes pour de futures recherches.

General Introduction

Since the early 1990s, there has been considerable growth in subcontracting in both the public and private sectors (Langfield-Smith and Smith, 2003b) due to the influx of globalization and developments in technology. This growth has resulted in a wave of new organizational forms that move away from the traditional bureaucratic configuration to a more flexible form. This movement has been heightened by the growth of subcontracting, which has proven strategic and economic advantages including cost savings, flexibility, external expert advice, and the ability to focus on core business practices of the organization all while improving services through subcontracting (Smith et al., 2005). As a result, subcontracting is becoming the business practice rather than the rare exception, but may expose both parties to a great deal of risk (Das and Teng 1999, 2001) as each party may have different agendas which could lead to opportunistic exploitation (Langfield-Smith and Smith, 2003). This risk is exacerbated by the organizational distance between two separate entities of the contractor-subcontractor relationship. However, despite its vast development, management literature has only recently begun to study subcontracting practices, the advantages, the risks and the implications of control on subcontracting.

French Alternative Energies and Atomic Energy Commission (CEA), is an industrial organization and an important player of the French Nuclear Energy Industry. The CEA known in France as the “*Commissariat à l'énergie atomique et aux énergies alternatives*” is a French governmental agency and a public body established in October 1945 by General de Gaulle. With nine research centers across France, the CEA is a leader in research, development and innovation of nuclear and alternative energies. The CEA has particular status, which classes it as a public establishment of an industrial and commercial aspect also known as EPIC (*Etablissement Public à Caractère Industriel et Commercial*).

Several scholars (Chaillou, 1977, Holmes, 1986; Watanabe, 1971; 1972) have classified several types of subcontracting relationships where a fundamental dissimilarity exists with the power dynamics of the relationship: no mutual interest as the contractor produces the same product as the subcontractor vs. mutual interest as the firms produce a component the contractor cannot easily obtain.

We are interested in the second of these categories, as the CEA employs a particular subcontracting style of mutual interest known as **specialization subcontracting** - a vertical integration first defined by Houssiaux in 1957 as **quasi-integration** - and today referred to as “**vertical quasi-integration**”. In this relationship, the subcontractor controls the method of production and the labour process but does not assume the risks and the rigidity of ownership present in other forms of subcontracting (Blois, 1972), 1972), as the CEA assumes complete responsibility for the production process.

Generally speaking, the structure of the market for this kind of subcontracted product or services is *oligopolistic with a few actors* (Holmes, 1986), and *monopolistic (no competitors)* (Holmes, 1986) as the subcontracting firm is the only producer of subcontracted parts or services during the contractual period. In fact, the production of products or services, are entirely carried out by the subcontracting firm under a single subcontractor-contractor business unit without further processing (Blois, 1972). Therefore, the

subcontractor produces a specialized component or service that the contractor cannot easily obtain (*specialization*) yielding a complementary and interdependent longer-term relationship built on mutual interest (Baudry, 2013; Houssiaux, 1957a, 1957b). The nature of this affiliation establishes co-dependency as the contractor is dependent on the specialized knowledge provided by the subcontractor and the subcontractor is dependent on the contractor to run its production (Larsson, 1999).

Holmes (1986) further differentiates between the *specialization (vertical quasi-integration)* and the other two typologies by three key questions:

4. What is the degree of control over the production process?
5. What type of market is available for the subcontracted product?
6. Does the parent firm manufacture the subcontracted part themselves?

Figure 1 below details the possible responses to the three questions by Holmes (1986), and then applies this theoretical typology on the left to the empirical context of CEA on the right. The CEA’s use of vertical quasi-integration subcontracting detailed above are also summarized in this graph.

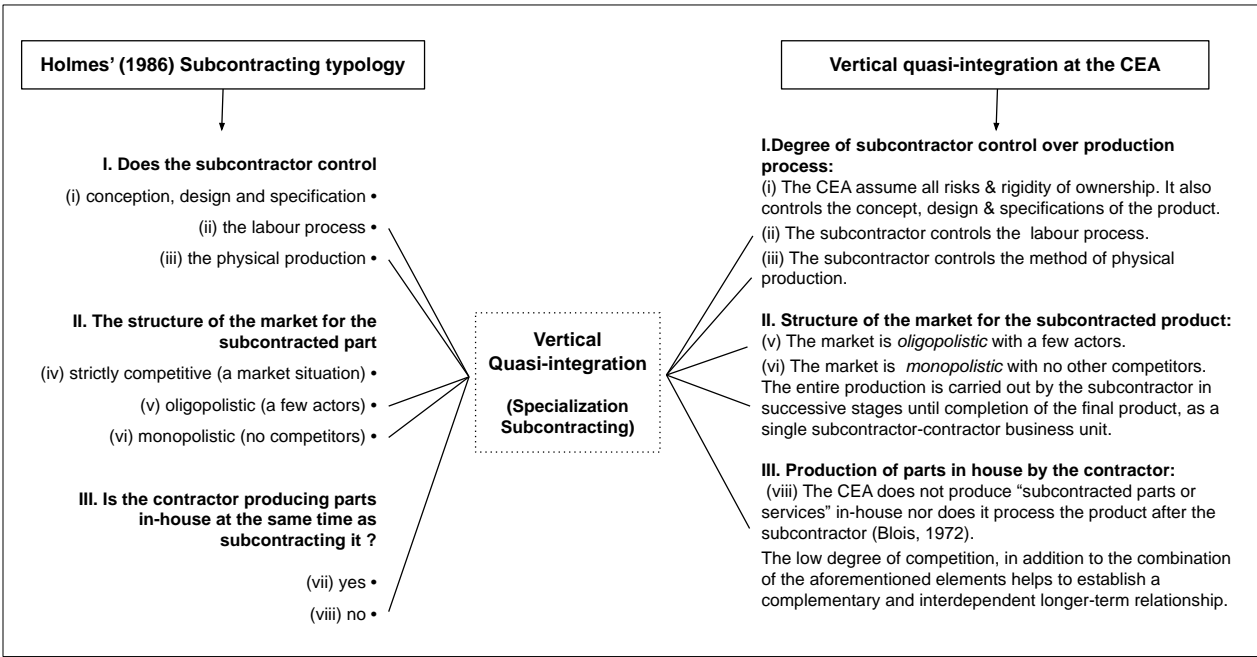


Figure 1. Properties of vertical quasi-integration (specialization subcontracting) at the CEA (Adapted from Holmes (1986) typology of subcontracting relationships)

The CEA operates several facilities by quasi-integration with subsidiaries of specialist firms. Despite the positive aspects of quasi-integration, as with all types of subcontracting – this practice entails numerous **risks**. Additionally, the CEA’s historical evolution, the legal implications of its quasi-integration and the difference of experience within the newly established subcontracting firms it employs further augment the CEA’s level of risk exposure. In fact, the CEA is considered a high-risk industrial organization as it exercises nuclear-related activities deemed as activities of risk by the French nuclear authorities.

Additionally, the lack of equal treatment of contractors and employees known in France as the “*délit de marchandage*” (articles L8231 of the Civil Code -Code du travail), is the biggest subcontracting risk in France and has been in the legislation since 1848. This law is also detailed in the EU directive 2008/104/EC and the recent UK Agency Worker Regulations and entails the treatment of subcontractors as if they were the contractor's own employees. The CEA must avoid indicating how the production must be carried out and not interfere with the scheduling or termination of the subcontractors in order to avoid being requalified as the direct employer and risking “*délit de marchandage*”. Such illicit behaviours are punishable by law with prison and fines⁴, as a result, the subcontractor of a contractor must remain under the authority of his employer (the subcontracting firm) and not under the authority of the contractor. However, the contractor is simultaneously obliged to control the subcontractors without speaking directly to them, but rather only to the project leader⁵. Such hierarchical dynamics imposed by this law creates an additional barrier for the CEA to control and manage their subcontractors in an already high-risk industry, leaving the CEA facilities more prone to errors. The need for effective control systems is ever more essential as the CEA is the entity of the contractor- subcontractor relationship that is legally responsible.

The CEA implements controls and monitoring procedures to ensure the proper functioning of facilities including daily field inspections, daily rounds and monthly monitoring procedures. Each facility employs its own method and means of monitoring employees and subcontractors according to the regulations of each nuclear site. Therefore, CEA aims to set up a surveillance system that adapts, evolves and ensures the safety of nuclear facilities while complying with the specific regulations of each site. Additionally, of the Nuclear Sites and Facilities in France are overseen on behalf of the State, by *The Nuclear Safety Authority (ASN)*, an independent administrative authority established by the “*Law on Transparency and Safety in the Nuclear Field (TSN Law 2006-686)*” from June 13th, 2006. The ASN is tasked with regulating nuclear safety and radiation protection of nuclear workers, nuclear medicine patients, the public and the environment from the risks at Nuclear Facilities.

Management control systems such as contracts and procedures do help in controlling certain tasks and procedures; but not everything can be detailed in these formal controls; thus obligating managers to foster a strong contractor- subcontractor relationship and empower their subcontractors’ abilities and intentions⁶.

⁴ The « *délit de marchandage* » is punishable up to 2 years of prison time and up to 150 000 euros in fines in addition to being banned from using subcontractors from 2-10 years.

⁵ According to page 109 in the Parliamentary Mission’s Report published on June 30th, 2011 on Nuclear Safety following the Fukushima disaster, there are legal predicaments with subcontracting: The activity of the subcontractor is subject to a control by the contractor, which adds an additional task to the contractor of ensure the inspection of the subcontracting firm. At the same time, the actor from the contracting firm assigned to control of the subcontracting firm, is in principle not entitled to speak directly to the subcontractor's staff, but rather only to the subcontracting firm’s management.

⁶ Elements of a strong contractor-subcontractor relationships such as trust were identified throughout the empirical setting. However, this thesis does not focus on the notion of trust, and instead is interested in other elements including safety leadership that help shorten the distance within the subcontractor-contractor entity. As a result, any observations or results regarding trust will be looked at from the angle of safety leadership and their simultaneous effects along with Management Control Systems on risk mitigation.

Faced with these dissatisfactions, the CEA has proposed evolutions and axes of improvement in their implementation of specific management methods to control and oversee the subcontractors. This thesis is part of these propositions and has been financed by the CEA to propose a model of control of subcontractors within the nuclear facilities while simultaneously averting and mitigating subcontracting-related risks. The current theoretical management control models proposed in Management Science literature are detailed in the following section.

1. Theoretical Foundations

The theoretical foundations of the thesis are at the intersection of three principal themes within Management Accounting: Management Control System (1.1.), Risk and Risk management (1.2.), and Inter-Organizational Control (1.3.). More precisely, this thesis looks at controls used by managers (Management Control Systems, MCS) on subcontractors (Inter-organisational Relationships, IOR) to prevent and mitigate subcontracting related risks (Risk and Enterprise Risk Management, ERM) in a context where the temporality of these controls is crucial in ensuring nuclear safety.

1.1. Management Control System (MCS) Literature

Control and **Management Control Systems (MCS)** are important fields of study in Management Science. **Management Accounting** enables managers to monitor business activities and institute strategy by exerting influence on members of the organization (Anthony, 1965; Carenys, 2010) and/or by orienting the decision-making process. **Management control** is an essential process by which managers influence other members of the organization to implement the organization's strategies and goals. Abernethy and Chua (1996: p 573) define MCS as "*a combination of control mechanisms designed and implemented by management to increase the probability that organizational actors will behave in ways consistent with the objectives of the dominant organization coalition.*" Management controls yield a clear advantage "*necessary to guard against the possibilities that people will do something the organization does not want them to do or fail to do something they should do.*" Merchant and Stede (2007: p 8).

Different types of controls can be used to achieve different purposes (Ouchi, 1977; Ouchi and Maguire, 1975). There are numerous approaches to studying different elements of MCS that focuses on both formal and informal controls (Baines and Langfield-Smith, 2003; Chenhall and Langfield-Smith, 2003). However, MCS such as **formal controls** (*rules, policies and procedures for monitoring and rewarding performance*) contain limits since most are based on the observation and evaluation of the elements declared by the subcontractor as the contractor is not physically present to observe and evaluate for themselves. Therefore, the relationship between the subcontractor and the contractor must contain an essential dimension of **informal controls** (*shared values, beliefs and goals amongst members of the two firms to reinforce and reward appropriate behaviours*) (Das and Teng, 2001). Informal controls promote the internalization of goals by members of the firm, which then increases their commitment and motivation to achieve these goals.

Simons (1995) proposed a control *Levers of Control (LOC) framework* consisting of four control elements: beliefs, boundary, diagnostic and interactive controls. Boundary and belief systems are related to opportunity seeking and boundary setting, and interactive and diagnostic controls are related to performance management (Simons, 1995). Malmi and Brown (2008) use the term "*MCS Package*" to describe how different control elements support and reinforce each other. Given the number of control tools that exist in an organization, it is imperative to explore the design of MCS in various ways to identify the most suitable for a given situation (Grabner and Moers, 2013; Merchant and Stede, 2007). Given that MCS can be used to manage both intra-organizational and inter-organizational actors (Dekker, 2004; Tomkins, 2001; Vélez et al., 2008), MCS implemented in the contractor-subcontractor relationship, require resourceful management of systems and controls as the actors do not belong to the same firm. Additionally, Simons (1995) expressed the importance of also balancing the different types of controls. Mundy (2010) questions whether firms are able to identify and maintain an optimal balance of management control use and proposes several control elements (*internal consistency, logical progression, historical tendency, dominance and suppression*) that affect the organization's ability to balance such controls. Several scholars (Lukka and Granlund, 2004; Sjöblom, 2003) have expressed the growing interest and importance of a balanced use of management control systems as organizations are exposed to unpredictable environments and more volatile risks.

1.2. Risk and Enterprise Risk Management (ERM) Literature

According to the Oxford Dictionary, the word *risk* is defined "*as a change or possibility of danger, loss, injury or other adverse consequence*". According to ISO 31000 (2018) and ISO Guide 73 (2009), risk is defined as "*the effect of uncertainty on objectives*", where by risk refers to both the positive and negative consequences of uncertainty on the ability of an organization to meet its objectives. Risk under this definition is defined as a conceptual manner with a focus on goal-oriented terms. Management scholars have proposed numerous definitions of risk that lack consensus (Baird and Thomas, 1990; Bettis and Thomas, 1990). Risk should not be confused with the concept of *uncertainty*, that according to Galbraith (1977, p. 5), can be defined as "*the difference between the amount of information required to perform a task and the amount of information already possessed by the organization*".

Since the 1990's academics have become increasingly interested in risk and risk management (Berry et al., 2005) and have thus made significant progress on how risk is perceived and addressed in management (Bettis and Thomas, 1990). Hutter and Power (2005, p. 9) affirm that "*risk functions as an organizing category for management in general*". Therefore, they do not perceive risk as being "*independent of management processes in organizations but rather, representations of risk, its management and the organizations that do the managing are co-produced*" (Hutter and Power, 2005, p. 9).

There exist nearly as many definitions for *Enterprise Risk Management (ERM)* as for management control, and according to Power (2007) it is becoming an "*umbrella concept*" rather than a "*coherent set of*

practices". Despite the multitude of proposed definitions, three core concepts of ERM have emerged (Bromiley et al., 2015):

- (1) Managing firm risk collectively as a corporation throughout all activities is more efficient than managing the risk of each individual parts of the corporation or individual activities;
- (2) ERM incorporates both traditional risks (product liability and accidents) as well as strategic risks (product or production decline and competitor actions); and
- (3) Firms should not envision risk as a problem to mitigate, but rather manage the risk to seek a competitive advantage.

In fact, **ERM** encourages a company to address its risks comprehensively and coherently rather than managing each of its risks individually. Historically, firms have managed risk separately, as different functions within the firm managed risk differently. Additionally, according to (Bhimani, 2009), Risk management is another kind of formal management control therefore : *"It is inept to consider management control as being distinctly separate and independent from risk management or corporate governance concerns"* (Bhimani, 2009, p. 9); as control processes by definition intend to *"monitor the degree of alignment between organizational activities and precepts of desirable managerial outcomes [and] placing boundaries on risk-taking and organizational function by identifying acceptable variances from predefined parameters of actions"*.

In fact, numerous scholars (Beasley et al., 2005; Bhimani, 2003, 2009; Gordon et al., 2009; Mikes, 2009; Mikes and Kaplan, 2012; Subramaniam et al., 2011) encompass Enterprise Risk Management in the definition of management control, as they consider that risk management as part of an organization's MCS. However, the management of risks is seen as its own entity within MCS and therefore it is inadequate for firms to merely deploy generic MCS that are considered effective in a general control sense, and must instead implement transparent risk-specific controls that signal to organizational actors the "adequacy" of the internal management control mechanisms deployed. Such actions endorse the perception that control is exercised while both taking a risk and while managing it (Bhimani, 2009).

Certain risks for the contractor may be heightened by the very nature of subcontracting, as it is the subcontractors themselves that provide the elements used to evaluate and monitor their performance. Moreover, inaccurate or unavailable data provided by the subcontractor may hinder decisions, operational performance of the firm and undermine the integrity of the organization (Christ et al., 2014). Failure to comply with pre-mandated rules may result in regulatory sanctions for the contracting firm as well as potentially endangering the safety of the workers. The risks are further exacerbated given that the contracting firm is generally responsible for the tasks performed by the subcontractor and thus may incur financial and legal sanctions should there be negligence on the part of the subcontractor. There exists growing evidence in both management accounting and risk management research indicating that subcontracting relationships may carry a great deal of risk for both parties as each may have different agendas which could potentially lead to opportunistic exploitation (Langfield-Smith and Smith, 2003b) of

resources and power. Two sets of authors (Bleeke and Ernst, 1990; Das and Teng, 2000) also indicate that failure rates of alliances, such as subcontracting, are significantly elevated compared to single firms.

This thesis is particularly interested in the **risks associated with subcontracting**. These risks may be mitigated by *Management Control Systems (MCS)* discussed in sub-section 1.1. (Anderson et al., 2014; Das and Teng, 1999, 2001; Eisenhardt, 1985; Hopwood, 1976; Kirsch, 1996; Merchant, 1985; Ouchi, 1979; Ouchi and Maguire, 1975). In fact, risk management is so much in demand by regulators, executives, other company consultants that academics have created an entire discipline dedicated to managing risks in organizations.

1.3. Inter-organizational Relationship (IOR) Control Literature

In recent years, an increase in globalization, rapid technological transformation and increased technical complexity of products has seen a propagation of subcontracting practises into nearly all other industries of the public and private sector (Langfield-Smith and Smith, 2003). There are particular complexities that arise from interactions between firms, *regardless of the number of firms in the inter-organization configuration*, that impose additional difficulties to the classical control issues extant within the *intra-organization configuration* of a single firm. Control in this inter-organizational setting occurs in separate company settings and hence no longer ascribes to a hierarchical authority of control. As a result, the concepts created to interact in vertical and hierarchical operations are no longer adapted to the functioning of organizations (Hopwood, 1996). Instead, the inter-organizational control will take different forms with different aims according to the type of inter-organizational setting (Håkansson and Lind, 2006). Additionally, the surge in the quantity and significance of in inter-organizational relationships imposes new demands on managers and managerial controls. Traditionally, managers focused MCS on the activities and resources within the company (*intra*) drawing the line at the external parameters of the firm. However, with this new relationship, managers of the contracting firm must implement management controls within the firms (*inter*) thereby extending their MCS practices beyond the company borders. As a result, "the scope of the activity of management control is enlarged and no longer confined within the legal boundaries of the organization" (Otley, 1994, p. 293). Such organizational transformations provide interesting research settings for researchers to study the controls implemented between these firms (Berry et al., 2009).

In designing and implementing such inter-organizational management controls, managers of the contracting firm need to not only consider their own company's activities, resources and performance but additionally anticipate these same factors of the subcontracting firm (Kraus and Lind, 2007). Similarly, the subcontracting firm managers also need to consider the activities, resources and performance of the contracting firm and analyze the effects of these elements on their own company strategies (Kraus and Lind, 2007). Inter-organizational relationship (IOR) literature distinguished between three types of management controls presented in (Merchant and Van der Stede (2007)'s typology: *Behaviour* i.e. *Process controls* "first specify how parties should act then they evaluate whether the specifications have been followed"(Kraus and Lind, 2007, p. 279). *Output* i.e. *Outcome controls* "measure, evaluate and reward

the outcome or results of the inter-organizational relationship” (Kraus and Lind, 2007, p. 276). **Social controls** i.e. **Input controls** “relate to the values, norms and culture that influence the behaviour [of organizational actors] (Kraus and Lind, 2007, p. 280). These controls have strong similarities to Simons’ Belief Systems mentioned in sub-section 1.1.

2. Research Question(s)

The research questions of this thesis are at the intersection of the Empirical Implications described at the beginning of this Introduction, and the Theoretical Foundations detailed in section 1. Subcontracting in the French Nuclear Sector presents an interesting context to study Management Control Research and Risk management for a number of reasons. *Firstly*, France relies on nuclear energy to obtain 75% of its power, but nuclear power in the world has seen several catastrophes and accidents at an international level that have resulted in a strong societal impact. *Secondly*, France is one of the world leaders in nuclear advances and nuclear technology. *Thirdly*, the nuclear sector is at the forefront of risk management and safety management and thus the nuclear industry has become the reference for other high-risk industries. *Fourthly*, there have been very few studies in Management Control Research and Risk management within the French Nuclear Sector, even fewer with an in-situ perspective allowing direct access to the actors and daily management procedures. Given this context, the French Nuclear Industry is an important setting to study risk aversion and mitigation subcontracting-related questions at a managerial level.

Figure 2 below further substantiates the main research question at the heart of the Theoretical Foundations and the Empirical Implications. In light of the empirical setting that informs us that the CEA is unable to monitor and observe its subcontractors at all times, and given the contextual elements of the literature that indicates that management controls are not enough to ensure optimum safety behaviours from the subcontractors.

This research aims to explore: ***How does the CEA design Management Control Systems (MCS) that can effectively avert and mitigate subcontracting risks associated with quasi-integration, in the context of the specific characteristics of its nuclear facilities?***

As a result of the overarching research aim, the main objective is to “**Design MCS tailored to the Nuclear Facilities**”, which breaks down into four Research Objectives (RO):

- The *first* RO is **Mitigation (of Risks)**: ***How do the MCS employed by CEA Managers (on subcontractors) avert and mitigate risks?***
- The *second* RO is **Balancing**: ***How do CEA managers balance MCS “as a package” to avert and mitigate subcontracting-related risks and events?***
- The *third* RO is **Overcoming**: ***What dimension is implemented to orchestrate MCS as a package to enhance safety behaviours at the CEA?***
- The *fourth* RO is **Implementation**: ***What implementation approach(es) of MCS, following a near miss or a minor event, enable the controls to support and reinforce each other “as a package”?***

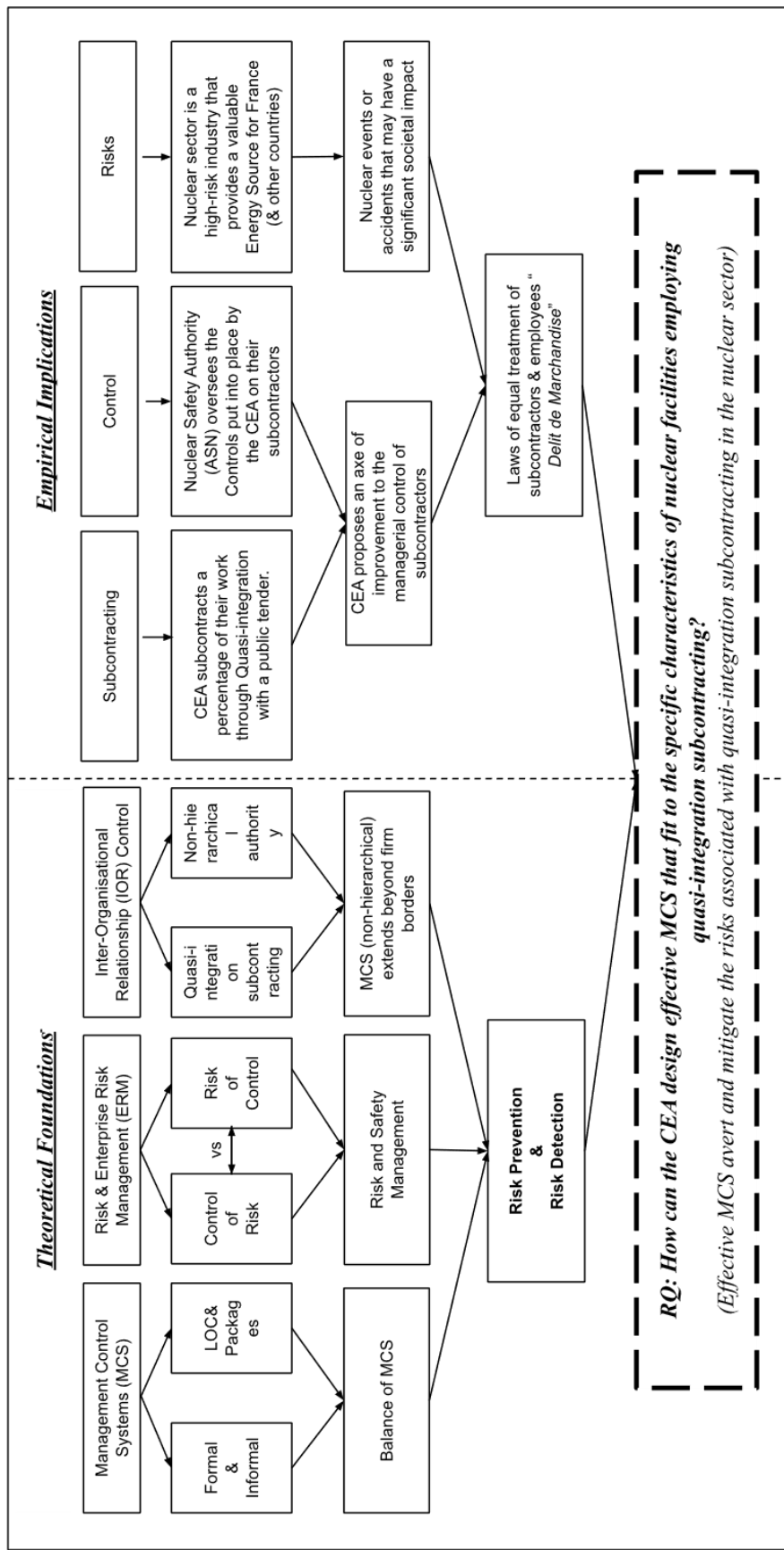


Figure 2. The Research Question at the Heart of the Theoretical Foundations and the Empirical Applications

3. Theoretical Framework of the Research

A significant focus of the research design and the selection of theoretical framework arose from the intention of providing a holistic research angle (Ferreira and Otley, 2009) to the research questions. This thesis is interested in the merger of both General Systems Theory described in sub-section 3.1 and Contingency theory detailed in the sub-section 3.2 below.

3.1. General Systems Theory

A system is a global unit made up of a “set of elements which interact together in a dynamic manner and are organized to achieve a specific goal” (De Rosnay, 1975, 2014). Systems thinking connects the units of a system, provides a holistic vision that unifies a group of variables, and sheds clarity on the effect of their interactions. System thinking is a combination of organizational tools from multiple disciplines, designed to analyze complex interactions between multiple actors, at multiple levels and the interaction between these actors and the system (De Rosnay, 1975, 2014). The resultant global template permits elements of the system to be acted upon either directly or indirectly by changing a parameter in parallel to the element. We can apply a systems thinking approach to safety, in order to complement the traditional safety approaches. Systems thinking helps to manage the complex interactions occurring at every level of the organization, by identifying interactions between human, organizational and technological factors and then, considering the complexity of the interrelationship, and assessing their effects on safety (IAEA, 2014; Leveson, 2004). We can think of accidents, as “Events” caused by the degradation of safety performance (N. Leveson, 2004). They are usually the result of the interaction of several causal factors at multiple levels, rather than the interaction of a single causal factor at a single level (N. Leveson, 2004). Given that traditional causal analysis tools model events and causal factors linearly, they are not designed to analyze complex interactions. This highlights the importance of using systemic modelling tools such as an AAS to act upon elements of the system and to take into account how these actions (be it direct or indirect) (single or multiple actions) affect the entire system. Particularly as “only complexity can cope with complexity” that is only complexly-designed management systems can help firms cope with the risk complexity of the current safety environments. Safety is viewed as a “control problem” and safety is managed by a control structure (N. Leveson, 2004). One such control structure is “Management control”.

3.2. Contingency Theory

The word “*contingency*” implies that an outcome is only valid under specified conditions and hence the outcome is “contingent” on particular characteristics. **Contingency theory** claims that “*there is no universally accepted model of the organization that explains the diversity of organizational design*”, therefore, “*organizational design depends on contingent factors relevant to the situation*” (Hoque, 2002, p. 12). Contingency theory studies, therefore, allows managers to predict which particular management control systems will be present in specific organizational context or **contingent variables** (*external environment, technology, size, organizational structure, strategy and culture*) and determine if the specific

design of control systems will yield (or not) improved firm performance or effectiveness. Contingency-based research in MCS studies assumes that managers consciously adapt the firm to changes in contingencies in the scope of attaining fit and enhanced performance (Chenhall, 2003, 2006), thereby implementing tailored control design.

Empirical findings in contingency literature and contingency frameworks (Chenhall, 2003, 2006; David T Otley, 1980) aim to provide comprehensive links between MCS element, MCS design and organizational context to augment the desired organizational outcomes (performance, organizational effectiveness) (D. T. Otley, 1980). Similarly, Nedaei et al. (2015) propose a Contingency Model of Enterprise Risk Management (ERM), a subset of an organizational control system, that argues that organizational performance is dependent on the fit between the ERM methods and three contingency variables (*size, decentralization and enterprise resource planning*). For optimal results of performance and proficiency levels, organizations must tailor their MCS designs to “fit” their particular context. The notion of “fit”, has been developed (Drazin and Van de Ven, 1985; Gerdin and Greve, 2004) and implemented across multiple contingency studies in Management Control literature (MCS) and Enterprise Risk Management (ERM) literature with the aims of designing innovative approaches to attain higher levels of control. In the case of MCS, this includes a general design of management controls to improve performance and organizational efficiency, while in the case of ERM the design of management controls aims to prevent and mitigate risks.

4. Methodology

The research questions studied are very specific and strongly linked to the context and its backdrop in the nuclear sector. The *pilot study* at one of the two Nuclear Sites of the CEA, guided the final formation of the case study, provided preliminary information regarding the nuclear sector, and helped to guide the development of the theoretical framework of the study. For this reason, this dissertation consists of a *qualitative embedded single-case study* of Facility A, Facility B and Facility E⁷ of the French Alternative Energies and Atomic Energy Commission (CEA); a governmental agency that subcontracts a large percentage of their work. Theoretical propositions and constructs emerged following nine phases of empirical data collected, separated by a period of analysis during which there was “*constant movement back and forth between theory and empirical data*” (Wodak, 2004. p.200). This is used to make sense of the observations (Dubois and Gadde, 2002; Dumez, 2016) by creating a learning loop (S. S. Taylor et al., 2002), typical of *abductive reasoning*. During this iterative back and forth aspect, the empirical data collection and theory building occur simultaneously, which accentuates the exploration for suitable theories to “match” an empirical observation; a process that Dubois and Gadde (2002, 2014) refer to as “theory matching”, or “*systemic combining*”. “*Systemic combining is a process where theoretical framework,*

⁷ The names of the Facilities (Facility A through to Facility E) have been chosen at the request of the CEA to ensure the two theses carried out at these Facilities share the same letter. As a result, the nomination of the Facilities is mirrored in the thesis of Amaury Bazalgette.

theory, empirical fieldwork, and case analysis evolve simultaneously” (Dubois and Gadde, 2002, p. 554). Moreover, it compares and contrasts the research problem and the analytical framework to the empirical world, to generate new concepts and develop theoretical models (Dubois and Gadde, 2002). The **Modeling Process** was used to generate these new concepts produced and reformulated in one Facility and then exhibit and validate this knowledge in another Facility; as “*a model [is a] representation of knowledge*” (Le Moigne, 1987, p. 3). Theory building or **theory development** from case studies has numerous strengths including testability and empirical validity due to its close linkage to empirical evidence (Eisenhardt, 1989b; Eisenhardt and Graebner, 2007; Siggelkow, 2007) as it is “*derived from data, systematically gathered and analyzed through the research process*” (Strauss and Corbin, 1990:12). The data collection and interview guide are located in Appendix A and B.

5. The purpose of the thesis and the contributions

This thesis is part of a descriptive and comprehensive approach to understand the control procedures and interactions among the actors of the Nuclear Facilities to improve collaboration and reduce subcontracting-related risks. Specifically, this study proposes a new approach to risk management and safety management, based on "Thinking Systems", which applies the empowerment leadership principles (Arnold et al., 2000) to develop and overcome the limitations of management control systems (MCS). It combines a systemic approach to MCS with a systemic approach to safety leadership, through an Ago-Antagonist model.

From a theoretical point of view, the results contribute to enrich the knowledge in the field of the inter-organizational management control and contingency literature, in the very specific case of three Nuclear Facilities of the CEA that outsource a percentage of their work but have different managerial configurations. This inter-organizational relationship provides strategic and economic benefits, but exposes the parties to subcontracting related risks, which can impact nuclear safety and occupational safety. In fact, these risks are exacerbated by the organizational distance between the two entities of the contractor-subcontractor relationship thereby demonstrating the importance of the inter-relationship between top CEA managers, Middle Managers and subcontractors. To clarify, the Middle Managers are the managers of the subcontracting firm that oversee the subcontractors in their daily tasks.

In addition to contributing to the field of Inter-organizational (IOR) Control, Management Control Systems (MCS), and Enterprise- Risk Management (ERM) Literature that focus on control, this dissertation also makes transversal academic contributions to the field of Safety Science and Human and Organizational Factors (HOF) Literature. Specifically, this research contributes academically to:

- The ERM literature by describing two types of control used in risk management (Preventive and Detective control) and by illustrating how the temporal aspect of these controls determines their ability to avert and/or detect the risks that, if undetected, can lead to nuclear events.
- The MCS literature, by relating Preventive and Detective controls to Simons' (1995, 2013) Levers of Control (LOC), and by proposing a method to balance these ago-antagonistic forces.

Additionally, this research illustrates how leadership styles promote safety by helping to overcome the limits of management control systems.

- The Contingency Literature of MCS (and ERM), by exhibiting how control preferences and leadership styles are contingent on and fit to the contingency factors of the organization (*external environment, technology, organizational structure, size and ratio, strategy and culture*).
- The IOR Control literature by demonstrating the effects of the subcontracting and contractor managers' leadership style and their implication and promotion of safety culture.
- The Safety Science and HOF literature by employing the use of Systems Thinking and Ago-antagonistic Systems to define and model preventive and detective controls in order to show their role in combination with safety leadership to reinforce safety and risk management practices.

From a practical point of view, the research makes it possible to formulate suggestions for improving the managerial control of subcontractors. The suggestions formulated are intended for the managerial actors in the risk management process: the Facility Chief (or RCI or Chief) and the CEA managers that oversee the Facility (Occupational Safety Engineers, Nuclear Safety Engineers), while simultaneously taking into account the role and impact of the Middle Managers in implementing these suggestions. The study provides a series of Systemic models of the management approach used at the CEA to avert and mitigate subcontracting-related risks, in light of Contingency Theory and Systems Theory, which highlight the contingency factors and the Ago-antagonistic nature of the risk management practices.

Specifically, this research contributes practically by:

- Identifying the cycle of control common to all three nuclear facilities and classifying the different controls based on the temporal aspect of the controls (in relation to the task) and the position of the actor performing the task.
- Identifying the ago-antagonistic virtues of the controls and demonstrating how to balance ago-antagonistic controls for an improved prevention and mitigation of subcontracting-related risks and events.
- Proposing a rigorous system of control management guidelines, adapted to the particularities and specificities of the nuclear industry, an industry that upholds a strong standard of excellence in safety.

Finally, these managerial contributions align with the appeals made by the International Atomic Energy Agency (IAEA) following three major nuclear accidents: Three Mile Island in 1979, Chernobyl in 1986, and Fukushima Daiichi in 2011. Specifically, the (IAEA): stresses the importance of human factors in nuclear safety; calls for effective leadership practices considered as "levers of change" for the safety culture; and accentuates the need to complement traditional safety approaches through a systems approach.

6. Thesis Structure

The construction of an explanatory (*cognitive*) model that help to explain the phenomenon by illustrating the fundamental interactive mechanisms of inter-organizational control in the nuclear industry. This inter-organizational control, underpinned by Systems Thinking, is organized around the themes of : prevention and detection of risks or nuclear events; the nature of control contingent upon the nuclear facility (based on its managerial configuration); the temporal aspects and nature of MCS and their effectiveness in averting and mitigating events; and the managerial strategies (leadership, systemic tools to balance) that in combination with MCS as a package interact in a complex system to strengthen safety performance.

The thesis structure is detailed in Figure 3, distinguishing themes of this analysis in the construction process of the explanatory cognitive model – risk – management control – strategies, and the theoretical (Ago-antagonistic Systems and the balance of controls) and practical contributions (Safety Leadership, Middle Management).

This dissertation is organized into four chapters:

Chapter 1 presents the theoretical framework of Systems Thinking and Contingency Theory as well as the literature review of existing theories on Management Control Systems including Simons' Levers of control, MCS Packages and the use of Inter-Organizational Control in Risk Management. This Chapter allows us to situate the study in the existing literature by discussing the studies of management control systems that have implemented systems theory and contingency theory.

Chapter 2 and presents the methodological framework of the research, including the research design and methods of the dissertation, especially focusing on design strategy, research setting, data collection and analysis methods. Specifically, in designing the MCS model, first, the aim of the model is discussed and the System (CEA) where the model will be applied is analyzed thereby presenting the context of the nuclear sector. Next, the model is formalized and presented using the appropriate modelling language, including the use of metaphors related to driving or controlling an automobile. Specifically, the *initial model* is reframed and refined at the first nuclear facility, re-designed and formalized into the *developed model* at the second facility once the missing components are identified, and finally re-evaluated and validated at the first nuclear facility. Findings from the third nuclear facility do not invalidate the model.

Chapter 3 provides two in-depth case studies of how managers implement MCS in three nuclear facilities that execute similar activities by subcontracting located at two different CEA centers, which yield different organizational and managerial configurations and contrasting leadership styles. The purpose of chapter 3 is to contrast the characteristics of each nuclear facility and determine the types of MCS utilized in risk management. Specifically, this chapter details: the prevention and detection of risks or nuclear events; their ago-antagonistic nature, the nature of control specific to each nuclear facility's managerial configuration; the temporal aspects and nature of MCS and their effectiveness in averting and mitigating events; and the managerial strategies including leadership and systemic tools implemented in combination with MCS

packages to rebalance and re-enforce safety. Findings from this Chapter, therefore, serve to enrich the comparative analysis between the different characteristics of the three nuclear facilities and their effects on managerial controls through an embedded single case study.

Chapter 4 presents the discussion of the findings and presents both the academic and managerial contributions. First, it details the use of Ago-antagonistic Systems, a systemic modelling tool, to identify imbalances and rebalance management control systems. Second, Leadership Styles, their implementation into management control practices, and their effects on regulating safety procedures through employee empowerment to improve safety performance are discussed. Finally, the impact of a strong Middle management presence and their effects in minimizing the distance between the contractors –subcontractor relationship are also discussed.

The conclusion summarizes the findings, discusses limitations and contributions of the study, and suggests avenues for further research.

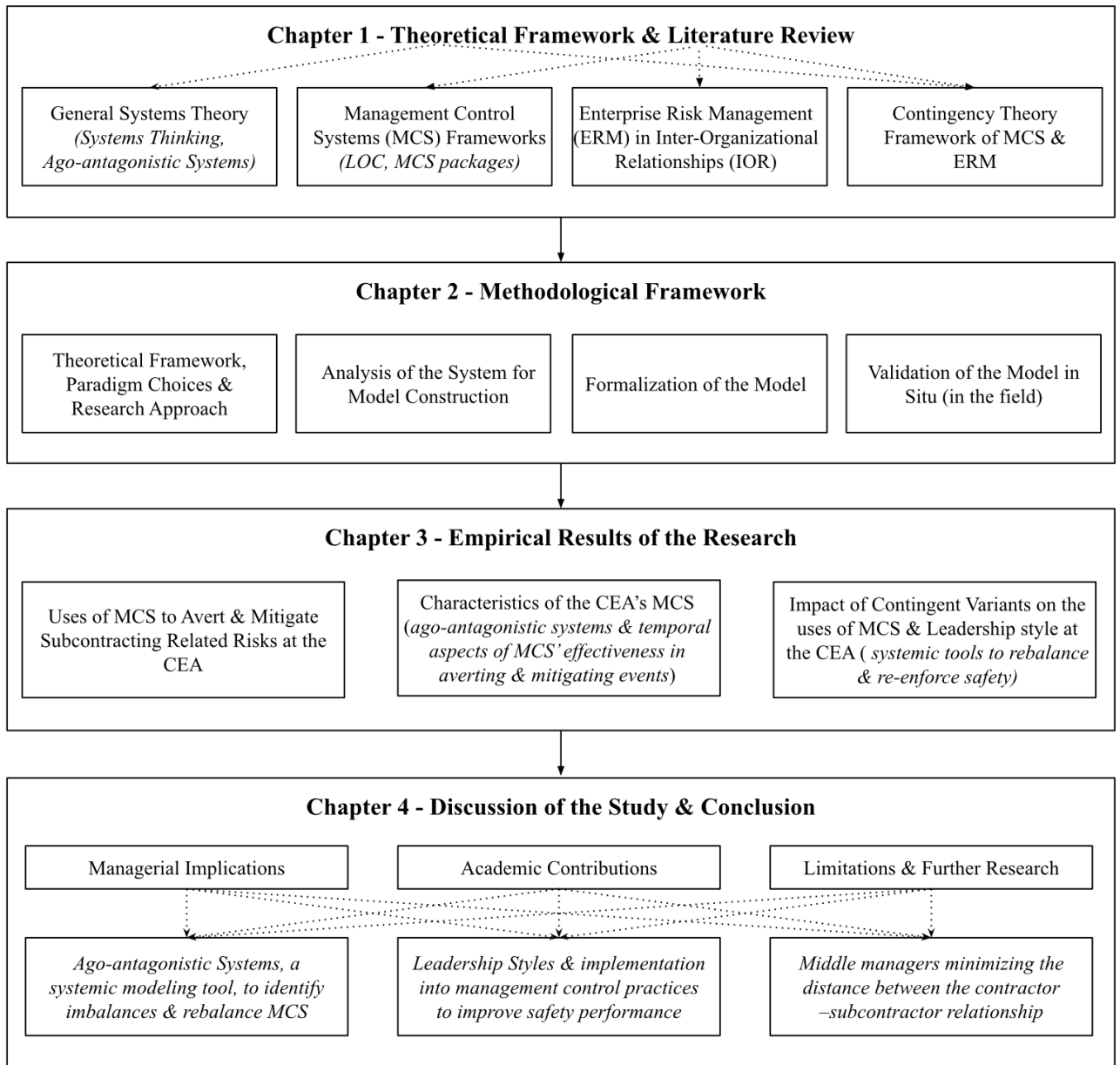


Figure 3. Layout of the Thesis

Chapitre 1 – Revue de la littérature

(Résumé en Français)

Ce chapitre présente une revue de la littérature sur le contrôle de gestion et deux théories du management (la théorie générale des systèmes et la théorie de la contingence). La section 1 donne un aperçu de la théorie générale des systèmes. La section 2 pose les bases des études sur les systèmes de contrôle de gestion (SCG). La section 3 détaille les risques et la gestion des risques dans les relations inter-organisationnelles (RIO), y compris la gestion des risques d'entreprise (GRE). La section 4 détaille la théorie de la contingence et fournit un cadre basé sur la contingence qui intègre la gestion des systèmes de contrôle de gestion et le risque d'entreprise.

Le contrôle de gestion est le processus par lequel les managers influencent les autres membres de l'organisation afin de mettre en œuvre les stratégies de l'organisation. Les SCG ont été décrits comme un ensemble de dispositifs de contrôle qui servent de "*système de recherche et de collecte d'informations organisationnelles, de responsabilisation et de rétroaction conçu pour garantir que l'entreprise s'adapte aux changements de son environnement substantiel et que le comportement au travail de ses employés est mesuré par rapport à un ensemble de sous-objectifs opérationnels (qui sont conformes aux objectifs généraux) de sorte que l'écart entre les deux puisse être concilié et corrigé*" (Otley et Emmanuel, 2013, p. 8). Compte tenu de cette définition, les SCG sont utiles dans la gestion des acteurs intra-organisationnels et inter-organisationnels (Dekker, 2004) tels que la relation contractant-sous-traitant qui, en raison de la distance entre les entreprises, nécessite une gestion ingénieuse des systèmes et des contrôles.

Le développement et la mise en œuvre de mécanismes de contrôle formels et de mécanismes de contrôle informels dans une organisation permettent aux managers d'obtenir des résultats de manière stratégique (Caglio et Ditilio, 2008 ; Eisenhardt, 1985). Une organisation dispose de deux types de contrôles formels (Reason et al., 1998 ; Ouchi et Maguire, 1975) : les contrôles dits comportementaux et les contrôles par les résultats. Les contrôles comportementaux, c'est-à-dire les contrôles de processus (Merchant et Van der Stede, 2007), normalisent le processus de travail à l'aide de règles et de procédures prescriptives, mesurant souvent le comportement pour s'assurer que le processus est approprié et réalisé conformément aux spécifications prédéterminées (Anderson et al., 2014 ; Das et Teng, 2001a ; Eisenhardt, 1985a ; Ouchi et Maguire, 1975). Les *contrôles comportementaux* permettent de s'assurer que le sous-traitant respecte les règles de sécurité en appliquant les règles et les comportements prescrits par le contractant ou les autorités réglementaires externes. Les contrôles par les résultats mesurent les résultats de ce comportement par le biais d'un processus de contrôle par rétroaction qui oppose les mesures de sortie aux performances et aux objectifs organisationnels (Anderson et al., 2014 ; Das et Teng, 2001a ; Eisenhardt, 1985a ; Ouchi et Maguire, 1975). Le *contrôle par les résultats* sert à évaluer avec précision les principales mesures de performance, ce qui permet aux contractants d'adapter les changements à ces mesures, garantissant ainsi que les sous-traitants mettent en œuvre leurs compétences et leurs ressources pour obtenir des résultats

conformes aux règles de sécurité. Enfin, les *contrôles informels ou sociaux* minimisent les divergences d'objectifs entre le contractant et le sous-traitant en établissant une culture, des valeurs et des croyances communes (Anderson et al., 2014 ; Das et Teng, 2001a ; Ouchi et Maguire, 1975), assurant ainsi la convergence des objectifs ou la compatibilité des objectifs de sécurité non convergents. Compte tenu de la complexité et de la pléthore de contrôles managériaux, il est essentiel d'explorer la conception du SCG à l'aide d'une approche systémique, afin d'identifier les composants de conception les plus appropriés et leurs interactions à plusieurs niveaux de l'organisation. Cependant, la recherche indique que le simple renforcement des règles et des procédures ne suffit pas à favoriser des comportements sûrs sur le lieu de travail ; il est donc essentiel de compléter le SCG par d'autres éléments pour garantir des résultats positifs en matière de comportement de sécurité.

Le concept de gestion des risques fait intervenir deux notions : contrôle et risque. Cependant, ces deux notions peuvent être examinées sous deux angles : le premier examine comment les systèmes de contrôle de gestion soutiennent la gestion des risques - et donc "*le contrôle des risques*" ; et le second détaille les risques qui sont associés aux systèmes de contrôle de gestion - et donc "*les risques du contrôle*". *Le contrôle du risque* nécessite une conception organisationnelle pour une gestion optimale du risque qui tient compte des structures, procédures et stratégies organisationnelles face à l'incertitude. Galbraith (1977) propose quatre stratégies organisationnelles à employer en présence d'une incertitude accrue telle que l'incertitude de l'information. En employant une combinaison de ces stratégies, la capacité de l'organisation à traiter l'information est améliorée, ce qui permet à l'organisation de fonctionner même lors des pics d'incertitude, lorsque les attentes les plus élevées en matière de performance organisationnelle sont imposées. *Le risque de contrôle* est accru par les niveaux réduits de flexibilité imposés par les organisations lors de changements environnementaux inattendus. Les ouvrages de gestion partent souvent du principe que la quantité de contrôle à appliquer à une situation est directement proportionnelle à la quantité de risque. Par conséquent, plus le risque est grand (et plus les conséquences de ce risque sont importantes), plus la quantité de contrôle nécessaire pour gérer ce risque est grande. Cependant, selon Berry et al. (2005), c'est souvent le contraire qui se produit, car l'exercice d'un contrôle en soi comporte souvent un risque, et donc la mise en œuvre d'une plus grande quantité de contrôles pour compenser le risque accru perçu peut entraver ou empêcher le fonctionnement de ces techniques de gestion des risques. Plus précisément, ces contrôles supplémentaires peuvent diminuer la capacité d'anticipation, d'imprévu et de flexibilité de l'acteur organisationnel, qui sont des composantes essentielles de la gestion des risques. Par conséquent, à mesure que les plans, les politiques et les budgets deviennent plus restreints et manquent de souplesse pour faire face à des situations inattendues, la capacité des acteurs de l'organisation à naviguer dans un climat turbulent est également restreinte, ce qui entraîne une augmentation du risque au lieu de la réduction prévue. Par conséquent, les contrôles sensibles qui permettent une réponse flexible aux changements environnementaux inattendus (Berry et al., 2005, p. 299) sont essentiels pour les managers, car ils doivent faire face à des variations de risques qui fluctuent en fonction des caractéristiques internes (culture, taille, maturité, etc.) et externes (concurrents, environnement) de l'organisation.

Cette thèse fusionne deux cadres théoriques, la théorie générale des systèmes et la théorie des contingences, et s'intéresse à leur application aux systèmes de contrôle de gestion (SCG) et à la gestion des risques d'entreprise (GRE) dans les relations inter-organisationnelles (RIO). Des études antérieures, qui ont fusionné les deux cadres théoriques (Efferin et Hopper, 2007 ; Hewege, 2011 ; Hopper et al., 2009), ont étudié les facteurs de contingence culturels, sociaux, politiques et anthropologiques profondément enracinés qui affectent les contrôles de gestion. La théorie générale des systèmes et la théorie de la contingence soulignent, toutes deux, l'importance d'analyser les SCG selon une approche holistique qui examine les effets de multiples éléments ou facteurs de contingence sur le système. La théorie de la contingence exprime en outre que ce ne sont pas les systèmes de contrôle de gestion qui affectent la performance organisationnelle, mais plutôt l'adéquation entre les systèmes de contrôle de gestion et les facteurs de contingence (*environnement, technologie, taille, stratégie, structure, culture*) de l'organisation. Par conséquent, le SCG et la GRE doivent évaluer de multiples facteurs spécifiques à chaque scénario afin de déterminer la meilleure stratégie de gestion des risques qui peut être appliquée et de s'assurer que la conception du SCG ou de la GRE tient compte de ces facteurs de contingence. Par exemple, les variables de contingence telles que la *structure, la taille et la planification des ressources de l'entreprise* et leur lien avec la *sophistication des méthodes de GRE et la performance de l'organisation*. Par conséquent, il n'existe pas de solution universelle unique pour la gestion des risques. Au contraire, les entreprises doivent évaluer leurs caractéristiques individuelles, tout en évaluant les effets de ces caractéristiques sur l'ensemble du système, afin de proposer une solution sur mesure qui résout au mieux les particularités des risques spécifiques.

L'analyse des éléments contextuels dans la littérature existante sur le SCG, la GRE et le RIO, en combinaison avec les implications empiriques de la sous-traitance au CEA (détaillées dans l'introduction), révèle la nécessité d'aborder la question principale de recherche et les sous-questions discutées dans l'introduction, qui n'ont pas encore été résolues dans la littérature de gestion.

Une meilleure compréhension de ces concepts permettra au CEA de comprendre le couplage des contrôles formels et informels, et leur rôle dans la prévention des risques dans plusieurs installations nucléaires. Le caractère unique des variables contingentes de chaque installation (*environnement, technologie, taille, stratégie, structure, culture*) mettra également en lumière l'influence entre les variables contingentes et les types de leadership et la combinaison des systèmes de contrôle de gestion utilisés.

Puisque les organisations utilisent simultanément un large éventail de mécanismes de contrôle pour servir des objectifs multiples, Otley (1980) explique que cela "rend difficile, voire impossible, d'isoler l'effet d'un moyen de contrôle spécifique". En conséquence, il déclare que "peut-être une stratégie de recherche initiale serait-elle d'essayer d'identifier les combinaisons de contrôles qui semblent être particulièrement adaptées à certaines circonstances". Par conséquent, le chapitre suivant détaille la méthodologie utilisée dans cette thèse pour répondre aux questions de recherche susmentionnées et tenter d'identifier la combinaison de contrôles adaptée à la prévention et à la détection des risques. Plus précisément, le chapitre 2, identifie les différentes particularités et les variables de contingence de plusieurs installations nucléaires et l'analyse de

l'utilisation des SCG pour prévenir et atténuer les risques liés à la sous-traitance. Il présente et justifie le choix du cadre théorique présenté dans ce chapitre (théorie générale des systèmes et théorie des contingences) ainsi que les choix philosophiques (paradigmes), les approches de recherche et l'utilisation de deux méthodes de recherche fondées sur la logique d'abduction. Le processus centré sur le modèle, en conjonction avec l'approche de combinaison systémique, utilisé dans cette thèse, a conduit à l'élaboration du modèle initial et développé de l'utilisation des systèmes de contrôle de gestion.

Chapter 1 – Literature Review

This chapter provides a literature review of the two management theories and the three management control literatures detailed in the introduction. Section 1 provides an overview of the General Systems Theory. Section 2 sets the groundwork of studies in Management Control Systems (MCS). Section 3 details Risks and the management of Risk in Inter-Organizational Relationships (IOR) including Enterprise Risk Management (ERM). Section 4 details the Contingency Theory and provides a Contingency-based Frameworks that integrates the management of Management Control Systems and Enterprise Risk.

1. General Systems Theory

As systems became more and more complex, classical analysis techniques could no longer cater for these systems complexities. In the 1930s and 1940s, Systems theory originated in response to the need for analysis of more complex systems (Checkland, 1981). Norbert Wiener developed this new approach for control and communications engineering (Wiener, 1948, 2019), while Ludwig von Bertalanffy (1968) applied the concept to biological systems and suggested that the concept be implemented across numerous fields. The emergent ideas are combined into a “general theory of systems”.

Traditional analysis techniques known as *analytic analysis* differ greatly from *systemic analysis techniques*, in their assumption of system behaviours. Analytic analysis treats a system by *compartmentalizing different sections into separate parts that are examined separately*, alluding to a “divide and conquer” mentality. The physical components are decomposed or “*analytically reduced*” into *separate physical components where behaviour is separated into discrete events over a temporal line* (N. G. Leveson, 2011). In fact, the *analytic analysis assumes that the disjunction of system components is viable* by making the following assumptions: (1) each component or subsystem operates individually; (2) the analysis of a single component has the same results when viewed on its own as if it were considered as part of the system (N. G. Leveson, 2011). As a result, for components analyzed under analytical analysis, the *systems are not exposed to the feed-back loops or non-linear interactions of a complex system and the behaviour of the system is identical whether examined individually or as a whole* (Leveson, 2011). (3) The principles of the component assembly are straightforward and simple, thereby permitting the *interactions between the subsystems and their behaviour to be considered as separate entities* (Leveson, 2011). The aforementioned assumptions are in fact rational as they describe a number of physical regularities in the universes such as physics that employ analytic reduction in *structural mechanics* (Leveson, 2011). This description of a system known as *organized simplicity (a)*, occurs when the *degree of complexity and the degree of randomness are low*, and is one of three categories of systems that also include *unorganized complexity*, and *organized complexity* (Weinberg, 1975) (See Figure 4 below).

According to Baumgartner and Ménard, (1996) in (Vautier, 2018), the term *complexity* arises from the Latin terms *complexus* (surrounding, encompassing and encircling) and *complicare* (to fold by rolling).

These last terms give rise to the concept of “*unfolding piece by piece, a complicated system, to better understand it*” (Vautier, 2018, p. 8). According to Ludwig Von Bertalanffy (1968) in Vautier (2005), a system is complex when it is composed of different elements, combined in a manner which is not immediately perceptible. The complexity of a system is determined by the three main characteristics of a system: a purpose, a structure, and the internal interactions (between the elements) and the external interactions (between the system and the environment) that result from the conjuncture between the purpose and the structure (Vautier, 2004). Vautier (2018) indicates that the complexity can be both an intrinsic property or an extrinsic property of the system, depending on whether the actor in relation to the system is considered. In the first case, **complexity of the system** is an ***intrinsic property***, independent of the actor and only depends on the three aforementioned characteristics (Vautier, 2004; 2018). In the second case, complexity of the system is an ***extrinsic property***, that varies according to the actor’s understanding of the structure of the system and their ability to anticipate its behavior (Vautier, 2004; 2018). Under this second case, “*complexity resides in the eye of the observer*” Klir (1986) in Vautier (2018). As a result, the complexity of the system may evolve over time, either by “*reduce the difficulty by acting on the system [by creating elements the actor envisions as missing within the system ... or by] reducing the difficulty by acting on the actor [through training]*” (Vautier, 2004, p.7).

Unorganized complexity (b), occurs when both the *degree of complexity and randomness are high*, resulting in the deficiency of underlying organization that allows analytical reductionism to be applicable (Leveson, 2011). These subsystems can thus be analyzed through statistics of aggregates given that their behaviour is complex but sufficiently regular and random. Such is the case in Physics, specifically *statistical mechanics*, where the larger the population sample, the greater the probability that a randomly selected value is representative of the predicted average value. ***Organized complexity (c)***, on the other hand, occurs when the *degree of complexity is high but the degree of randomness is low*; therefore, these systems are far too complex for complete analysis and far too structured for statistics as the average values are destabilized by the lack of randomness (Weinberg, 1975). Such is the case in most *biological systems and social systems* as well as *complex engineering systems and computer systems*. ***Systems theory*** originates from this third type of system that considers the system as a whole rather than as separate parts of the same entity. It also presumes that properties of the system need to be assessed in their entirety accounting for all the features of the combined social and technical aspects (Ramo, 1973); thereby considering how the subsystems interact and fit together. Systems theory in human anatomy considers how the different organs (the subsystems) of the body (the system) interact with each other identifying that no single organ functions or survives as a separate entity from the entire body. For example, the heart requires both the lungs and the venous arterial system to operate and pump blood through out the tissues: the pulmonary artery transports deoxygenated blood from the heart to the lungs (to be oxygenated), the pulmonary veins carry the oxygenated blood from the lungs back to the heart, and the coronary arteries supply the blood to the heart muscle.

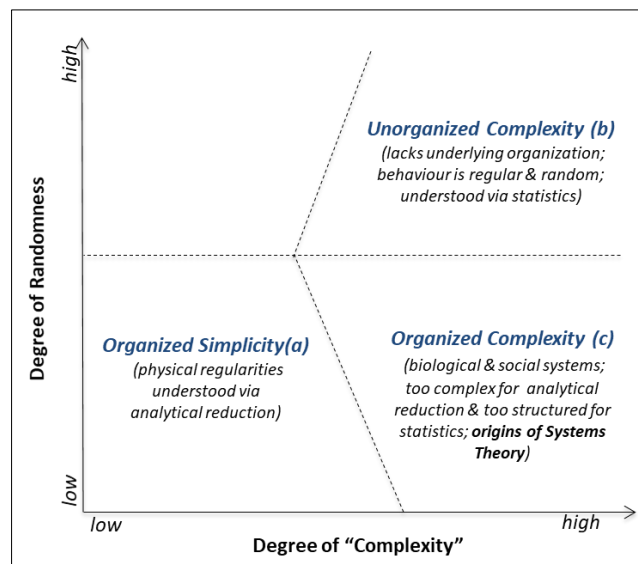


Figure 4. The three classifications of Systems Adapted from Leveson, 2011 (who adapted their Figure from An Introduction to General Systems Thinking [John Wiley, 1975])

This first section of Chapter 1 provides an overview of General Systems theory in six subsections. The first details Systems Thinking, the second discusses elements of Systems theory, the third provides an overview of how to manage safety and accidents from a Systems Theory Approach, the fourth provides a description of the systems approach and Systems theory in the Nuclear Industry, the fifth describes the systems theory approach in Management Science Literature and the sixth details Ago-antagonistic systems.

1.1. Systems Thinking

A system is a global unit made up of a “set of elements which interact together in a dynamic manner and are organized to achieve a specific goal” (De Rosnay, 1975, 2014). Systems thinking is a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviours, and devising modifications to them in order to produce desired effects (R. D. Arnold and Wade, 2015). These skills work together and are “methodological supports that link knowledge, expertise, and data from various disciplines relating to the same system” (Garbolino et al., 2019). By connecting the units of a system, systems thinking provides a holistic vision that unifies a group of variables and sheds clarity on the effect of their interactions (De Rosnay, 1975, 2014). The resultant global template permits elements of the system to be acted upon either directly or indirectly by changing a parameter in parallel to the element. Durand (2006) characterizes the systemic approach by four characteristics:

- Elements within a system must **interact** with each other, performing actions on certain elements while being subjected to actions from other elements. Elements that do not interact are external to the system (Garbolino et al., 2019).
- Elements have irreducible properties (cannot be reduced to the sum of their parts) that transform depending on the degree of agreeability between these elements and on their hierarchy within the system (Garbolino et al., 2019). Durand (2006) referred to this as **comprehensiveness**.

- The **organization** of the system takes into account the structure of the system and its operations in attaining a common goal.
- The system's **complexity** can be witnessed by its sensitivity to changes in conditions and by its adaptability constraints (Garbolino et al., 2019). This complexity impedes the ability to predict the dynamics and evolution of the system (Donnadieu and Karsky, 2002).

These four characteristics of the systemic approach highlight the importance of using systemic modelling tools in risk management; particularly as traditional causal analysis tools model events and causal factors linearly. As a result, such traditional tools are not designed to analyze complex interactions between actors, the temporal and spatial gaps between these actors or their consequences (Goh et al., 2010). This highlights the importance of using systemic modeling tools such as Ago-Antagonistic Systems (AAS) (see section 1.6 of Chapter 1) to act upon elements of the system and to take into account how these actions (be it direct or indirect) (single or multiple actions) effect the entire system. In fact, the [AIEA, \(2016, p. 1\)](#) defines a systemic approach, is “*an approach relating to the system as a whole in which the interactions between technical, human and organizational factors are duly considered*”. It considers such an approach as essential to the fostering of adequate safety measures and a strong safety culture. Therefore, given the importance of the interactions between controllers and actors (subcontractor-contractor) and the temporal aspects of *control loops*, a systems thinking approach is extremely pertinent.

1.2. Emergence, Hierarchy, Communication and Control in Systems Theory

According to [Checkland \(1981\)](#), systems theory relies on two sets of concepts: *hierarchy and emergence and control and communication*:

- **Hierarchy** in terms of the levels of the organization, as each level is more complex than the one before. *Hierarchy theory* highlights the fundamental differences between one level of complexity and the next, thus identifying what generates, separates and links each of the levels. Higher more complex levels demonstrate the concept of **emergence**, that is, *emergent properties* or characteristics (*emergent* at that level) that cannot be reduced. The language used to describe emergent properties at a meta-level (higher level) is separate from the terms used to describe another level, such as the components themselves. For example, the word “reliability” can be used to describe a component, while “safety” is an emergent property at the system level that can only be determined when observing the entirety of the context. In other words, reliability looks at a component in isolation while safety is determined by understanding the relationship of the component to the other system components. A component that is reliable and safe in one system based on its relationship with the other components and its environment, when placed in another system may continue to be reliable in isolation, but not necessarily safe due to altered states in that system. One such example is the difference in metric units and English units that were used in two separate components of the Mars Climate Orbiter. Each component is reliable within a system that adheres to the same units (metric units or English system), however when one component in one unit is placed within a system that employs alternate units, errors may occur. In September of 1999, after nearly

10 months of travel to Mars, an error in units sent from one system from the ground (supplied by a Lockheed Martin a subcontractor in English Units) to another system in orbit (supplied by NASA and expected in metric units) resulted in a miscalculations of the intended orbit. As a result, the Mars Observer was placed on the wrong trajectory, disintegrating into Mars' atmosphere and losing communication.

- A *regulatory* or **control** action imposes constraints upon the activity at one level of the hierarchy, thereby defining the “laws of behaviour” of the level. According to Checkland (1981, p. 87), hierarchies are characterized by the control processes that occur between the levels:

“Control is always associated with the imposition of constraints and an account of a control process necessarily requires our taking into account at least two hierarchical levels.... But any description of a control process entails an upper level imposing constraint upon the lower. The upper level is a source of an alternative (simpler) description of the lower level in terms of specific functions that are emergent as a result of the imposition of the constraints.”

Leveson (2011) revises this concept by imposing safety constraints on system behaviour to avoid unsafe events, conditions or hazards, rather than focusing on avoiding failures of contemporary principles in Nuclear Safety, and Occupational Safety Engineering. Control in open systems, such as biological systems, man-made systems or companies requires **communication**. Von Bertalanffy (1968) differentiates between (1) open systems that are exposed to external elements that result in exchanges with their environment and hence alterations to the equilibrium (for example cars on a highway exposed to weather changes and the actions of other vehicles, resulting in a change of speed), and (2) closed systems that are isolated from exterior elements allowing the unchanged components to settle into a state of equilibrium (for example a single train moving through a tunnel isolated from the rain and unaffected by other elements allowing it to settle into a state of equilibrium or constant speed). *Control theory* views open systems as interrelated components of the system that maintain a state of dynamic equilibrium through communication via feedback loops of information and control.

An example of a **standard control loop** consists of a manager (the controller) that assesses a set of measured variables from the information received via the *feed-back loops* and then requests that the agent (*actuator*) initiates a set of actions by *manipulating the controlled variable* to ensure the process continues within the *pre-defined limits (set points)*. Therefore, the maintenance of open-system hierarchy requires processes that ensure communication of information to then regulate and control (Checkland, 1981). However, there may be **temporal delays** in communication caused by delays in the propagation of the signals within the control loop. Specifically: *dead time* is the delay from when the controller commands the signal and when the actuator responds; *time constants* is the delay from when the variables are manipulated and the process occurs; and finally *feed-back delays* are the pauses between sampling intervals. As a result, timing delays within the control loop can impede the rapidity at which turbulences or disturbances can be mitigated, thereby imposing additional pressures on the controller (Leveson, 2011). One example of this is the Wake Vortex Encounter phenomenon in aviation that occurs when cyclical turbulence (cyclical vortex) that is

generated by the passage of a first aircraft in flight is encountered by a second smaller aircraft. The result is a loss of control of the second aircraft, that prompts the pilot to react to the rolling motion often overcompensating with a maneuver that due to feed-back delays exacerbates the effects of the external disturbance. Therefore, the controller must continuously discern the current state of the control process in order to act if required to impose creative control actions that take into account the estimation of the effects of those various control actions on that state. Figure 5 depicts the standard control loop described above.

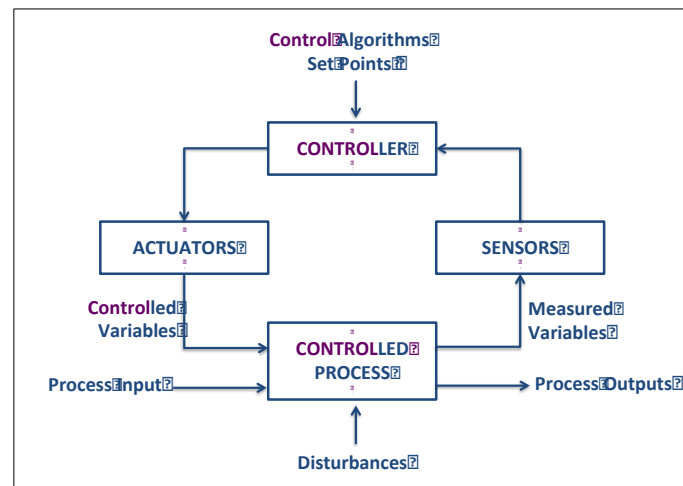


Figure 5. A Standard Control Loop (adapted from Leveson, 2011)

1.3. Managing Safety and Accidents from a Systems Theory Approach

According to systems theory, accidents or incidents are the results of degradation in the safety system's performance due to the interaction of several causal factors at multiple-levels (component failures, external disturbances, and/or dysfunctional interactions among system components) rather than a single causal factor at a single level (Leveson, 2004; Leplat, 1987). Therefore, in the event of an accident, *systemic safety models* investigate the oversights of the operations and the organization of the system rather than simply unsafe acts or conditions; as is the case with non-systemic safety models that concentrate on a single element.

As indicated in section 1.2. above Safety is considered an *emergent property* that occurs when components in an open system interact with the environment. Thus, safety can be enforced through control laws that act on the behaviour of the system component. When interactions amongst these system components violate these control laws or constraints, accidents occur. Lack of safety is thus viewed as a "control problem", that occurs from inadequate control during the *design process* or the *operational process* that may result in component failures, external disturbances, and dysfunctional interactions (Leveson, 2011).

Safety is thus managed by a control structure embedded in an adaptive socio-technical system (Leveson, 2004; Leplat, 1987) that must adequately maintain the constraints on the behaviour of the system. Therefore, preventing accidents requires designing a safety control structure that is specific enough to impose the required constraints on the system and large enough to effectively encompass all of the managerial factors that influence the system's development and its operations (Leveson, 2004). As such,

system thinking in combination with organizational tools can provide opportunities for productive dialogues and methods for leaders to create and implement fundamental changes and improvements within the organization leading to sustained superior safety performance.

Additionally, safety may be considered as a social activity and management cannot bring about effective safety performance alone (M. Cooper and Finley, 2013). Instead, in a “plural leadership perspective” (Denis et al., 2012), leadership roles (skills and responsibilities) can be dispersed throughout different levels of the organization over time, permitting multiple actors to adopt leadership roles to encourage more widespread implementation and adoption of safety practices, thereby enhancing safety compliance. As a result, by combining a systems theory approach to develop or redesign *System Safety* in the design, the specific components or subsystems can be integrated into a system with peak efficiency that achieves the overall objectives and meets the prioritized set of design criteria; thereby optimizing the system design (Leveson, 2011). Specifically, the System Safety is implemented by first *identifying the high-level objectives and criteria on the system design* and then proposing alternative designs (*system synthesis*). The finest alternative is selected after a lengthy selection process whereby each alternative is analyzed and evaluated according to the stated requirements and constraints of the design criteria. In fact, the selection process may take several cycles of results that produce modification of objectives, criteria, design alternatives (Leveson, 2011). Nonetheless, in order to enhance System Safety in complex systems, several system theory principles must be taken into account: (1) the optimization of individual components or subsystems generally does not yield an optimal system, but rather may yield an inferior overall system performance due to non-linear interactions amongst the components; (2) individual components can only be understood by considering their role and interactions with other components within the system and therefore isolated changes to individual components may have undesired consequences. By incorporating these systems theory principles, while designing or redesigning System Safety, the resultant operations and the management of the system can strengthen Safety, risk analysis and risk management practices (Leveson, 2011).

1.4. Systems Approach and Systems Theory in the Nuclear Industry

Systems approach and systems theory has been progressively recognized within the safety science literature as an essential factor in examining safety within complex socio-technical systems (IAEA Report, 2013; N. Leveson et al., 2009; Reason, 1990; Reason et al., 1998; Vautier et al., 2018) and as an important complement to traditional safety approaches. In fact, the systemic approach to safety addresses a complex system of interactions across every level of the organization, by initially identifying interactions between human, organizational and technological factors and then considering the complexity of the interrelationship amongst them (IAEA Report, 2013; 2016; Leveson, 2004). Consequently, the French and International Nuclear Centers employ a systems thinking approach in their HOF approach to safety that is concerned with “human failure and the unsafe acts carried out by workers, as well as the factors within the system that influence human performance directly or indirectly; viewed from a human and social science

perspective” (Vautier et al., 2018) across different levels of the organization.

The International Atomic Energy Agency (IAEA) report (IAEA, 2014) highlights the importance of human factors in nuclear safety and illustrates the lessons learnt from three NPP accidents. The Three Mile Island accident in 1979 acknowledged the existence of nontechnical aspects in nuclear operations (IAEA, 2014). The Chernobyl accident in 1986 highlighted the importance of safety culture, management and organizational factors in nuclear safety (IAEA, 2014). The Fukushima Daiichi accident in 2011 accentuated the need to complement traditional safety approaches with a systemic approach, thereby considering the interactions between human, organizational and technological factors that contribute to safety, as well as the complexity of the interrelationship among them (IAEA, 2014, 2016). In recent years, numerous scholars have emphasized the need for system-oriented approaches to technical and organizational safety (Jari Kettunen, 2007; N. Leveson et al., 2009; Vautier, 2018). Given that traditional causal analysis tools model events and causal factors linearly, they are not designed to analyze complex interactions (Goh et al., 2010), particularly as “*only complexity can cope with complexity*” (Ashby, 1961), that is only complexly-designed management systems can help firms cope with risk complexity of the current safety environments (Weick, 1979).

1.5. Systems Theory in Organizations and Management Control

As organizations evolve, they develop more and more intricate systems that must coordinate with one another in order to process and convert inputs (information or raw materials) into outputs (results) (McShane and Von Glinow, 2003). The interdependencies between subsystems may be so complex that a minor event or a small glitch may result be amplified into a serious unintentional consequence elsewhere within the organization. Since organizations do not exist in a vacuum, organizations are dependent on their external environment much like how an organization is dependent on the economic system, the government laws and the society that it belongs to (Wehrich et al., 2019). More precisely, every organization belongs to an industry that itself makes up a large system, and multiple industries, in turn, create a larger system or a society, which are then arranged into the largest system of all – a global economy (Chikere and Nwoka, 2015).

Systems theory has also been used to explain the functioning of organizations and the functioning of Management Control (Berry et al., 2005). The systems approach – physical, biological or more recently managerial- aims to explain behaviour by examining the interrelationship of the behaviour and the actors as a whole rather than the individual nature of each of those parts. Since a system is viewed as an organized or complex assembly or combination of parts that form a complex or unitary whole (Mockler, 1970; Skyttner, 1996), similarly, an organization can thus be contemplated as a collection of interrelated parts working as a whole (Hewege, 2012). The organization is thus viewed as “*a system consisting of structure, processes, and technology and the human being is conceived as a system containing a biological-physiological structure, psychological processes, and a personality*” (Luthans, 1973, p. 69). According to Otley et al. (1995) and Scott (1981), systems, and hence organizations, can further be classified as *open (a*

or closed (b), and as rational (c) or natural (d). The combination of these factors yields four distinct categories: *closed rational systems*; *closed natural systems*; ***open rational systems***; and ***open natural systems*** (D. Otley et al., 1995). This thesis is primarily concerned with the last two of these categories, which will be discussed after defining each of the four distinct categories below.

The system or organization is bordered by an external boundary yielding either (a) ***an open system***, that exchanges information, energy or material with their environment or (b) ***a closed system***, that does not permit the system to interact with the external environment. Through the lenses of Systems Theory, an organization is therefore composed of “*input, process, and output components, as well as connected subsystems with a clearly defined system boundary*” (Hewege, 2012). The organization uses its numerous subsystems to accomplish both the goals of the organization and the goals of the individual participants (Johnson et al., 1964). In addition to the relationship with the external environment, there exist several other differences between closed and open systems theory with regards to the *number of variables, the forms of regulation or control and the purpose of the regulations* (Chikere and Nwoka, 2015). In general, closed systems have fewer variables than open systems, as open systems deal with a more complex set of interrelationships. Closed systems use error-controlled regulation, which is a “*feed-back control*” after the fact, while open systems use anticipatory control systems called “*feed-forwards control*” that anticipate errors and take corrective measures before the final output. Finally, closed systems do not aim to return the system to a pre-determined stable equilibrium, and instead, they regulate the system for a *new dynamic path*. Open systems, on the other hand, seek both continuous improvement and stability ultimately achieving a *dynamic equilibrium* (Chikere and Nwoka, 2015).

An organization can also be categorized as (c) ***a rational system***, consisting of “*organizations designed for the pursuit of explicit objectives*», or as (d) ***a natural system***, such as organizations that “*recognize the importance of unplanned and spontaneous processes with informal structures that supplement rationally designed frameworks*” (Hewege, 2012, p. 6). As indicated above, the combination of these factors yield four distinct categories (D. Otley et al., 1995) of which this thesis is interested in the last two: ***open rational systems*** and ***open natural systems***:

- ***Open rational systems*** recognize the “*the impact of external environmental factors and the external uncertainty on control systems...requiring organisations to adapt to the internal and external contingent variables of the organization [technology, environment, organizational structure, size, and corporate strategy]*” (Hewege, 2012, p. 6).
- ***Open natural systems*** view contingent variables as inadequate explanation of “*all the drivers of control systems*” and instead place an “*emphasis on the importance of power and related conflicts in understanding management control issues*. This category views organizations as “*manifestations of conflict and struggles between different groups pursuing diverse goals, [... that create] tensions resulting in power struggles among the groups affecting management control*” (Hewege, 2012, p. 6).

Open natural systems, are considered an emerging perspective in Management control research as researchers under this perspective (Bhimani, 1999; Bijlsma-Frankema and Koopman, 2004; Cowton and

Dopson, 2002; Efferin and Hopper, 2007; Hopper et al., 2009; Macintosh and Hopper, 2005) call for both larger social theoretical approaches in the design of conceptual frameworks of management control issues, as well as alternative research methodologies to better explain deep-rooted, complex management control issues (Hewege, 2012). As a result, systems theory clarifies the role of complex organizations in modern society and predicts that their complexity and the role of management to deal with these complexities will continue rise. In the context of complexity theory, this thesis employs an Ago-antagonistic systems (AAS) approach, an application of Systemic Theory, to model and balance formal and informal management controls within an open system.

1.6. Ago-antagonistic Systems (AAS)

The French Endocrinologist E. Bernard-Weil formalized AAS during his work on adrenal post-pituitary interactions. Specifically, as showd in Figure 6 below, (Bernard-Weil et al., 1975). Bernard-Weil (1975) found that patients began with similar levels two hormones: vasopressin (x) and adrenal-corticoid steroids (y). However, when these patients underwent an adrenalectomy (removal of the adrenal cortex gland on top of the kidneys), their levels of vasopressin (x) increased. Later when these same patients received adrenocortical therapy (y) consisting of injections of hormones produced by the adrenal-cortex, vasopressin levels (x) decreased and returned to their initial value. These results were later analysed and conceptualized into the AA model that successfully helped treat numerous endocrine disorders (Nunez, 1997). To date, this model proposes a more abstract and theoretical application to numerous scientific fields (Bernard-Weil et al., 1975; Corbel et al., 2007; Martinet and Payaud, 2006; Zouaghi and Spalanzani, 2009).

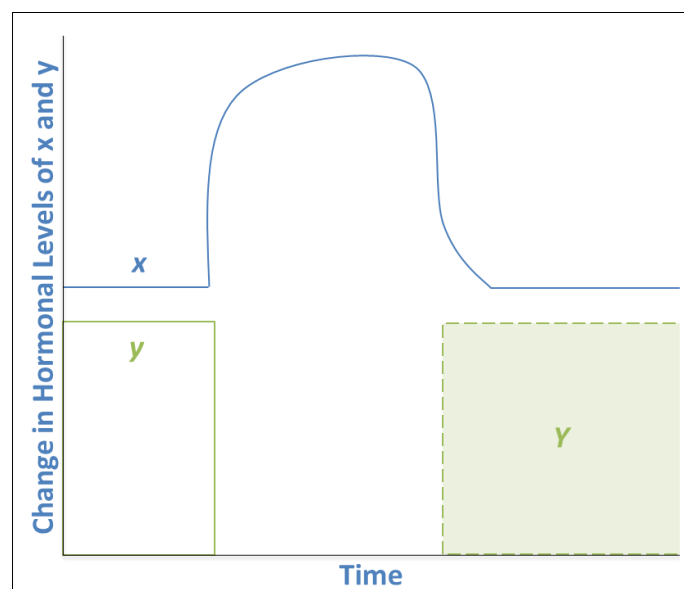


Figure 6. Physiological Model: after the suppression of y (adrenalectomy), x (vasopressin) increases. The addition of Y (adrenocortical therapy) led x to return to its initial value (adapted from Bernard-Weil, 1975).

The term “ago-antagonistic” (AA) is composed of two terms: antagonistic meaning “opposite effects”; and agonistic meaning “parallel positive effects” (Bernard-Weil, 2002, 2003a). The AA approach consists of analyzing couples whose forces have both “*opposite, antagonistic effects on certain receivers of these actions*” and “*parallel positive, agonistic effects on other parts of the same receiver*”, thereby “*taking into*

account the unity to which both sides belong” (Bernard-Weil, 2002, 2003a). The AA model, illustrated in Figure 7 below, contains four components: two forces (x, y), a regulator and a receiver. This systemic vision enables the regulator to consider the collective impact of adjusting either a single force (x or y) or both forces (x and y), particularly as action(s) on the couple may rebalance the overall system (Bernard-Weil, 2002, 2003a).

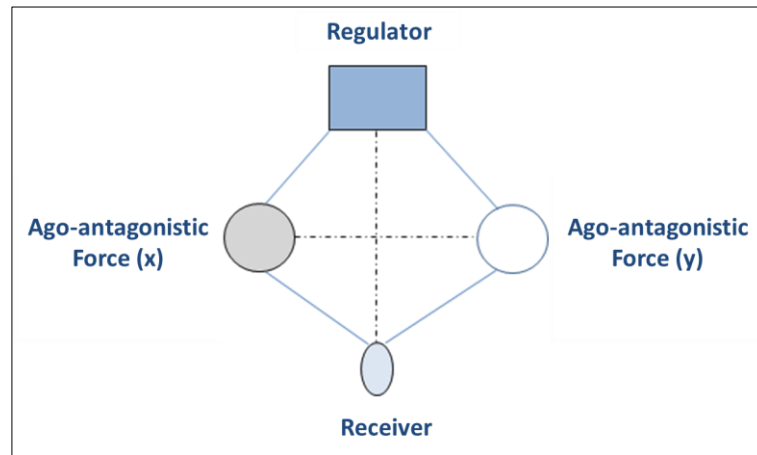


Figure 7. Ago-antagonistic Model of an Ago-antagonistic couple (Moreno Alarcon et al., 2019) adapted from (Bernard-Weil, 2002, 2003a)

1.6.1. Characteristics of Ago-antagonistic Systems

AAS can be identified by eight (8) principal characteristics (Bernard-Weil, 1999, 2003a, 2003b; Zouaghi and Spalanzani, 2009). The *first* defines an AA couple, whose poles have opposing actions on one part of the receiver and actions in the same direction on another part of the receiver (see Figure 7). The *second* denotes AAS as a dissipative system, a thermodynamically open system defined by Nobel Lauriat Prigogine, which describes equilibrium against a standard or a reproducible ready state. Mathematically AAS has two equilibrium states: a physiological equilibrium (if the standards are respected) and a pathological equilibrium (run on poor standards). As a result, equilibrium will oscillate around the equilibrium point known as equilibrium constant. The *third* describes an AA network made up of a combination of AA elementary couples. This network is organized into competing pressures of hierarchy and autonomy, explaining how an action on one part of the network can rebalance the entire network. The *fourth* is the concept of constituent division whereby one force acts in its own interest and simultaneously for the common interest of the system. The *fifth* explains that AAS integrates dichotomies, a series of properties typically opposing compatibility with each other (external-internal; dangers-safety; contractor-subcontractor). The *sixth* proposes that AAS have states comparable to pathological homeostasis or autonomy, thereby resulting in unusual strategies within these complex systems. The *seventh* highlights false AA couples such as imbalance and balance, good and evil, which are not AA despite their semantic opposition. The *eighth* characteristic indicates that all models irrespective of their “universality” require a meta-model. However, the meta-model of the AA model is yet to be created or identified.

This thesis uses Ago-antagonistic systems and the merger of two theoretical frameworks (Systems Theory and Contingency Theory), to investigate the application of Management Control Systems (MCS) and Enterprise Risk Management (ERM) in Inter-Organizational Relationships (IOR). Previous studies that have merged both theoretical frameworks (Efferin and Hopper, 2007; Hewege, 2011) have investigated deep-rooted cultural, social, political and anthropological contingency factors affecting management controls.

1.6.2. Strategies to Balance Ago-antagonistic Pairs

One of the essential property of AAS, is that despite their antagonistic properties, one force cannot eliminate the other (Corbel and Terziovski, 2008). As a result, the AA couple is in a constant process of “equilibration” and thus no stable equilibrium is ever achieved. Several strategies, which are the basis of endocrine therapies exist to re-establish the balance between the forces and minimize perturbations to the AAS (Bernard-Weil, 2003; Corbel and Terziovski, 2008). The medical community employs a combination three strategies (*supplementary, bipolar, unipolar paradoxical*) when “faced [with an AA couple (*A and B*) that has] a deficiency in one partner of the couple (*B*)” (Nunez, 1997, p. 100). Specifically:

- The “**supplement strategy**” that consists of *supplementing the organism with a “normal concentration [of the] deficient partner molecule (*B*)”* to counter-balance the antagonistic second agent (*A*). However, this strategy is ineffective as supplementing the deficient molecule serves only to reproduce the initial disequilibrium, and thus no equilibrium constant is restored.
- The “**bipolar strategy**” consists of introducing both partner molecules (*A and B*) with ago-antagonistic effects, thereby restoring the equilibrium constant.
- The “**unipolar paradoxical strategy**”, consists of identifying and administering another molecule (A_1) with agonistic effects similar to the molecule already in excess in the body (*A*). This restores a normal equilibrium constant and “[promotes] the organism to increase production of the deficient partner (*B*)” (Bernard-Weil, 1992; Corbel and Terziovski, 2008; Nunez, 1997).

Each situation requires a specific strategy as there is no single universal solution exists to re-establish this balance. Additionally, several sources of endocrinological disturbances need to be considered (Nunez, 1997, p. 99) when selecting a strategy :

- i) “*the equilibrium constant is altered*”
- ii) “*one of the components is less synthesized, more synthesized or destroyed*”
- iii) “*the agonistic or antagonistic receptor is naturally or therapeutically deficient*”
- iv) “*the two [forces] are no longer present, an inadequate time or location to exert their action*”

2. Management Control Systems (MCS)

Control and control systems are topics that have fascinated researchers for numerous decades. Control systems are ubiquitous and surround our every second from the control systems of a car, an industrial

machine to the control systems present in organizations that control people. However, unlike the first two, the latter type of control consists of interrelated communication structures between human beings that assist managers in processing information, allowing them to coordinate the essential components to achieve the organizational objective while assuring harmony throughout diverse activities. There exists a plethora of control mechanisms each with their own functionalities and their own impracticalities; therefore, choosing the adequate type of control pertinent for the situation is critical. Unfortunately, due to the lack of a universal control mechanism, the control systems tailored for repetitive and mechanistic activities may be ineffective during circumstances that require adaptability to unprecedented situations.

This second section of Chapter 1 provides an overview of Management Control Systems (MCS) in six subsections. The first details central concepts of MCS, the second discusses the evolution of traditional management control theories, the third provides several typologies of MCS, the fourth details Simons' (1995) Levers of Control Framework, the fifth details Malmi and Brown's (2008) MCS as a Package Framework, and the final subsection discusses the complementary nature of Formal and Informal Controls and their complementary nature.

2.1. Central Concepts in Management Control Systems

Control and Management Control Systems (MCS) are important fields of study in Management Science, particularly in Management Accounting. Chenhall (2003, p. 129) defines Management Accounting as “*a collection of practices such as budgeting or product costing*” and describes MCS as the systematic use of Management Accounting that allows managers to establish an inclusive strategic and operational control system that integrates the function of organizational control, personnel and cultural controls.

There exist numerous definitions of MCS in accounting research which have led to a number of problems with the interpretation of results and the design of MCS (Malmi and Brown, 2008).

- Abernethy and Chua (1996, p. 573) define MCS as “*a combination of control mechanisms designed and implemented by management to increase the probability that organizational actors will behave in ways consistent with the objectives of the dominant organization coalition.*”
- Otley (1999) states that “*MCS provide information that is intended to be useful to managers in performing their jobs and to assist organizations in developing and maintaining viable patterns of behaviour*”.
- Simons (1995, p. 5) defines MCS as “*the formal, information-based routines and procedures managers use to maintain or alter patterns in organizational activities*”.

Numerous studies have observed the broader effects of control systems on strategy design and the implementation of strategic change (Abernethy and Brownell, 1999; Bisbe and Otley, 2004; Chenhall and Langfield-Smith, 2003). However, Merchant and Van der Stede (2007) focus on the employer and employee relationship, differentiating between (1) management controls that deal with employee behaviour and (2) strategic controls that are concerned with company tactic. Specifically, Merchant and Van der Stede

(2007, p. 8) state that *“it is people in the organization who make things happen. Management controls are necessary to guard against the possibilities that people will do something the organization does not want them to do or fail to do something they should do... If all employees could always be relied on to do what is best for the organization, there would be no need for an MCS”*.

MCS enable managers to monitor business activities and institute strategy by exerting influence on members of the organization (Anthony, 1965; Carenys, 2010) and/or by orienting the decision-making process. Numerous studies have observed the effects of control systems on strategy design and the implementation of strategic change (Abernethy and Brownell, 1999; Bisbe and Otley, 2004; Chenhall and Langfield-Smith, 2003). Although strategy and control are often viewed as separate procedures, they are intertwined concepts that play a key role in the management of control function (Carenys, 2010). In management accounting literature, management control is seen as the systematic activities employed by managers to ensure that employee behaviour and organizational resources are aligned with the organizational strategies and objectives (Bedford et al., 2016; Das and Teng, 1998; D. Otley, 2001; Zawawi, 2018). Control is defined as *“a regulatory process by which elements of a system are made more predictable through the establishment of standards in the pursuit of some desired objective or state”* (Leifer and Mills, 1996, as cited in Das and Teng, 2001).

MCS have been described as a collection of control devices (Wilson and Chua, 1993) that according to (Lowe (1970, cited in (D. Otley and Emmanuel, 2013, p. 8), serve as *“a system of organizational information seeking and gathering, accountability and feed-back designed to ensure that the enterprise adapts to changes in its substantive environment and that the work behaviour of its employees is measured by reference to a set of operational sub-goals (which conform to overall objectives) so that the discrepancy between the two can be reconciled and corrected for.”* As a result, MCS can be used to manage not only intra-organizational, but also inter-organizational actors (R. Cooper and Slagmulder, 2004; Dekker, 2004; Håkansson and Lind, 2004; Tomkins, 2001; Vélez et al., 2008) as is the case with outsourcing during which the actors do not belong to the immediate firm and thus may require resourceful management systems and controls.

2.2. Evolution of Traditional Management Control System Theories

Management control system theories have demonstrated a distinct evolution in Management Sciences, possibly explained by society's transformation linked to market changes, and an increase in competition which could be secondary to globalization (Carenys, 2010). Traditional organizational theory shaped by Taylor (1911) and Fayol (1916, 1949) schools of management align with Anthony (1965) description of a rational view of management systems, which is only concerned with formal aspects of control. This view is also characterized by clearly established objectives and measurable outputs used to control the performance of “passive subjects” (Carenys, 2010). Although formal aspects of control apply to repetitive and mechanistic activities, they fail to consider informal and more complex psychosocial factors of the

individual (Carenys, 2010) and have difficulty adapting to organizational change. In fact, the contingency theory of management accounting highlights the lack of a universally applicable control system and instead encourages choosing an appropriate control technique based on the specific circumstances of the organization, including the environment, structure, management and competition style. As a result, recent developments, aiming to surpass the limitations of formal and mechanistic approaches, use contingency theory to incorporate an ampler and informal or contemporary control system specific to the organization. Such a system would not originate from the passive and rational behaviour of subjects (as is the case in formal control) but instead would evolve to incorporate psychosocial mechanisms which would allow for greater consideration for organizational and motivational factors (Amat, J.M., 1991; Carenys, 2010; Hared et al., 2013; D. Otley, 1999). There exist numerous approaches to classifying control, which are detailed in the following section.

2.3. Typology of Management Control Systems

Numerous authors have provided their own typology of control to the literature. For example, (Eisenhardt, 1989a) introduced formal and informal controls, Simons (1995, p. 161) presented loose and tight controls, Burns and Stalker (1961), Chenhall (2006) and Perrow (1970) classified controls into mechanistic to organic controls; and Otley (1994, p. 298) described the dichotomy between restricted accounting controls and flexibility. Scholars also detailed specific types of control including output, behaviour, market, bureaucracy and clan controls (Ouchi, 1979a); administrative and social controls (A. G. Hopwood, 1976); action, results and personnel/ cultural controls (Merchant, 1985; Merchant and Van der Stede, 2003). For the purpose of this dissertation, we will focus on two types of typology. According to (Eisenhardt, 1985b), and the control literature, there are two basic approaches to control: an external measure-based control and internal value-based control. The first of these often called “*formal control, objective control and conventional control*”, and provides an establishment of *formal rules, procedures, and policies to monitor and reward desirable performance*. Similarly, Chenhall (2006, p. 168) describes ***mechanistic controls*** as those that “*rely on formal rules, standardized operating procedures and routines*”.

The second of these, also known as “*informal control, clan control (Ouchi, 1979a), social control, normative control, and contemporary control*” consists of an establishment of organizational norms, values, culture and the internalization of goals to encourage desirable behaviours and outcomes. In this case, control is intended to minimize goal misalignment between firms. Similarly, Chenhall (2006, p. 168), defines organic controls as “*more flexible, responsive, involving fewer rules and standardized procedures and tend to be richer in data*”. This formal and informal classification, has not only been employed in numerous studies in management accounting literature (Alvesson and Kärreman, 2004; Burns and Scapens, 2000; Lukka, 2007; Simons, 1995, 2000; Tuomela, 2005), but is also one of the classifications that has been used for the longest time (Alvesson and Kärreman, 2004).

Table 1 below presents a grouping of the MCS and control elements used in research under the classification of *mechanistic and organic controls* [adapted from Chenhall (2006)]. According to Chenhall (2006, p. 168), understanding how all of the different types of management accounting relates to broader control concepts

can “assist in researching the complementary of substitution effects of non-accounting controls”; particularly as an important part of the research in Management Accounting is the understanding of how different controls combine (see Section 1.3.6), to suit the specific circumstances of the organization (Chenhall, 2006; J. Fisher, 1995). Furthermore, being aware of the boundaries that organizations, accountants and scholars place around the classification of controls limits confusion as to what is formal accounting control, structural control, personal and informal controls.

MCS categorized under Mechanistic and Organic Forms of Control

Mechanistic Controls	- Sophisticated Controls (Khandwalla, 1972) (standard costing, incremental costing, statistical quality control, inventory control)
	- Operating procedures, budgets and statistical reports (Macintosh and Daft, 1987)
	- Inter personnel controls (Bruns and Waterhouse, 1975) (lack of autonomy, pressure inducing actions by supervisors)
	- <u>Output and results controls</u> (Macintosh and Quattrone, 2010; Merchant, 1985)(<u>outcomes and effectiveness</u>)
	- <u>Behaviour controls</u> (Merchant, 1985; Ouchi, 1979b; Rockness and Shields, 1984) (<u>standardization, rules, formalization</u>)
	- Patriarchal control (Whitley, 1999) (centralized control from the top)
	- <u>Action controls</u> (Merchant, 1985); <u>process controls, manufacturing performance measures</u> (Chenhall, 1997) (<u>direct measures of the production process</u>)
	- <u>Diagnostic Controls</u> (Simons, 1995) (<u>use of control to provide feed-back on operations</u>)
	- Coercive controls (Ahrens and Chapman, 2004)
	- Clan controls (Govindarajan and Fisher, 1990; Ouchi, 1980) (Control Cultures and Norms)
Organic Controls	- <u>Social Controls</u> (Merchant, 1985) (<u>self and group controls</u>); <u>Rockness and Shield, 1984</u>) (<u>input controls – social controls and budgets</u>)
	- Personal controls (Merchant, 1985) (selection, training, culture, group rewards, resources); (Abernethy and Brownell, 1997) (socialization and training).
	- <u>Sophisticated interactive mechanisms</u> (Abernethy and Lillis, 1995) (<u>task forces, meetings</u>)
	- <u>Prospect controls</u> (Macintosh and Quattrone, 2010) (<u>focus on plans and the future, general reporting</u>)
	- <u>Interactive controls</u> (Simons, 1995) (<u>use of performance evaluation for strategic planning</u>)
	- Enabling controls (Ahrens and Chapman, 2004)

Table 1. Mechanistic and Organic Forms of Control (source: Chenhall 2003; 2006)

The following section will explore several of these typologies used in traditional management accounting literature including formal (mechanistic) and informal (organic) control (Caglio and Ditillo, 2008; Chenhall, 2006) which are further classified into the following three subcategories of controls first pioneered by (Ouchi, 1977, 1979a): *behaviour, output and social control*; Simons' (1995) four Levers of Control (LOC) Framework that include both Diagnostic (organic) and Interactive controls (mechanistic) detailed above; and Malmi and Brown's (2008) conceptual typology of MCS as a package. The thesis

incorporates all of these typologies while focusing on the three subcategories of behaviour, output and social control that have been widely accepted in the literature (Eisenhardt, 1985b) as modes of control and incorporated in Enterprise Risk Management Literature of Inter-organisational Relationships (Anderson et al., 2014; Christ et al., 2014; Das and Teng, 2001a).

2.4. Simons' (1995) Levers of Control (LOC) Framework

The levers of control (LOC), proposed by Simons (1995) provides an understanding of how control is used in the organization to produce goal congruency amongst its activities, through the implementation of the four control levers of control. The four levers (*belief systems, boundary systems, diagnostic control systems, and interactive control systems*), which are connected to four key concepts (*core values; risks to be avoided, critical performance variables and strategic uncertainties*), each address a different type of control exercised by management. See Figure 8 below for a visual representation of the four controls.

- **Core values** are controlled by the **belief systems** lever, which are “*an explicit set of beliefs that define basic values, purpose, and direction, including how value is created, the level of performance and of human relationships*” (Simons, 1995, p. 178). These controls include mission statements, vision statements and statements of purpose; that “*provide momentum and guidance to opportunity-seeking behaviours*” such as changes in strategic direction. As a result, belief systems guide the process of exploring new opportunities and instilling shared beliefs (Ferreira and Otley, 2009) through the symbolic use of information (Feldman and March, 1981); allowing managers to nurture organizational behaviour and culture (Widener, 2007).
- **Risks to be avoided** are controlled by **boundary systems**, which are “*formally stated rules, limits, and prescriptions tied to defined sanctions and credible threat of punishment*” (Simons, 1995, p. 178). These controls are often implemented through codes of business conduct, strategic planning systems, and operational guidelines (Widener, 2007); that “*allow individual creativity within defined limits of freedom*” (Simons, 1995, p. 178), thereby discouraging opportunity-seeking behaviours and controlling business risk.
- **Critical performance variables** are controlled by **diagnostic control systems**, which are “*feed-back systems that monitor organizational outcomes and correct deviations from pre-set standards of performance*” (Simons, 1995, p. 179). These controls set standards, measure outputs and controls that link incentives to goal achievements and provide feed-back on current progress (Widener, 2007). As a result, diagnostic control systems are used to coordinate and implement management strategies. Results are benchmarked against a pre-set target and any deviation is identified. This allows subordinates to align their behaviour with organizational aims and informs managers of issues that may require their attention. By informing subordinates of their performance through diagnostic systems, managers *can identify “effective resource allocation, define goals, provide motivation, establish guidelines for corrective action, allow ex-post evaluation, and free up scarce management attention”*; thereby channeling subordinate behaviours toward desired goals (Simons, 1995, p. 179).

- **Strategic uncertainties** are controlled by *Interactive Control Systems*, which are “used by managers to involve themselves regularly and personally in the decision activities of the subordinates” (Simons, 1995, p. 180). Interactive Control Systems were first introduced by Simons (1995). These controls encourage organizational learning through “discussions with subordinates, face-to-face meetings with subordinates that continually challenge and debate data, assumptions and action plans”; thereby “allowing managers to focus organizational attention on strategic uncertainties and provoke the emergence of new initiatives and strategies”. Interactive Control Systems aim to encourage and monitor the implementation of emergent strategies, much like every MCS system. However, interactive control systems engage senior management to discuss and exchange with subordinates at nearly every level of the organization. However due to timing constraints, managers may only select a single MCS instrument as an interactive control system. Nonetheless, such intensive face-to-face exchanges transmit rich information and encourage the development of ideas and creative new solutions.

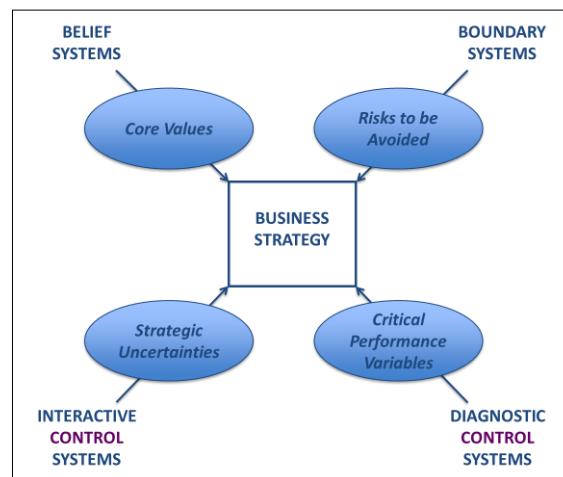


Figure 8. Simons' Four Levers of Control [adapted from Simons, 1995. pg. 7]

The framework contains numerous limits including that at any one moment a single control mechanism may be classified under more than one lever of control (A. M. F. Ferreira, 2002). Therefore, these levers are not separate and individual controls, but instead are complementary and hence must be used in combination to produce effective results (Widener, 2007). According to Simons (1995), a successful implementation of strategy requires all four levers in an appropriate combination. Widener (2007, p. 782) also demonstrates the interdependence and complementarity between all four LOC, as well as the importance that “managers consider all four control systems when designing their control systems”. Additionally, this framework fails to include socio-ideological controls (Collier, 2005), such as the informal controls that exist in organizations (A. M. F. Ferreira, 2002). Therefore, Simons' (1995) LOC fails to provide information on how to combine and balance formal or mechanistic and informal or organic controls. Other scholars criticize the framework as it focuses on top-level management and fails to detail the interactions that occur between the different levers of control and fails to give clear instructions of how to balance the four potentially conflicting levers (Ahrens and Chapman, 2004; Ferreira and Otley, 2009, p. 265). Nonetheless, this framework also contains numerous strengths including its ability to define how

these control systems are used by companies (A. M. F. Ferreira, 2002; Ferreira and Otley, 2009), while establishing a meaningful typology of alternative uses of MCS (Abernethy and Lillis, 1995; Bisbe et al., 2007; Bisbe and Otley, 2004; Henri, 2006; Widener, 2007) and a manner to study the balance between positive and negative controls (A. M. F. Ferreira, 2002; Simons, 1995) (see 2.4.1).

Simons, further explains the dichotomy of the four levers:

- (1) *Boundary and Belief systems* are based on superimposed rules of behaviour and hence lack automated feed-back loops by managers or rewards that classify them as non-cybernetic. They also act in an integrated manner, to encourage subordinates to search for new opportunities. Belief-systems provide positive inspiration while boundary systems indicate where to halt the search.
- (2) *Diagnostic control systems and interactive control systems* aim to increase cooperation through feed-back loops, thereby classifying them as cybernetic. However, whether a control is defined as one or the other is based on whether the manager uses the control in an interactive or a passive manner. On one hand, interactive controls require the continual attention of the manager, thereby augmenting the feed-back loop of the system yielding a more responsive and effective control that promotes the sharing of information, learning and emergent new modes of obtaining strategic goals (Simons, 1995, p. 99). On the other hand, diagnostic controls merely confirm that the organization is on the right track. According to Ferreira and Otley (2009, p. 265), “*diagnostic use of MCS follows the mechanistic, repressive, traditional control approach, while interactive use of MCS takes an organic, constructive, learning-oriented control approach*”. Widener (2007) also contrasts these two controls, stating that interactive control systems are based on measurement and coordination, and are more forward-looking than diagnostic controls.

2.4.1. Dynamic Interplay of Forces between the Four LOC

Simons describes dynamic energy or inherent tension amongst the 4 levers of control. Two forces make up the positive system, the “yang of Chinese philosophy” as they inspire organizational actors to “*search creatively and expand opportunity space*”; while the other two forces make up the “yin of the Chinese philosophy” in their use “*to constrain search behaviours and allocate scarce attention*” (Simons, 1995, p. 158). More specifically:

- (1) *Belief systems and interactive control systems* promote innovation and are considered as driving forces for adaptability to strategic uncertainties encouraging intrinsic motivation and a positive informational environment that encourages information sharing and learning ” (Simons, 1995, p. 158).
- (2) *Boundary systems and diagnostic control systems* limit their focus to eliminating undesired behaviour by imposing extrinsic restrictions to delimit opportunity-seeking. An effective organization must achieve an adequate balance between forces, achieving “simultaneous high degrees of learning and high degrees of control; [in other words a balance between] efficiency and innovation” ” (Simons, 1995, p. 158).

In fact, according to Simons (1995), all four control levers have both control and learning, and hence must work simultaneously. He adds that “the power of these levers in implementing strategy does not lie in how each is used alone, but rather in how they complement each other when used together. The interplay of positive and negative forces creates a dynamic tension” (Simons, 2000, p. 301; Widener, 2007). And according to Henri (2006, p. 533), these positive and negative forces ‘create dynamic tension that contributes to manage inherent organizational tension’. Milgrom and Roberts (1995) demonstrated the complementary nature of such control features.

Mundy (2010) explored how firms balance controlling and enabling uses of MCS using Simons' (1995) LOC framework. The author found that the balance of both controlling and enabling controls facilitated the “creation of *dynamic tensions* and unique organizational capabilities” (Mundy, 2010, p. 499). The interactive levers of control also assisted in the balance of controlling and enabling uses of MCS, thereby creating dynamic tensions. The relationship between interactive processes and other levers of control is essential to managers as they aim to direct and empower subordinates (Mundy, 2010). Since managers are limited to one MCS interactive control at a time (Simons, 1995), it is of utmost importance that they select the “correct” MCS for interactive use. Mundy (2010) found five control elements that affect a firm’s ability to balance between controlling and enabling use of MCS: *internal consistency, logical progression, historical tendency, dominance, and suppression*. Specifically, the *internal consistency* of MCS ensures that subordinates obtain clear and consistent information. According to Mundy (2010, p. 513), it “*plays an important role in balancing the different uses of MCS by ensuring that employees perceive clear and coherent messages about the importance of particular organisational imperatives and priorities*”. The *logical progression* details the order that different MCS are employed and “occurs naturally as part of the organization’s life-cycle”. The *historical tendency* describes the affinity that a manager or a company has to employ particular MCS. The *dominance* is “evident when one or more levers persistently determine the use of the remaining levers, regardless of the environmental context”. And finally, *suppression* occurs when managers fail to employ a particular LOC thereby “*impacting their ability to balance the remaining levers [which in turn] affects the inter-relationship between the levers of control by reducing manager’s abilities to deal with inherent organizational conflicts. Thus limiting opportunities for dynamic tensions to develop*” (Mundy, 2010, p. 516). Therefore, given all of these different elements, the attainment of a balance of controls presents a “*complex challenge for organizations*”, as the managers aim to both direct and empower their subordinates. Managers must therefore balance these competing demands of management and empowerment through the use of the appropriate LOC. Additionally, their choice of appropriate LOC will be “*influenced by a range of individual and organizational factors that have immediate consequences for the capacity of an organization to generate dynamic tensions*” (Mundy, 2010, p. 516).

2.5. Malmi and Brown’s (2008) MCS as a Package

Numerous scholars (Chenhall, 2003; Fisher, 1998; D. T. Otley and Berry, 1980) have alluded to the idea that MCS should operate as “a package”; a package of different control elements that support and reinforce each other (Malmi and Brown, 2008). The concept behind the MCS package is even more evident,

particularly as MCS do not operate in isolation. In fact, the study of the different control systems in isolation can lead to “the potential for a model under specification” (Chenhall, 2003, p. 131) leading to erroneous conclusions and fragmented results (Berry, Coad, Harris, Otley, and Stringer, 2009; Chenhall, 2003; Fisher, 1998; D. T. Otley and Berry, 1980).

In the past, a major focus of MCS research has been on accounting-based controls and the formal system rather than “the impact of other types of control (such as administrative or cultural) and whether/how they complement or substitute each other in different contexts” (Malmi and Brown, 2008, p288). Malmi and Brown (2008, p288) continue stating that “*gaining a broader understanding of MCS as a package may facilitate the development of better theory and how to design a range of controls to support organization objectives, control activities and drive performance*”. Particularly, MCS packages pay attention to variables previously studied in isolation such as the connections between cultural, personal, action and results control (Bedford et al., 2016; Grabner and Moers, 2013; Sandelin, 2008). Given the number of control tools that exist in an organization, it is imperative to recognize how the design of the control system can support organizational development and effective decision-making (Malmi and Brown, 2008; Simons, 1995).

Malmi and Brown, (2008) have developed one of the most inclusive MCS frameworks by analyzing and synthesizing empirical results of MCS research for the past four decades. This control framework provides a broader approach to research the MCS packages phenomenon empirically and aims to facilitate and stimulate discussion as well as research in this area. The strength of the typology lies in the broad scope of the control in the MCS as a package rather than the individual discussion of each component. Specifically, the framework proposes five forms of control: **cultural controls, planning, cybernetic controls, reward and compensation, and administrative controls**. Figure 9 below provides an overview of these five forms of control.

- **Cultural:** organizational culture is “the set of values, beliefs and social norms which tend to be shared by its members and, in turn, influence their thoughts and actions” (Flamholtz et al., 1985) Cultural controls can be used to control behaviour as the organization either: deliberately employs employees with certain desired values; tries to change the values of their employees; or conveys to their employees how the organization wants and expects them to act, as well as which values they should have, irrespective of whether the employees agree on them or not (Malmi and Brown, 2008). Cultural controls can be further subdivided into 3 aspects: (a) *clan controls*: distinct subcultures within an organization that share a set of skills or values; (b) *value-based controls*: this includes Simons' (1995) belief systems communicated by senior managers via credos, mission statements, and statements of purpose; and (c) *symbol-based controls*: a form of culture control illustrated visually in uniforms or office design. In fact, (Merchant and Stede, 2007) state that people define themselves as groups based on profession and organizational units or divisions. These clans work by establishing certain values and beliefs through the ceremonies and rituals they perform (Malmi and Brown, 2008).

- **Planning** permits organizational goal setting and is thus an ex-ante form of control that guides employees. It serves as the main carrier for promoting goal congruence between the individual and the organization (Flamholtz et al., 1985). It takes on two forms: (a) long-range planning: which has a strategic focus on the planning of goals and actions for the medium or long-term; and (b) action planning: which has a tactical focus and is the shorter planning of goals and actions within the next 12 months (Malmi and Brown, 2008).
- **Cybernetic**: Malmi and Brown (2008, p. 289) inscribe to the definition given by (Green and Welsh, 1988) “by cybernetics, we mean a process in which a feed-back loop is represented by using standards of performance, measuring system performance, comparing that performance to standards, feeding back information about unwanted variances in the system, and modifying the systems’ comportment”. According to Malmi and Brown (2008, p. 292), “the linking of behaviour targets, and establishing of accounting for variations in performance takes a cybernetic system from being an information system to support decisions, to a management control system”. There exist four types of cybernetic systems: (a) budgets; (b) financial measures; (c) non-financial measures; and (d) hybrids: a combination of b and c such as the balance scorecard. Non-financial measures have become increasingly important for firms as they provide drivers of performance while helping to overcome the shortcomings of financial measures. An example of a hybrid measurement system includes the Balance-Score-Card.
- **Reward and compensation**: aim and motivate employees by creating congruency between the objectives of the individual and the organization (Malmi and Brown, 2008). Rewards may intrinsically or extrinsically control: (1) the subordinate’s effort direction (the task they will focus on), (2) the subordinate’s effort duration (the length of time they will devote to the task), and (2) the subordinate’s effort intensity (the quantity of attention they will devote to the task) (Bonner and Sprinkle, 2002; Malmi and Brown, 2008b). Such controls include salaries and bonuses as well as other non-monetary forms of rewards. There are two types: (a) positive: which includes rewards employees appreciate such as autonomy, power, recognition, promotions, titles, job security, vacations, time off, and stock options; and (b) negative: such as punishments or absence of positive rewards such as job interference from superiors, job loss, no promotion, zero salary increase and public humiliation (Merchant and Stede, 2007).
- **Administrative**: intend to direct employee behaviour directly. These controls function by: (a) governance structure: by monitoring employee behaviour making them accountable for their actions ; (b) organizational design and structure: that is directing the behaviour of individuals and groups within the organization; (c) Policies and procedures: detailing how tasks or behaviours should be performed or not performed (Malmi and Brown, 2008).

CULTURAL CONTROLS						
<i>Clans</i>		<i>Values</i>			<i>Symbols</i>	
PLANNING		CYBERNETIC CONTROLS				REWARDS & COMPENSATIONS
<i>Long range planning</i>	<i>Action planning</i>	<i>Budgets</i>	<i>Financial Measurement Systems</i>	<i>Non Financial Measurement Systems</i>	<i>Hybrid Measurement Systems</i>	
ADMINISTRATIVE CONTROLS						
<i>Governance Structure</i>		<i>Organizational Structure</i>			<i>Policies & Procedures</i>	

Figure 9. Management Control Systems Package (adapted from Malmi and Brown 2008, p.291)

Malmi and Brown's (2008) MCS as a package taxonomy, integrates both organic or informal and mechanistic or formal controls; encouraging a holistic view of MCS. Thus, given the complexity and the plethora of managerial controls, it is essential to explore the design of MCS in various ways and by the manner of a package, to determine the most appropriate design elements and combinations for different situations (Merchant and Stede, 2007).

2.6. Formal and Informal Controls

In general, formal controls “rely on rules, policies, and procedures for monitoring and rewarding performance” (Christ et al., 2014) and include accounting-based approaches driven by short term incentives such as planning, budgeting, performance measurements and motivation management (Hared et al., 2013). Falkenberg and Herremans (1995) provide their own definition of formal control as “the written procedures and policies that direct behaviour so as to achieve the organization’s goals, and/or detect or deter misconduct”. The main reason for implementing formal controls is linked to the agency relationship between the manager and the workers (Jensen and Meckling, 1976) as a formal control framework minimizes the incentive to “cheat” on the principle.

According to (Ouchi and Maguire, 1975), an organization has two types of formal control. The first measures the behaviour and thus is often referred to as “**behaviour control**”, as it “ensures the process is appropriate” (Das and Teng, 2001a). **Behaviour Controls** i.e. **Process controls** (as conceptualized in Merchant and Van der Stede's (2007) typology) “first specify how parties should act then they evaluate whether the specifications have been followed” (Kraus and Lind, 2007, p. 279). They require managers to understand the process and identify the kind of behaviour desired throughout a task (Anderson et al., 2014; Christ et al., 2014; Das and Teng, 2001a). These controls are very similar to Simons' (1995) Boundary Systems controls discussed in sub-section 2.4. The second measures the outcome of these behaviours and thus is often referred to as “**outcome control**”, which “relies on an accurate and reliable assessment of members’ performance” (Das and Teng, 2001). **Outcome Controls or Output controls** (as conceptualized in Merchant and Van der Stede's (2007) typology) “measure, evaluate and reward the outcome or results of the inter-organizational relationship” (Kraus and Lind, 2007, p. 276). They can include both financial and non-financial measures that aid managers to focus on key performance measures, and quickly react to changes in those measures (Anderson et al., 2014; Christ et al., 2014; Das and Teng,

2001a). These controls resemble Simons' (1995) Diagnostic Control Systems discussed in sub-section 2.4. As a result, formal control has been further subdivided into output control and behaviour control (Eisenhardt, 1985b, 1989a; Ouchi, 1979a). According to Falkenberg and Herremans (1995, p. 134), “*formal controls work best when the environment is stable, routine behaviours are required, the transformation process (or employee behaviour) can be monitored, and the employees’ output measured*”.

Informal controls, are developed in a more organic way that impacts subordinate behaviour indirectly, as compared to the formal “mechanistic” controls previously discussed. They include **socio-cultural controls** based on cultural artifacts, such as norms, emotions, stories, ceremonies, values and beliefs. According to Alvesson and Kärreman (2004, p. 426), such *socio-cultural controls* can be defined as “*efforts to persuade people to adapt to certain values, norms and ideas about what is good, important, praiseworthy, etc. in terms of work and organizational life. Ideologies justify certain principles, actions and discourage others*”. **Social Controls or Input controls** (as conceptualized in Merchant and Van der Stede's (2007) typology) “*relate to the values, norms and culture that influence the behaviour [of organizational actors]*” (Kraus and Lind, 2007, p. 280). Social controls cannot be explicitly designed (Kraus and Lind, 2007) but they rather minimize goal discrepancies between the contractor and the subcontractor by establishing common culture and values (Anderson et al., 2014; Christ et al., 2014; Ouchi, 1979b). These controls have strong similarities to Simons' (1995) Belief Systems detailed in sub-section 2.4.

Informal control also refers to Ouchi's (1979) proposed clan control that occurs when firms “do not specify task-related behaviours or outputs”. Instead, such clan controls “focus on developing shared values, beliefs, and goals among members” to reinforce and reward appropriate behaviours (Das and Teng, 2001). Therefore, firm members internalize the goals which then increases their commitment and motivation to achieve these goals (Das and Teng, 2001). Informal controls also allow managers to transmit their values in order to change subordinates’ behaviour and improve organizational performance, as subordinates that do not adhere to the “socio-cultural controls” will be sanctioned. Often managers are not aware they employ informal controls in a subconscious manner, as these controls are often rooted in tradition, corporate history and organizational culture. Nonetheless, according to Schein (2010), managers can conscientiously promote organizational culture through the socialization, formal communication of organizational objectives and values and through the selection of employees.

Figure 10 below provides a recapitulative diagram of the typology control in Inter-Organizational Relations (IOR) used within this thesis. These types of control are most effective in particular situations. A detailed analysis of the complementary nature of formal and informal controls is provided in the next subsection.

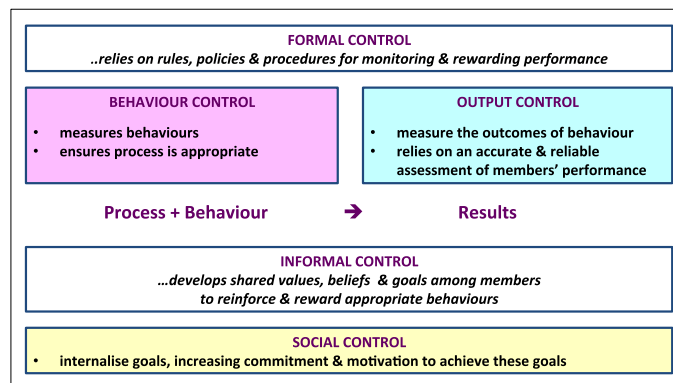


Figure 10. Recapitulative diagram of the Typology of Control

2.6.1. Complementary nature of Formal and Informal Controls

Early MCS studies focused mainly on formal controls, while more recent studies acknowledge the importance of both formal and informal controls. [Flamholtz \(1983, p. 160\)](#) also expressed the importance of informal controls: “*The traditions which characterize an organization’s culture may be an equally or even more important factor predicting behaviour than the formal core control mechanisms*”.

Additionally, MCS scholars (Alvesson and Kärreman, 2004; Bedford and Malmi, 2015; Eric G Flamholtz, 1983) have also stressed the potential complementary nature between formal and informal controls. This is because formal controls will always be incomplete as firms are unable to anticipate all undesired behaviours and hence are unable to develop the specific rules or norms to apprehend such behaviours. Thus, firms with strong informal controls, may intrinsically motivates employees and intuitively transmit the company’s expectations, thereby reducing the limits of formal controls.

Eisenhardt (1985), using (Thompson, 1967) and (Ouchi, 1979a) research on task characteristics, suggests using task programmability and output measurability to accurately assess the control type required. Task Programmability, also known as “the knowledge of the transformation process”, refers to the extent “managers understand the transformation process in which appropriate behaviours are to take place” (Das and Teng, 2001a). Output Measurability refers to the “ability to measure outputs in a precise and objective manner” (Das and Teng, 2001a). For example, behaviour controls are most effective when task programmability is high, that is when managers understand the process of the task in which the appropriate behaviour is to take place” (Das and Teng, 2001a). Output controls are most effective when output measurability is high. This takes place when managers are able to precisely measure the outputs or the performance in an objective manner (Das and Teng, 2001a). Social controls, on the other hand, are most effective when both task programmability and output measurability are low, and hence do not require the manager to understand the process of the task nor be able to precisely measure the performance of such task. Finally, in the event where both Task Programmability and Output measurability are high, then both behavioural controls and output controls can be effective (Eisenhardt, 1985b, 1989a; Ouchi, 1979a; Thompson, 1967). Figure 11 below provides a recapitulative diagram of the task characteristics in each type of control.

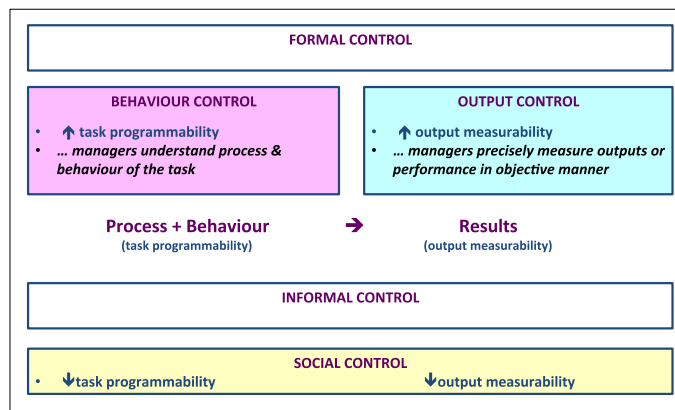


Figure 11. Recapitulative diagram of the Task Characteristics in each type of control

3. Risk and the Management of Risk of Inter-Organizational Relationships (IOR)

Due to the growing incidence of risks (economic, sanitary, health, industrial, etc.), Risk Management is proclaimed as being more important than ever before (J. Lam, 2006; Woods, 2009) and such importance has seen the development of a new field in management literature called *Enterprise Risk Management (ERM)*. ERM proposes that firms “address all of their risks comprehensively and coherently, instead of managing them individually” (Bromiley et al., 2015, p. 265). Razali and Tahir (2011) state that risks can take many forms and each risk should not be managed independently. Haimes (1992) stresses the need for “the evolution towards a more holistic approach” - a type of “total risk management”. Organizations have seen a paradigm shift from a silo-based perspective of risk management that handles risks individually, towards the more comprehensive and holistic view that resides at the core of ERM (D’arcy and Brogan, 2001). However, the majority of research surrounding ERM focuses on statistical risk tools, with only a handful of management scholars (Kanu, 2020; Miller, 1992; 1998; Miller and Waller, 2003) focusing on an integrated approach to risk management practices.

This thesis is particularly interested in the risks associated with subcontracting, and incorporates the alliance risk framework developed by Das and Teng, (1999, 2001b) and by Anderson et al. (2014) discussed in this section. This third section of Chapter 1 further explores the links between risk, control, management control systems and specifically how management control systems can mitigate risks associated with Inter-Organizational Relationships (subcontracting related risks) in four subsections. Specifically, the first subsection defines the risks associated with subcontracting. The second subsection contrasts the “Risk of Control” and the “Control of Risk”. The third subsection describes Enterprise Risk Management (ERM) and highlights the relationship between ERM and MCS. The fourth sub-section details Risk Management practices in Inter-Organizational Relationships (IOR), specifically how management control systems (MCS) can mitigate and manage sub-contracting related risks.

3.1. Risks of Subcontracting

In the 1990s researcher's understanding of how risk was perceived and addressed in management was limited (Bettis and Thomas, 1990). Since then numerous academics have become increasingly interested in risk and risk management (Berry et al., 2005). To date, management literature lacks a consensus of a definition of risk, instead proposing numerous definitions (Baird and Thomas, 1990; Bettis and Thomas, 1990). For example, McNamee (2000) defines risk as a concept used by auditors and managers to express concern about the probable effects of an uncertain environment on business goals and suggests that risk is merely a conceptual device to help deal with the consequences of being unable to predict the future of "uncertainty". It is essential not to confuse risk and uncertainty, both defined below. The Oxford Dictionary defines risk "*as a change or possibility of danger, loss, injury or other adverse consequence*", highlighting its negative consequences. In contrast, the ISO definition of Risk, used in this thesis, carries both positive and negative consequences of uncertainty in the organization's ability to attain its objectives. Specifically, as mentioned previously, ISO 31000 (2018) and ISO Guide 73 (2009), define **risk** as "*the effect of uncertainty on objectives*", whereby risk is demarcated in a conceptual manner with goal-oriented terms (of both positive and negative consequences). According to Galbraith (1977, p. 5), **uncertainty** can be defined as "*the difference between the amount of information required to perform a task and the amount of information already possessed by the organization*".

This thesis is particularly interested in the risks associated with subcontracting, and incorporates the alliance risk framework developed by (Das and Teng, 1999, 2001a), which distinguishes between *relational risk* and *performance risk*. It also mobilizes the classification scheme introduced by Anderson, Christ, Dekker, and Sedatole, (2014) which identifies *compliance and regulatory risk* as a third category of inter-firm risk.

- **Relational risk** encompasses: "*all threats to the organization's objectives, due to poor cooperation from an opportunistic [subcontracting] organization*" (Christ et al., 2014). According to Das and Teng, (1996), relational risk occurs due to the potential for opportunistic behaviour such as information distortion, appropriation of resources, from the part of both the subcontractor and the contracting firm. Such opportunistic behaviour is the result of conflict between firms due to misaligned personal interest and or hidden agendas; which can hinder cooperation. These threats arise due to the lack of central authority, shortage of governance and an absence of distinct profit motives between the two firms (Christ et al., 2014). Although scholars Fitoussi and Gurbaxani, (2012) have proposed contracts provide a "primary instrument to control relational risk", the contract design can have a profound effect on risk. Specifically, the use of fixed-price contracts incite the subcontractor to reduce costs and hence engage in opportunistic behaviour, while in cost-plus contracts the subcontractor does not need to minimize costs as it is the contractor who is responsible for the costs (Christ et al., 2014; Williamson, 1971).
- **Performance risk** can be defined as "*all threats to the organization's objectives, due to operational or performance factors despite full cooperation from the [subcontractor]*" (Christ et al., 2014). According to Das and Teng (2001), performance risk may be due to intense rivalry with competitors, new entrants, technological developments, changes in governmental policies or market preferences, incompetence

from one of the firms, and bad luck. For example, Lam (1997) found that despite a desire to learn, partner firms often fail to achieve successful knowledge transfer and effective learning in alliances.

Clear differentiation between relational risk and performance risk is essential (Das and Teng, 1999); as this allows firms to evaluate the more important risk and decide on a strategy to acquire the partnering firm's valuable resources while protecting their own (Christ et al., 2014). Therefore, clearly defined alliance goals that are specific and precise are essential for long term alliance success (Currie, 1998).

- Later Anderson et al. (2014) identified ***compliance and regulatory risk***, which includes “*all threats to the organization's compliance with regulations*”. This last risk may result from reasons related to relational risk, performance risk or a combination of both. For example, (Christ et al. (2014) explain that penalties incurred from inaccurate or nonconforming reports that are the subject of intense regulatory scrutiny, containing data provided by the subcontractor may be the result of (a) *poor cooperation from an opportunistic [subcontracting] organization*, (b) *operational or performance factors despite the full cooperation from the [subcontracting] organization*, or (c) *a combination of both*.

These risks (*relational; performance; and compliance and regulatory*) may be mitigated by **Management Control Systems (MCS)** (Anderson et al., 2014; Das and Teng, 1999, 2001; Eisenhardt, 1985; Hopwood, 1976; Kirsch, 1996; Merchant, 1985; Ouchi, 1979; Ouchi and Maguire, 1975) which will be discussed in subsection 3.4.

3.2. The Control of Risk and the Risk of Control

The concept of risk management involves two terms: control and risk. However, these two terms can be examined from two angles with the first assessing how management control systems support the management of risk- and hence “the ***control of risk***”; and the second assessing which risks are associated with management control systems –and hence “***the risk of control***”. The following two subsections detail each of these concepts.

3.2.1. The Control of Risk: Organizational Design for Optimal Risk Management

Galbraith (1977) explains that the success of an organizations goals and rules are dependent on the frequency of exceptions to those goals/rules and the capacity of managers to navigate through those exceptions. Therefore, in the face of uncertainty, organizational structures and procedures and strategies for managing the risk play an important part in risk management. Galbraith (1977) proposes ***four organizational strategies to employ in the presence of increased uncertainty*** (information uncertainty), of which only the last two are applicable in the context of the thesis:

1. Increasing the availability of resources (Creation of slack resources), thereby minimizing the exceptions by relaxing budget and production targets, creating lower delivery times and buffering inventories

2. Augmenting self-contained tasks, thereby altering the divisions of labour to promote self-contained tasks thus reducing the possibility of lower performance standards that often arise from interdependencies between business units
3. Investing in vertical information systems, allotting the analysis of the information at the task performance level, without overloading the hierarchy.
4. Creating a lateral relationship between key players (managers, liaison roles, task forces, teams and integration roles) thereby shifting decision making to the source of the information ensuring not to create self-contained groups.

According to Galbraith (1977), as uncertainty increases so does the need for information processing. By combining the second last two strategies (investing in vertical information systems and creating lateral relationships between key players), the organization's capacity to process information is improved thereby allowing the organization to function even at peaks of uncertainty, when the highest organizational performance expectations are imposed. The concept of uncertainty and asymmetry is discussed throughout sub-section 3.1, 3.2, 4.3, and 4.5

3.2.2. The risk of control: Diminished Flexibility to respond to unexpected environmental changes.

From the definition of risk provided in the previous sub-section (3.1), risk is stipulated from a positive and negative point of view. Similarly, IFAC (1999) contrasts "risk as a hazard" with "risk as an opportunity", whereby risk should not be avoided but rather managed through "Risk Architecture". A type of risk architecture will be discussed in sub-section 3.3. Likewise, the Turnbull Report from the Institute of Chartered Accountants in England and Wales places an emphasis on profits as a reward that stems from successful risk taking. They further indicate that risk should be "managed and controlled" rather than eliminated.

In management science and in corporate governance approaches, there is often an implied assumption that the amount of control implemented should be directly proportional to the quantity of risk. That is, the greater the likelihood of risk and the greater the consequences of such risk, then the greater the quantity of control required to manage that risk (Berry et al., 2005). However, Berry et al. (2005) indicates that the contrary is often the case, as a greater quantity of control is often not conducive to managing situations of high risk and high consequences. More specifically, the risk is designated as great due to: (1) the uncertainty of the situation; (2) the grandeur of the consequences associated with the situation; or a combination of both (1) and (2). However, "*if the likelihood and the consequences of a risk may be controlled*" then by definition such can not be classified as a risk (Berry et al., 2005).

Moreover, while numerous risk management techniques such as anticipation methods, contingency plans and flexible practices may be efficient in controlling internal risks; however external risks remain outside of the scope of such methods. Additionally, exerting control in itself carries a risk: a greater quantity of control implemented to offset perceived increased risk may impede or prevent the functioning of such risk

management techniques thereby preventing anticipation, contingency and flexibility. According to Berry et al. (2005), *“this is the risk of control”*. This is because the control becomes prescriptive and hence reliant on the predictive model used to implement the control. As a result, Berry (2005) indicates that the organizational actors’ ability to navigate the turbulent climate is restricted to the specified prescriptive control measures yielding an increase in risk rather than the initial aim of decreasing the risk, as plans, policies and budgets lack the flexibility required to cope with unexpected situations.

The control to risk ratio requires consideration as excessive control and risk management practices that aim to reduce the risk rather than balance risks and rewards (Adams, 1999) may result in missed opportunities. Conversely a lack of control may also have catastrophic results. Therefore, sensitive controls that allot for flexibility allow a flexible response to emerging trends and unexpected environmental changes (Berry et al., 2005, p. 299). Galbraith's (1977) model of organizational strategies to employ under uncertainty, presented in the sub-section 3.2.1, states that as uncertainty augments, the performance standards will decrease unless one of the four strategies is implemented. However, despite promoting a flexible response and sensitive controls, the implementation of Galbraith's (1977) four strategies, may also result in negative consequences (Berry et al., 2005). Augmenting self-contained tasks and the creation of lateral relation promote flexibility but they may transfer the risk throughout the organization in what Collier and Berry (2002) refer to as risk transfer between and within the organization. In their study, Collier and Berry (2002) found that risks were transferred along the supply chain to various managers and individuals. As a result, procedure-driven or prescriptive approaches to risk management that lack flexibility may *“mask or render invisible some of the very problems they are expected to solve. [Therefore], the role of managers must deal with the risk that changes over time in organizations with different cultural characteristics, size and maturity, is crucial in the practice of management”*. The appropriate implementation of a risk management system, will allow managers to manage the *hazards of risk* rather than eliminate them, thereby benefiting from the *opportunities of risks* IFAC (1999). The following section presents such Risk Management Systems.

3.3. Enterprise Risk Management (ERM)

According to (Khurana et al., 2004), the Harvard Business Review considers Enterprise Risk Management (ERM) as one of the “breakthrough ideas of 2004”. ERM, first described by Holton (1996) proposes that firms target risks in an aggregated, comprehensive and coherent manner rather than managing the risks independently (Bromiley et al., 2015); thereby yielding an overall risk management approach to business risk (D’arcy and Brogan, 2001). Previous to the “Umbrella Concept” of ERM (Power, 2007), firms managed different types of risks disjointedly, as different departments fragmented their particular risk strategy independently of the other departments. Later Kloman's (1976) “Risk Management Revolution” advocated a coordinated approach to risk management, where multiple disciplines could work in unison to “manage future uncertainty” (Bannister and Bawcutt, 1981). Later scholars (D’arcy and Brogan, 2001; Haimes, 1992) called for a more holistic and cross-disciplinary approach to ERM. According to Haimes (1992), this holistic approach coined “Total Risk Management”, could be achieved by ensuring that the

proposed risk management decisions, made employing multiple-criteria decision making (rather than single criteria decision making), influenced the optimal allocation of the organization's resources.

ERM first appeared in an academic paper in 2001 and has since been defined by numerous scholars as: “*a systematic and integrated approach of the management of the total risk a company faces*” (Dickinson, 2001); and “*the process by which organizations in all industries assess, control, exploit, finance and monitor risks from all sources for the purpose of increasing the organization's short and long term value to its stakeholders.*” (from ACA, 2001 in D'arcy and Brogan, 2001). Numerous researchers consider that ERM systems are part of an organization's Management Control Systems (M. S. Beasley et al., 2005; Bhimani, 2003; Gordon et al., 2009; Mikes, 2009; Mikes and Kaplan, 2012; Subramaniam et al., 2011). Nonetheless, risk management is viewed as a separate academic discipline within MCS and thus firms are encouraged to adopt specific transparent risk-specific controls rather than deploying generic MCS to address the risks (Bhimani, 2009).

The use of ERM assumes that corporations employ a constant “risk culture” or “risk appetite” throughout the firm, which are often considered vague risk-related terms that are “*notoriously difficult concepts to define*” (Barley et al., 1988; 1995, p. 121 in Bromiley et al., 2015). Nonetheless, (Brooks, 2009; 2010, p. 87 in Bromiley et al., 2015) describes [**Risk**] **culture** as “*what determines how decisions are made in an organization*”, and further quantifies a “*strong culture [as] one in which decisions are made in a disciplined way, taking into account considerations of risk and rewards on an informed basis*”. This definition of a strong culture from ERM literature adopts a positive connotation, a contrast to organizational approaches that view strong culture as the impact of cultural values on behaviour (Bromiley et al., 2015; Saffold, 1988). **Risk appetite** is defined by COSO (2004) as “*the broad-based amount and type of risk that an entity is willing to accept in pursuit of its mission, vision, strategic objectives, and value goals*”. As a result, not only do researchers need to better define these concepts, but they also need to conceptualize managerial perception of risk (James G March and Shapira, 1987; Shapira, 1995) as risk concepts vary dramatically within and between organizations (Bromiley et al., 2015). More specifically, how managers that assess objective or quantifiable risk concepts that often yield positive or negative results likely employ different concepts and models than managers that assess subjective or non-quantifiable risk concepts that often yield mainly negative outcomes (Bromiley et al., 2015).

Over the past years, the intra-firm empirical research in the ERM literature continues to grow and scholars have called for more research in inter-firm ERM. According to Miller (1994, p. 9), risk management “*could not, and should not, be studied as an organizational practice in isolation from the wider social and institutional context in which it operates*”. Management Control and Risk Management literature has revealed many styles and forms of control practices and factors that are context-specific and highly organizationally dependent (Hopwood and Miller, 1994 in Bhimani, 2009; Scapens, 2006). Das and Teng (1996, 1999, 2001) have provided an Integrated ERM Framework of Trust, Control and Risk in Strategic Alliances that is discussed in sub-section 3.4 below. Mikes and Kaplan (2014) and Nedaei et al. (2015)

have proposed a contingency-based framework for managing enterprise risk that will be discussed in Section 4.

3.4. Risk Management: Use of MCS to Advert and Mitigate Risk in IOR

Control in Inter-organizational Relationships (IOR) such as subcontracting can be of two types: controlling the partner or controlling the alliance, but both are integrated and discussed as one in the literature (Das and Teng, 2001a). Therefore, effective control is essential in regulating and monitoring to achieve organizational goals and assure positive contractor -subcontractor relationships by mitigating risk. Scholars have linked certain types of control as mitigating specific types of risk. This section aims to detail the formal and informal control mechanisms present in subcontracting relationships and how they work together to prevent and mitigate subcontracting risks. Additionally, Dekker (2004) affirms that inter-organizational relationships require both formal and informal control mechanisms.

The following section discusses the use of particular types of management controls (discussed in subsection 2.6) to mitigate particular types of risk (detailed in sub-section 3.1). More specifically, this section discusses the use of behaviour control to mitigate relational risk, the use of output control to mitigate performance risk, the use of social control to mitigate both relational and performance risk and consequently compliance and regulatory risk.

Behaviour Control, also referred to as “**Process Control**” (Das and Teng, 2001a; Merchant and Van der Stede, 2007), measures the behaviour itself and not the final output as this latter is often imprecise and subjective. As a result, it requires managers to understand the process and identify the kind of behaviour they desire as well as the kinds of behaviour that are undesired throughout task completion. Dekker (2004) identified several types of inter-organizational behaviour controls including policy documents, procedures, and structures that specify the roles and the acceptable behaviours of the different actors in the relationship. Therefore, as indicated previously, behaviour control is most effective in situations of high task programmability and low output measurability (Das and Teng, 2001a). It appears that it would be most suitable to mitigate relational risk, that is, that **perceived relational risks present in subcontracting relationships are better mitigated by behaviour controls than by performance controls** (Das and Teng, 2001a). For example, we find evidence of this mitigation directly in subcontracting. Behaviour controls, depicted in specific clauses within contracts, assist in specifying particular behaviours that are desired as well as undesired. These clauses ensure that contracting managers minimize such relational risks. Figure 12 below depicts a summary of how the three controls mitigate three subcontracting related risks, including behavioural control’s ability to mitigate relational risk.

Output Control (Das and Teng, 2001a; Merchant and Van der Stede, 2007), measures a subcontractor’s ability to achieve or not the contracting firm’s objectives. This measure of performance requires satisfactory cooperation from the subcontractor. According to Dekker (2004), examples of inter-organizational output controls include: goal setting, measurements of cost reduction and ordering quantities, and financial reward systems. Van der Meer-Kooistra and Vosselman (2000) also included non-financial measures such as productivity, quality, client satisfaction, and the ratio of indirect and direct supporting hours. Such measures

helped both parties develop well-functioning IOR by assisting the coordination of interdependent tasks and encouraging important goals for collaboration. As previously indicated, output control is most effective in situations of high output measurability and low task programmability whereby the contractor does not require knowing how the tasks are performed but merely be able to assess the final result. As a result, it would appear that output control would be most suitable to mitigate performance risk, which is the result of competition between firms and lack of competence from the subcontractor. More specifically, that **perceived performance risks present in subcontracting relationships are better mitigated by output controls than by behavioural controls** (Das and Teng, 2001a). Direct evidence of this mitigation can be seen in a contracting manager's use of performance measures to assess the performance of the subcontractor. This allows the manager to determine any change in performance levels and as a result, react quickly should performance risk arise to alarming levels. Figure 12 below depicts a summary of how the three controls mitigate three subcontracting related risks, including output control's ability to mitigate performance risk.

Social Control, also referred to as "*Input Control*" (Das and Teng, 2001a; Merchant and Van der Stede, 2007), reduces goal discrepancies between the contractor and the subcontractor by the establishment of common culture and values (Kirsch, 1996). Dekker (2004) identified several types of inter-organizational behaviour controls including joint governance design, short term goals, open book agreements, and shared decision making and goal making. The main difference between formal and informal control (social control) is that with social controls, neither the behaviour nor the outcome are predetermined before the task, and hence no boundary is predetermined as to what can and cannot be done. As a result, social control is most valuable in situations that do not require neither task programmability (the understanding of the process or the behaviour required during a task) nor output measurability (the ability to measure performance objectively as is required during an audit). As a result, social control is most suitable to mitigate both relational risk and performance risk simultaneously (Das and Teng, 2001a). Furthermore, given the close relationship between the two aforementioned risks and compliance and regulatory risk, it would appear that social control is also suitable to mitigate compliance and regulatory risk. More specifically, it would appear that **social controls are able to simultaneously mitigate both the relational risks and the performance risks present in subcontracting relationships, which are potential instigators of compliance and regulatory risk** (Anderson et al., 2014). As a result, social controls may mitigate all three subcontracting-related risks. For example, team-building exercises encouraged the contracting and subcontracting firm to establish common cultures and values that may discourage opportunistic behaviour and hence reduce relational risk. These communicative exercises may also allow both firms to propose and agree on achievable goals and any additional training required that are essential in reducing performance risk. Figure 12 below depicts a summary of how the three controls mitigate three subcontracting related risks, including social control's ability to mitigate relational, performance risk and consequently compliance and regulatory risk.

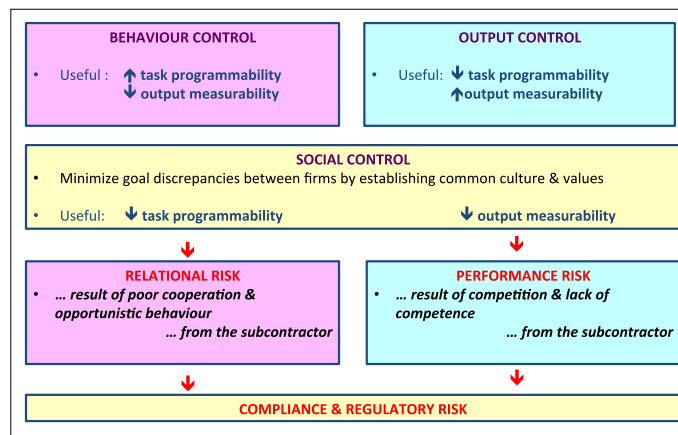


Figure 12. Recapitulative Diagram of the Uses of Controls to Mitigate Subcontracting-related Risks

According to Dekker (2004) managers employ a combination of these three controls to achieve control. Similarly, according to Kraus and Lind (2007), all three controls (*behaviour, output and social*) are thought to be useful in coordinating inter-dependent tasks, while *output controls* on their own appear to address appropriation concerns. Due to the dynamic nature of these controls, these three forms change over time (Dekker, 2004). *Output controls* are used more often when companies learn about the processes and activities, thereby specifying the intended outcomes measures and the standards required to meet those measures (Kraus and Lind, 2007). *Behaviour controls* gain in importance with the passage time, while *social controls* tend to be of most importance at the beginning of the relationship if the firms possess insufficient information to detail outcome and behaviour controls (Dekker, 2004; Kraus and Lind, 2007). Scholars have also called for further research to determine the most appropriate combination of controls (Kraus and Lind, 2007) and the timing of when along the life cycle of the organization they should be emphasized; particularly throughout the life cycle of the inter-organizational relationship. Numerous studies highlight the “successes and failures of subcontracting” however few studies contemplate how management control systems can be tailored to the “specific characteristics of the relationship” (Auzair et al., 2013). Van der Meer-Kooistra and Vosselman (2000) studied the manner in which firms organized their management control in inter-organizational relationships. They observed that the different types of control patterns (market-based, bureaucracy-based, trust-based) were each associated with a different type of control. Specifically, market-based pattern, which corresponded with competitive bidding, did not require a specific control. However, bureaucracy-based patterns that are associated with specific norms, rules, standards, and the evaluation of performance correspond with behaviour and outcome controls. Finally, firms with a trust-based pattern, which use personal consultation and coordination are associated with outcome and social controls (Van der Meer-Kooistra and Vosselman, 2000).

Control systems are shown to vary significantly in the type and combination of controls employed across organizations. This is because there is no single best way to maximize organizational performance, reduce risks, promote employee participation, lead or “control organizations which would universally apply to all organizations at all times and in all circumstances” (Chenhall, 2006, p. 96). Instead, according to Otley, (1980, p. 413), “particular features of an appropriate accounting system [type and combination of controls]

will depend upon the specific circumstances in which an organization finds itself". Therefore, organizations must design their configuration and control systems to conform or "fit" to their specific contingent variables and context of the firm. Section 4 will present the Contingency theory and detail both the Contingency Theory Framework of both MCS and ERM, providing details of the best type and combination of controls for the specific circumstances (contingent variables) of the organization.

4. Contingency Theory Framework of Management Control Systems (MCS) and Enterprise Risk Management (ERM)

"There is no universally accepted model of the organization that explains the diversity of organizational design", therefore, "organizational design depends on contingent factors relevant to the situation" (Hoque, 2002, p. 12). The word "**contingency**" implies that an outcome is only valid under specified conditions and hence the outcome is "contingent" on particular characteristics. Contingency Theory of management, which is not a single theory but rather a plethora of theories, describes and predicts an organizational outcome (usually in the form of performance or organizational effectiveness) in light of specific organizational conditions. Therefore, **Contingency Theory** assumes that there is not a universal efficient method to organize and control an organization, but rather that organizations have unique and varying requirements of management control systems founded on their specific **organizational characteristics** also known as **contingency variables** (external environment, technology, size, organizational structure, strategy and culture). Contingency theory studies, therefore, provides the framework for analyzing control within an organization (Dent, 1990, p. 9), and allows managers to predict which particular management control systems will be present in specific organizational contexts and determine if the specific design of control systems will yield (or not) improved firm performance or effectiveness.

Empirical findings in contingency literature that aim to provide comprehensive links between MCS element, MCS design and organizational context, have been generalized into several contingency frameworks by several management scholars (Chenhall, 2003, 2006; David T Otley, 1980). These frameworks aim to augment desired organizational outcomes including performance and organizational effectiveness (D. Otley, 1980) based on the specific organizational context. For optimal results performance and proficiency levels, organizations must tailor their MCS designs to "fit" their particular context. This notion of "fit" has been developed (Drazin and Van de Ven, 1985; Gerdin and Greve, 2004) and implemented across multiple contingency studies in Management Control literature (MCS) and Enterprise Risk Management (ERM) literature. Both MCS and ERM literature use the contingency approach to adapt to variations of the organizational context by designing innovative approaches to attain higher levels of control. In the case of MCS, this includes a general design of management controls to improve performance and organizational efficiency, while in the case of ERM the design of management controls aims to prevent and mitigate risks. Of the multiple types of organizational fit (*selection, interaction, congruency,*

contingency and systems) described by academics, this dissertation merges both general systems theory and contingency theory and is therefore interested in the elements of systems fit.

This fourth section of Chapter 1 introduces contingency theory and details the contingent frameworks in both MCS literature and in ERM literature in five subsections. The first subsection presents the Contingency Theory, its uses and its limits. The second subsection details the development of Contingency Variables in MCS and in ERM Literature. The third section presents several Contingency Theory Frameworks in MCS: two of Otley's (1980) Contingency Theory Frameworks and Chenhall's (2003, 2006) Contingency Theory Framework. The fourth section details a Contingency Theory Framework of ERM, that is known as Nedaei et al.'s (2015) Contingency Model of Risk Management. And the final subsection provides an overview of Fit of contingency variables.

4.1. Contingency Theory

According to Otley (1980, p. 413), the contingency approach to management is based on the idea that there is *“no universal appropriate accounting system which applies equally to all organizations in all circumstances. Rather, [the contingency approach] suggests that particular features of an appropriate accounting system will depend upon the specific circumstances in which an organization finds itself. Thus a contingency theory must identify specific aspects of an accounting system which are associated with certain defined circumstances and demonstrate an appropriate matching”*.

Contingency-based research studies assume that managers consciously adapt the firm to changes in contingencies in the scope of attaining fit and enhanced performance (Chenhall, 2003). When designing and employing MCS, managers must consider a large number of situational factors or contingency variables that can individually and collectively impact the effectiveness of the numerous management controls (Merchant and Van der Stede, 2007). In using a contingency approach, both managers and scholars accept the design and implementation of management controls will be influenced by the internal and external context within which these controls operate (Chenhall, 2006). Since the internal and external context will vary from firm to firm, firms must implement tailored control design. Once the contingencies change, organizations implement new organizational characteristics to fit the new levels of contingencies, so as to avoid misfit. As a result, contingency variables not only shape the firm but also require the organization to adapt in order to maintain their effectiveness and performance over time (Donaldson, 2001). According to (Donaldson, 2001, p. 2), *“this results in organizations moving into fit with their contingencies, so that there is an alignment between the organization and its contingencies, creating an association between contingencies and organizational characteristics”*.

Several scholars (Chenhall, 2006; Klaas, 2004) consider Contingency Theory as the dominant approach to organizational theory and as a prevailing paradigm in empirical management accounting and control research (Hoque, 2002). Nonetheless, Contingency Theory contains numerous limits. *Firstly*, certain scholars (Chenhall, 2003; Hoque and Hopper, 1997) indicate that contingency theory considers contextual (contingent) variables merely at the organizational level or a single level, and therefore neglects the extra-

organizational level. As a result, the contingency approach does not consider the importance of social processes within managerial control practices such as meetings between managers and subordinates. *Secondly*, scholars also indicate that although there have been several replications of studies with a coherence of measurement

(Chenhall and Morris, 1986) to confirm the measurement of generic MCS characteristics such as broad scope, timeliness, aggregation and integration; *“there has been little replication or coherence of measurement development in studies examining MCS practices of contemporary interest such as static-flexible budgets, non-financial performance measures, activity-based accounting, competitor focused accounting, and product development information”* (Chenhall, 2003, p. 131). *Thirdly*, other scholars have also claimed the majority of contingency-based research has focused on specific elements of control and that only a few studies have examined broader elements of control such as clan and informal controls or integrative mechanisms (Chenhall, 2006). A concern for studying specific elements of MCS in isolation from other organizational controls may lead to *“serious model under-specifications”* (Chenhall, 2003, p. 131). Specifically, this may apply to studies that automatically link certain accounting controls with specific organizational controls and do not control for these elements within the research method, yielding “spurious findings”. Chenhall (2006) proposes that one manner of addressing such concerns is to categorize controls into a taxonomy of control and to determine how they relate to various aspects of Management Control Systems. A proposed classification or typology of MCS is provided in subsection 2.3 of this Chapter. The development of the Contingency variables in MCS literature and within ERM, a subsection of MCS, are discussed in the next section.

4.2. Development of Contingency Variables in MCS and in ERM Literature

Contingency Variables that were studied in relation to Contingency theory can be traced to the original contingency framework developed by the organizational theorists (Reid and Smith, 2000). Initially, theorists including Burns and Stalker (1961), Chandler (1962), Perrow (1970), Thompson (1967), Laurence and Lorsh (1967) and Galbraith (1973) investigated the impact of the technology and the environment on organizational factors. Next, scholars studied the importance of environment, technology, structure and size in designing Management Control Systems. Later Waterhouse and Tiessen (1978) and Otley (1980) provided an overview of earlier research and categorized the research into the key elements of technology, structure, and environment. These key elements were later “confirmed as descriptors of fundamental, generic elements of context” (Chenhall, 2006, p. 164). More recent studies focus on contemporary aspects of environment, technologies and company structure and demonstrate that the effectiveness of MCS is dependent on contemporary settings. The role of strategy has also been added as a key variable with Langfield-Smith (2006) demonstrating the links amongst strategy, environment, technology, organizational culture and Management Control Systems. National Culture was later included as a contingency variable Chenhall (2006). As a result, contingency research can help shed light on how Management Control Systems are implicated in these areas, and if their effectiveness is context-specific. Otley (1980) and (Chenhall, 2003, 2006) have provided an overview of both the empirical studies and the theoretical

formulations of contingency research. Otley's (1980) two contingency related frameworks of MCS literature and Chenhall's (2003, 2006) Contingency related frameworks with its six contingent variables are detailed in sections 4.3.

As previously indicated, ERM is considered by scholars (Beaskley et al., 2005; Ghimani, 2003; Gordon et al., 2009; Mikes, 2009; Mikes and Kaplan, 2013; Subramaniam et al., 2011) as a sub-section within Management Control Systems, as a result, both Nedaei et al. (2015) and Gordon et al. (2009), apply the general concepts of contingency theory of MCS to ERM. However, despite this general application, few studies have investigated the contingency theory and the contingency variables of ERM (Cescon et al., 2013; Gordon et al., 2009; Mikes, 2009; Mikes and Kaplan, 2013).

According to Gordon et al. (2009), the contingency theory of ERM indicates that organizational performance is not a result of using ERM, but rather dependent on the fit between ERM and the situational factors of the organization. Mikes and Kaplan (2014) explain that this is why numerous organizations are dissatisfied with the manner in which their risk practices are implemented, particularly when their lack of infrastructure impedes the organization from identifying emerging risks (M. Beasley et al., 2010). Therefore, contingency theory studies of ERM must speculate as to the links between the organizational factors and the design of its ERM system, and propose how the suitable fit between the organizational factors and its ERM system will improve organizational performance (Mikes and Kaplan, 2014; Nedaei et al., 2015). According to Nedaei et al. (2015, p. 55) “[Contingency Theory of ERM] *should echo a main alternative to contingency theory – the system approach*”. Nedaei et al. (2015) propose a Contingency-based Framework for Managing Enterprise Risk, which considers the contingency framework of Management Control Systems and fine tunes such findings for ERM by evaluating the effects of three contingency variables on ERM performance: decentralization (structure), organizational size, and enterprise resource planning. Nedaei et al.'s (2015) Contingency Framework of ERM, discussed in subsection 4.4, also investigates the suitability “fit” of these three contingent variables and the sophistication of the ERM system, anchored in the work of Chenhall (2003, 2006) (sub-section 4.3) and Drazin and Van de Ven (1985) (sub-section 4.5). An additional section for Safety Culture, as a Contingency Variable of ERM, has been added at the end in subsection 4.4.2.

4.3. Contingency Frameworks in MCS Literature

Several Contingency Frameworks in MCS literature will be discussed in this sub-section. The first includes Otley's (1980) Common Characteristics of Previous Contingency Studies and Otley's (1980) Contingency Framework for Studying Context. The second consists of Chenhall's (2003; 2007) Contingency Framework that details 6 contingency variables.

4.3.1. Otley's (1980) Contingency Variable Framework

Following several proposed contingency frameworks during the 1960s and the 1970s, Otley (1980) proposes a framework that includes ideas of organizational control and effectiveness to overcome the previously insufficient articulated models. A visual representation of this framework can be found in Figure

13 below. In the belief that there is no universally “best” design for management accounting, Otley (1980) states that previous frameworks of contingency variables have the following shared stages or characteristics:

- (1) A presumed contingent variable is defined and measured such as technology, environment, structure
- (2) The said variable is thought to affect the organizational design and thus affect the structure and or process of the organization
- (3) Commonalities in the type of accounting characteristics associated (or assumed to be associated) with effective performance are identified
- (4) The effects of these common characteristics are measured in terms of organizational effectiveness.

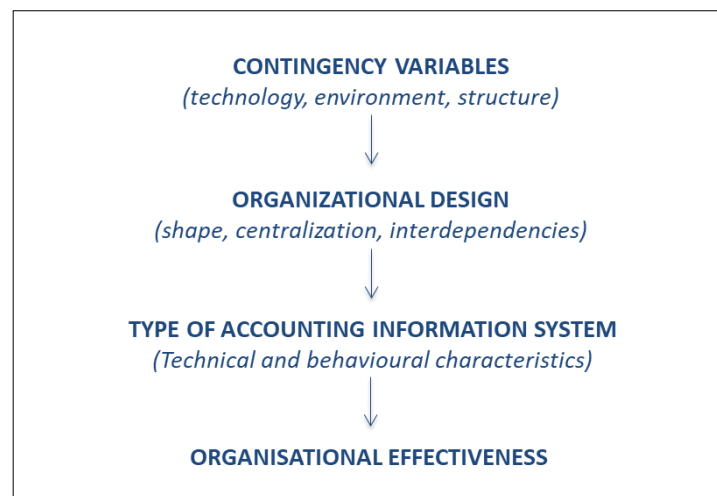


Figure 13. Common Characteristics of Previous Contingency Studies (adapted from Otley, 1980)

However, Otley (1980) indicates that from the empirical studies reviewed no single study combines all four stages, with the majority of studies only assessing a combination of the first three stages; thereby overlooking the organizational effectiveness. An additional criticism is that it appears that of the several studies that were interested in this fourth stage, there were factors in addition to the contingency variables measured that may have had an impact on the organizational effectiveness. Therefore, the effects of the contingent variables may be less significant than initially assumed and thus such studies may require additional controls to be adequately measured (Otley, 1980). Additionally, Steers (1977) indicates that there are multiple challenges to adequately measuring organizational effectiveness, as the firm’s effectiveness may be contingent on the aims of the organization. Based on such criticisms and limitations with measuring organizational effectiveness, Otley (1980) proposed his 1980s Contingency Framework for Studying Context, depicted in Figure 14 below.

In this Contingency Framework for Studying Context, Otley's (1980) Organizational Control Package is composed of Accounting Information Systems (AIS), Other Management Information Systems (MIS) design, Organizational Design, and other control Arrangements. According to Otley (1980, p. 422), “it is explicitly recognized that AIS design, MIS design, organizational design and other control arrangements

of the organization (such as collective agreements, personnel selection, promotion and reward systems and external lobbying) form a package which can only be evaluated as a whole”.

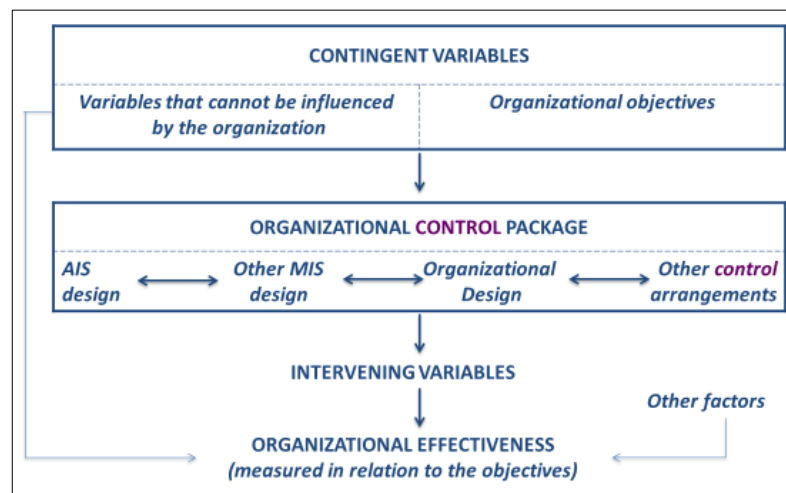


Figure 14. Contingency Framework for Studying Context (adapted from Otley, 1980)

The contingent variables are depicted outside of the control of the organization, even though Otley (1980) recognizes that organizations may attempt to influence such exogenous variables (as is the case with government regulations). Variables that are controlled by the organization are not considered to be contingent variables, but rather as a package of organizational controls. Instead, organizational objectives are considered as contingent variables due to their nature and the ability to help assess the organization’s effectiveness. The organization then adapts to these contingent variables (organizational objectives and variables that the organization does not control) by adapting and configuring the factors it is able to control, with the aims of improving performance. As a result, the organization designs its control package to fit its objectives and these contingent variables. Otley (1980) warns that since the operations in organizations are complex, there are sure to be some disturbances in any contingency model (D. Otley, 1980). Such a disturbance may be controlled for and portrayed as other factors, and researchers are advised to study how organizations adapt their MCS packages to the contexts to obtain their planned results.

4.3.2. Chenhall (2003; 2006) Contingency Framework

Following Otley's (1980) Minimum necessary for a Contingency Framework, numerous scholars have studied several contingency variables examining their effects either on performance or on MCS. Chenhall, (2003, 2006) proposed several variables that impact the organization’s performance and identified several studies that investigate the organizational context and their use of MCS. These variables include the external environment, technology, size, organizational structure, strategy and culture. Each of these contingency variables is detailed below.

4.3.2.1. *Environment as a Contingent Variable in MCS*

The external environment was one of the first contingency variables proposed by Management Control Scholars. Khandwalla (1977 cited in Chenhall, 2006, p. 172) has characterized the external environment as

consisting of turbulence, hostility, diversity and complexity. According to Gordon and Miller (1976, p. 60) the external environment has elements of dynamism, heterogeneity and hostility, while according to Chenhall (2006, p. 172), the external environment has aspects of ambiguity, equivocality and controllability. However, uncertainty, *the difference between the amount of information required and the amount of information obtained*, has been one of the most commonly studied aspects of the external environment (Chenhall, 2006, p. 172). As a result, environmental uncertainty can be defined as the gap between the information required to make a sound decision and the limited information to make the decisions comprehensively (J. Galbraith, 1973). Therefore during environmental uncertainty, there is an increased need for information and increased demand for MCS that can supply this additional information (Simons, 1995). According to Widener (2007), uncertainty may be associated with an increased emphasis on MCS. Nonetheless, organizations facing uncertainty due to the external environment need to balance their necessity of formal, tight control (Chenhall and Morris, 1986; Widener, 2007) with flexibility so to allow these formal, tight controls to adapt to the changing and uncertain environment (Ezzamel, 1990). It is important to note that uncertainty should not be confused with risk, as they are two separate concepts (see section 3.1.). Specifically, probabilities of the results of an event can be allocated to a risky assumption, whereas no probability can be allocated to uncertainties since uncertainties do not have a numerical likelihood of occurring. According to Chenhall (2006, p. 173) uncertainty due to the external environment demands more open and non-financial MCS, while hostile and competitive external, that is, riskier environments, demand more formal control.

4.3.2.2. Technology as a Contingent Variable in MCS

Technology is one of the contingency variables that have been scrutinized. Technology is related to the organization's work processes (Chenhall, 2003), techniques and modes of activity; that is processes within the organization that convert inputs into outputs. Therefore, technology also encompasses processes, people and knowledge and ensures that outputs are measured in goal-consistent terms. According to Ouchi (1977), by providing clear measurable units of output, managers are motivated through the allocation of decision rights and then held accountable for their results, as was the case when faculty was evaluated based on their research outputs. Even if the evaluation process is unclear, goals are 'crystallized' (Thompson, 1967), yielding feasible monitoring of outputs.

Technology can be characterized into three important aspects: ***standardization, task uncertainty and interdependences***: standardization is related to the degree of task-uniformity; task uncertainty is related to the analyzability and predictability of incoming work requests, and interdependencies are related to the net of dependencies between organizational units (Hirst, 1983). According to Hirst (1983), organizations that employ strongly standardized technologies are linked to using more formal control, while firms linked to high task uncertainty use more informal, social control, possibly in an attempt to lower already high tensions. Chenhall (2003, 2006) indicates that organizations with low interdependencies employ more formal and mechanistic control, while those with higher interdependencies adapt their MCS to allow for more flexibility, open communication, and customization of controls (given the higher level of

interdependencies between organizational units). Macintosh and Daft (1987) also show demonstrated that low levels of interdependencies rely more on formal controls such as budgets, standard operating procedures, and planning. It is important to note that technology also includes the level of interdependencies amongst and between the units of the organization Chenhall (2003, 2006). Chenhall and Morris (1986) empirical studies demonstrate that firms containing high interdependencies rely less on formal budgets and more on interpersonal communications.

4.3.2.3. Size as a Contingent Variable in MCS

Size, similarly to strategy, is considered an essential contingency variable as it dictates the communication and coordination constraints faced by the organization. Size also affects the other contingency variables (Chenhall, 2006). Often large scale firms are more capable of affecting their environment due to their size and have large-scale operations that allow specialization thereby diminishing uncertainty. However, larger organizations have a more demanding need for information to make decisions, making them more challenging to manage (Chenhall, 2003). In order to overcome these issues, large organizations often not only require a more decentralized hierarchy but also institute formal and complex control systems, as well as making modifications to their MCS to achieve organizational cohesion (Chenhall, 2003). According to Chenhall (2006), large firms are also linked to divided organizational structures with specialized operations that require high participation in formal aspects of MCS, such as budget controls.

4.3.2.4. Strategy as a Contingent Variable in MCS

Strategy, although categorized as a contingent variable, is thought to also provide organizational context (Hambrick 1980). A plethora of organizational strategies have been described in the literature including build-hold-harvest strategies (Govindarajan and Gupta, 1985), cost-differentiation (Porter 1980), and entrepreneurial-conservative (Miller and Friesen, 1982). Studies that look at strategy as a contingency variable are interested in determining what strategic positions are associated with specific MCS. Chenhall (2006) identified that firms that use conscientious strategies, such as defender or cost leader positions, are linked to employing more traditional and formal control systems.

Firms that have a competitive cost strategy use formal MCS that focus on their challenging areas (Chenhall, 2003). An empirical study by Chenhall and Morris (1995), found that firms with low-cost strategy monitored costs closely. On the other hand, firms with a differentiation strategy are not concerned with monitoring their costs and instead compete with other firms by providing a unique product or service at a premium price Chenhall (2003, 2006).

Since strategy influences organizational factors, it is essential that the organizational strategy ‘fit’ with the MCS, and that these MCS be designed to support the organizational strategy (Widener, 2004, 2007). Section 1.4.1. details the importance of “fit” and the different types of “fit” in contingency theory.

4.3.2.5. (Organizational) Structure as a Contingent Variable in MCS

Organizational Structure relates to the formal division of roles and relationships within the organization, specifically “who does what and how” Chenhall (2003, 2006). The structure is often associated with three

aspects: *differentiation*, *integration* and *decentralization*. **Differentiation** is associated with the “*extent to which sub-unit managers act as quasi-entrepreneurs*” (Chenhall, 2003, p. 145) and the degree of specialization of the different tasks carried out by the personnel. **Integration** is associated with the “*extent to which the sub-units act in ways that are consistent with organizational goals*” (Chenhall, 2003, p. 145) and **decentralization** can be described as a unit of measure of the authority each individual or unit possesses over their tasks. According to areas Chenhall (2003) differentiation is achieved by decentralization, while integration involves rules, operating procedures and committees. Decentralization in management research is considered as one of the important structural variables areas (Chenhall, 2003) and research indicates that larger organizations with higher differentiation utilize more formal MCS (Merchant, 1981).

Organizational structure also has been defined and discussed in a variety of terms: mechanistic and organic approaches that are achieved by rules, procedures and openness of communication and decision processes (Burns and Stalker, 1961); bureaucratic and non-bureaucratic (Perrow, 1970). Designers of MCS strive to implement MCS that are consistent with the organizational structure, thereby considering the extent to which MCS are mechanistic, organic or to what extent they differentiate or integrate areas (Chenhall, 2003). Organizational structure also encompasses an aspect of the relationship between the personnel and the other members of an organization that strive to accomplish organizational objectives (D. Otley, 1980); this includes the motivation with which work is performed areas (Chenhall, 2003) and therefore also includes the Manager’s leadership style. Managers with a **consideration leadership style** (Stogdill and Coon, 1957), which resembles a charismatic (Waldman et al., 1999) and a transformational (Bass and Avolio, 2000; 2004) leadership style, are mindful of their subordinates and involve them in participating meaningfully in their tasks such as the budgeting process areas (Chenhall, 2003). Abernathy et al. (2010) found that managers with a consideration leadership style have open lines of communication that ensure subordinates receive the information necessary to adopt responsibilities and to become empowered decision-makers. The use of a consideration style of leadership is associated with the use of planning and control systems as an interactive communication device to “reveal their preferences to subordinates and to obtain input from subordinates” (Abernathy et al., 2010, p.12). Similarly, Waldman and Yammarino, (1999) found that strong interpersonal leadership traits that promote communication and sharing, inspire the confidence in subordinates to meet their expectations. Managers with an **initiating leadership style** (Stogdill and Coon, 1957), which resembles a transactional leadership style (Bass and Avolio, 2000; 2004; Waldman et al., 1999), are also associated with interactive use of planning and control systems, but to a lesser extent than managers with a consideration leadership style (Abernathy et al., 2010). Managers with a strong imitating leadership style are “associated with “formal systems that specify targets and then take actions based on results” (Abernathy et al., 2010. p.12). Furthermore, there is an additional leadership style (not detailed within Chenhall’s (2003; 2006) Contingency Framework) that has been evoked by numerous scholars known as Delegative or “Laissez-faire” leadership style (Lewin, 1943). This type of leadership, employed in this thesis, entails the leaders making few decisions and handing over responsibility to the group to choose the appropriate solutions.

Finally, according to Child (1972), technology and organizational structure may have an important effect on one another and on how MCS function as *“the degree of interdependence that exists is a function of both technology and the organizational structure that is adopted; the organizational structure itself being influenced but not determined by technology”* (Child, 1972 in Otley, 1982. p.415).

4.3.2.6. Culture as a Contingent Variable in MCS

Scholars have proposed several definitions of culture. According to Kaplan (1965), there is a consensus amongst anthropologists that *“culture is composed of patterned and interrelated traditions, which are transmitted over time and space by non-biological mechanisms based on man’s uniquely developed linguistic and non-linguistic symbolizing capabilities”* (Chenhall, 2003, p. 154). Therefore, culture includes traits of knowledge, belief, art, morals, law, custom, capabilities and habits of members of a society (Seymour-Smith, 1986). Hofstede (1984) and Hofstede and Bond (1988), developed characteristics of cultural values in contingency-based MCS studies that include: power distance and hence the acceptance of the unequal distribution of power; individualism vs. collectivism, that is placing one’s interests ahead of the group’s; uncertainty avoidance, which is the preference to avoid uncertainty and rely on rules and structures; masculinity vs. femininity that contrasts achievement, assertiveness and material success with modesty and preference for quality of life; and finally Confucian dynamism which are related to status and respect for tradition. In MCS research, the impact of organizational culture and national culture on the behaviour traits of subordinates linked to these cultures has been closely studied (Chenhall, 2006). Organizational culture appears to have a stronger effect on the design of MCS than national culture areas (Chenhall, 2003) although different national cultures will respond differently to chosen MCS methods areas (Chenhall, 2003). Cultural elements and organizational structure (standardization and decentralization) appear to be associated with formal controls, the reliance on accounting performance measures and budgetary participation areas (Chenhall, 2003). However, it is not clear whether culture affects aspects of MCS, as few studies are able to draw clear comparisons and generalizations (Chenhall, 2006).

This thesis is primarily concerned with the Organizational Culture in the French Nuclear Sector, which as a High-Risk Industry, is strongly associated as “Safety Culture”. We will define Safety Culture in section 4.4.2. as a Contingency variable of both MCS and ERM.

4.4. Contingency Framework for ERM Literature

Changes to company organization (mergers, subcontracting, downsizing, outsourcing), increase in consumer demands and advancements in technology have contributed to a riskier corporate environment (Shenkir and Walker, 2006). In these situations, managers must manage risk based on the size and nature of their operations (Ping and Muthuvelo, 2012). Contingency control theory discussed in sub-section 4.1, 4.2 and 4.3 has been used to express how *“the effectiveness and design of organizations’ control systems rely on such [contingent] variables as organizational size and structure, strategy, environment, culture and technology”* (Nedaei et al., 2015, p. 55). Contingency theory stipulates that there is no universal control system applicable to all organizations in all circumstances (Chenhall, 2003, 2006; J. Fisher, 1995; David T

Otley, 1980; Rayburn and Rayburn, 1991) and therefore the design of MCS (and in the case of ERM, the design of the Risk Management Systems) must be a fit to the firm's context in order to maximize firm efficiency and performance (Chenhall, 2003; Chenhall and Morris, 1986; Gordon et al., 2009; Hoque, 2004; David T Otley, 1980) (fit will be further detailed in sub-section 4.5). However, Mikes and Kaplan (2014, p. 6) indicate that a *“useful contingency theory must be more powerful than ‘it depends’. The emerging theory should have a hypothesis about the specific linkages between organization-specific factors and the design of its ERM structure and systems, as well as a performance hypothesis about how improving the fit between an organization’s specific factors and its ERM system design will improve its performance along specific, measurable dimensions”*. The following sub-section presents Nedaei et al.'s (2015) Contingency Framework that details the organization-specific factors and the design of the ERM system in 4.4.1. A final sub-section regarding Safety Culture, which is not a part of Nedaei et al.'s (2015) Contingency Model is also presented in 4.4.2.

4.4.1. Nedaei et al.'s., (2015) Contingency Model of Enterprise Risk Management

Nedaei et al. (2015, p. 55) affirm that *“despite new trends in research that illustrate that an organization’s ERM system is part of its management control system, few studies have addressed the contingency theory of ERM”*. Some ERM studies have studied the effects of integrating ERM and the resultant organizational improvement (Lam, 2000; Nocco and Stulz, 2006) but empirical evidence to validate this relationship is limited (Nedaei et al., 2015). Other studies focusing on the size and the affiliated industry of a firm found conflicting results, as some scholars (Colquitt, Hoyt, and Lee 1999; Beasley et al. 2005; Pagach and Warr 2011) identified firm size and the affiliated industry as important contingency factors, while other studies (Liebenberg and Hoyt, 2003) found them to be non-explanatory. Additionally, Fisher (1995) states that the scope of contingency accounting studies should include the testing and development of a complete framework that integrates multiple components of several contingency factors and management accounting systems.

As a reaction to such limited evidence and in response to Fisher’s (1995) comment, Nedaei et al. (2015) propose a Contingency Model of Enterprise Risk Management. This ERM-based Framework for managing Enterprise risk, detailed in Figure 15 below, is a subset of an organizational control system, that argues the relationship between ERM and organizational performance is dependent on the fit between the ERM methods and three contingency factors: *size, decentralization and enterprise resource planning*. This ERM contingency framework also investigates the suitability, the *“fit”* between these three contingency factors and the sophistication of ERM systems, anchored in the works of Chenhall (2003, 2006) and Drazin and Van de Ven (1985); the first of these was detailed in subsection 4.3.2. and the second will be discussed in subsection 4.5.

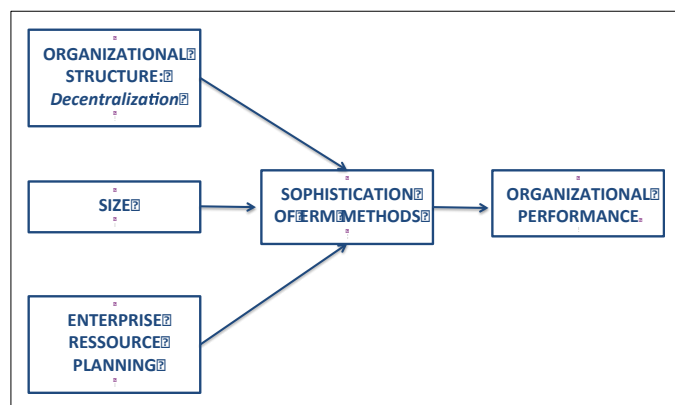


Figure 15. Contingency Model of Enterprise Risk Management (adapted from Nedaei et al., 2015)

Each of the contingency variables (Decentralization, Size, Enterprise Resource Planning) and their fit with the sophistication of the ERM systems in Nedaei et al.'s (2015) Contingency Framework are detailed in the following subsections. Finally, the sophistication of ERM methods on Organizational Performance is also presented.

4.4.1.1. Structure (Decentralization) and Sophistication of ERM as Contingent Variables

Decentralization, or the allocation of responsibility and authority to managers, is a factor that affects ERM methods (Nedaei et al., 2015). The quantity of decentralization within an organization provides an overview of the number of decisions that upper management allow lower management to make independently (Heller and Yukl, 1969), and impacts the manner in which the actors of the organization carry out their tasks to attain organizational goals areas (Chenhall, 2003). According to Chenhall and Morris (1986) decentralization may increase a manager's autonomy and accountability in planning and control activities, as such structuration provides managers with access to data that would not have otherwise been available in a centralized structure.

Several empirical studies (Abdel-Kader and Luther, 2008; Chenhall and Morris, 1986) have found that the greater the level of decentralization, the higher the need for complex information required to coordinate and control the activities of independent subunits, as the organizational units require information concerning their unit as well as the other units (Chong and Chong, 1997). Under such situations, sophisticated reports regarding the control systems and the subsets (such as ERM) provide managers with the necessary information allowing them to comprehend the issues, consider multiple resolutions, and thus make enhanced decisions to rectify the problems (Chenhall and Morris, 1986; Chong and Chong, 1997).

Since ERM is encompassed within the umbrella of MCS (Beasley et al., 2005; Bhimanim 2003; Gordon et al., 2009; Mikes, 2009; Mikes and Kaplan, 2013; Subramaniam et al., 2011), both Nedaei et al. (2015) and Gordon et al. (2009), apply the general concepts of contingency theory of MCS to ERM. Nedaei et al. (2015, p. 57) postulates that *“in highly centralized organizations, more sophisticated methods are required to analyze and manage the complex and integrated information gathered from all organizational subunits. Using sophisticated ERM methods, organizational leaders can conduct more thorough analyses that can help them better capture the information needed to mitigate their risks”*.

4.4.1.2. Size and Sophistication of ERM as Contingent Variables

The size of an organization has been classified as an important organizational variable in both contingency and organizational theory studies (Chapman, 1997; Chenhall, 2003, 2006; Donaldson, 2001), as size can affect the design of MCS (Merchant, 1984; Miles and Snow, 1978; Otley, Broadbent and Berry, 1995). As the size of the organization increases so does the need for more sophisticated MCS to manage the greater quantity of information and resources required to implement more complex systems (Abdel-Kader and Luther, 2008; Anthony and Govindarajan, 2001; Chenhall, 2003, 2006; Shields, 1995).

With regards to ERM practices, larger organizations are more likely to implement risk management practices than smaller organizations (Colquitt et al., 1999), as they have greater resources to allocate to the implementation of ERM procedures (Nedaei et al., 2015). Additionally, larger firms are also confronted with greater risks as a result of the more complex environment that surrounds them (Mintzberg, 1979) and thus have a greater requirement for more effective ERM methods than smaller firms that are confronted with fewer risks (Beasley et al., 2005; Pagach and Warr, 2011). As a result, it is essential that firms have an adequate amount of resources to implement and sustain ERM procedures. *Larger firms will require their managers to consider a higher quantity of data and information, thereby placing more importance on Sophisticated ERM methods.* This is to assist managers in their analysis of the available information, thereby supporting an improved apprehension and mitigation of risks (Nedaei et al., 2015; Subramaniam et al., 2011).

4.4.1.3. Enterprise Resource Planning (ERP)(Technology) and Sophistication of ERM as Contingent Variables

Technology and in particular IT technology has been identified as a contingency variable in MCS studies (Chenhall, 2003, 2006; Ittner and Larcker, 2001). Recent research on Enterprise resource planning (ERP) shows that this organization-wide data system allows managers across the firm to coordinate and manage resources from any location within the firm (Rom and Rohde, 2006), compared to the previous segmented data systems within the organization that only contained data for a specific unit. By combining all of the organizational data into a single network, not only does the Enterprise Resource Planning system permit the organizational objectives to be apparent (Dechow and Mouritsen, 2005), but it also promotes better-designed data systems that lead to improved firm effectiveness and efficiency (Nicolaou, 2004). Additionally, several studies (Chapman and Kihn, 2009; Cooper and Kaplan, 1998; Kallunki et al., 2011) have noted a link between Enterprise Resource Planning and the use of more sophisticated control systems to manage the large quantity of data that is generated by Enterprise Resource Planning systems. Zeng (2010) states that it is important to keep in mind that the sophistication of the ERM methods is dependent not only on the quantity of data attained from the Enterprise Resource Planning but also from the risks of implementing the Enterprise Resource Planning. Therefore, Nedaei et al. (2015) propose that *“to appropriately identify, evaluate, and handle these complexities and risks in implementing Enterprise Resource Planning and to manage the huge quantity of data generated by the system, more sophisticated ERM methods are required”*.

4.4.1.4. Sophistication of ERM methods on Organizational Performance

Several ERM methods with varying complexity exist to evaluate the likelihood and the impact of a potential event (Nedaei et al., 2015). Nedaei et al. (2015, p. 60) affirm that “*companies that adopt more mature and advanced ERM methods are able to make better-informed decisions, more efficiently deploy scarce resources, and reduce their exposure to negative events, thus increasing revenue and creating more competitive advantage*”.

Although several empirical studies (Mu, Peng and MacLachlan, 2009; Subramaniam et al., 2011) have observed that ERM sophistication has a directly proportional effect on organizational performance, Chenhall (2003) states that this relationship is inconclusive and contingent on circumstances. For example, the use of sophisticated ERM methods will yield greater organizational performance in a larger institution as a larger firm will have the resources required to implement the more complex ERM practices (Chenhall, 2003), which will, in turn, analyze a greater amount of data and hence manage a greater quantity of risks (Beasley et al., 2005; Pagach and Warr, 2011). Therefore, according to Nedaei et al. (2015), *larger institutions are more likely to adopt such sophisticated ERM systems in order to maximize their performance*.

4.4.2. Safety Culture as a Contingent Variable in ERM

The concept of safety culture was born following two major accidents in 1986: The Challenger Space Shuttle explosion in the USA and the Chernobyl nuclear explosion in Ukraine. Both of these explosions were organizational or systemic accidents as they could not be explained solely by incorrect or inappropriate behaviours of the subordinates but rather were due to the gradual accumulation of failures within the organization that surpassed each of the weakened protective barriers.

Safety culture is a contemporary practice in accident prevention, technical failure and human error, and has gained interest in the anthropology, sociology, psychology, management, and engineering scientific community (Henriqson et al., 2014). The discipline of safety culture pursues ‘socio-technical’ and ‘systemic’ oriented approaches to safety (Henriqson et al., 2014), and has attained an important status in the discourse of accident prevention, accident explanation (Starbuck and Farjoun, 2005) and organizational safety management performance (Hudson, 2007).

There exist a plethora of definitions of Safety Culture, and scholars (Antonsen, 2009a, Clarke, 2000, Guldenmund, 2000, Cooper, 2000, Choudhry et al., 2007) agree there is no universally accepted definition. Additionally, there is a continuous debate as to the similarities and differences between “safety culture” and “safety climate” (Deninson, 1996). Safety climate has origins in organizational psychology studies (Zohar, 1980) and is usually described as “the temporal state measure of safety culture” (Zhang et al., 2002, p. 10), while safety culture has origins in socio-anthropology (Haukelid, 2008) and is often associated with the organizational factors identified by accident investigators that detail accident causation (Sibley, 2009).

INSAG 4 (1991, p.1), a document by the International Nuclear Safety Advisory Group (INSAG) of the International Atomic Energy Agency (IAEA) defines safety culture of an organization as “*that assembly of*

characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance.” As such, Safety Culture is defined as based on the attitude of individuals and the structure of the organizations. Specifically, it associates Safety Culture to the actor’s attitudes and habits of thought as well as to the style of organization; requiring that all tasks essential to safety to be conducted with alertness, due thought and full knowledge, sound judgement and a proper sense of accountability (INSAG 4, 1991).

According to ICSI (2017), safety culture is *“a set of ways of doing and thinking that is widely shared by the employees of an organization in the context of managing the most significant risks associated with its activities.*

ACSNI (1993) defines safety culture of an organization as *“the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organization’s health and safety management. Organizations with a positive safety culture are characterized by communications founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures.”*

Overall, ‘safety culture’ definitions from organizational culture studies, include ‘the way we do things around here’, ‘process of fabrication of meaning’, ‘shared learning and practices’, ‘shared system of meanings’, ‘collective programming of the mind’, (Cooper, 2000, Edwards et al., 2013, Guldenmund, 2000, Pidgeon, 1998, Sibley, 2009, Tharaldsen and Haukelid, 2009). Other definitions consider safety culture as a specific aspect of organizational culture associated with the organizations’ attitudes, values, assumptions, beliefs, and consensual behaviours, shared, and learned to ensure that members understand risks and safety (Antonsen, 2009a, Clarke, 2000, Edwards et al., 2013, Glendon and Staton, 2000, Guldenmund, 2000, Richter and Koch, 2004). Nonetheless, *“most of the definitions are relatively similar in the beliefs perspective, with each focusing, to varying degrees, on the way people think and/or behave in relation to safety”* (Choudhry et al. (2007, p. 996)).

In fact, safety culture is closely linked to organizational culture as it affects how an organization thinks about and approaches safety. Organizational culture is closely related to the nature of the organizational activities (high risk, low risk), the environment and the risks, and the frequency and severity of incidents/events (minor, serious, fatal, major) it encounters in its day to day activities. Organizational culture can, therefore, influence safety behaviours and practices within an organization by supporting behaviours, rules, values that either improve or degrade safety practices ICSI (2017). Wiegmann et al. (2004, p. 121) indicates that “organizational safety culture exists on a continuum and that organizations can have either a good or poor safety culture”.

Henriqson et al. (2014) identified three statements that capture and address important attributes of safety culture in accident prevention: (a) safety is ‘the’ core organizational value; (b) safety requires management commitment; (c) safety requires workers’ commitment. The *first* of these statements indicate the importance of placing safety culture at the core of the firms’ beliefs thereby promoting “understanding that safety is the overriding priority” (Clarke, 2000, p. 76), and “the guiding principle” (Wiegmann et al., 2004, p. 126).

Generally, firms carry out this first statement by proposing formal written and documented ‘safety culture policies’ and campaigns for ‘safety first’ and ‘zero accidents’. The *second* of these statements highlights the importance of management commitment and supervision in safety practices, thereby encouraging managers to engage with their subordinates in both “the planning and the active oversight of safety activities” (Henriqson et al., 2014, p. 469). The practices include “critical risk operations, risk analysis processes, safety training, operation monitoring, corrective actions, continual improvement of the safety system, promotion of special campaigns, advertising of organizational safety values, provision of resources for safety, compliance with industrial regulations, rewarding and punishing of good and bad behaviour, coaching, participation on safety seminars and training, among others” (Henriqson et al., 2014). The *third* and final statement expresses the importance of the workers’ commitment to safety. Such commitment can be both intrinsic and extrinsic. ***Intrinsic and voluntary*** through the use of the worker’s participation, engagement in the communication of safety-related issues through reporting, self-vigilance through awareness of risks, and openly discussing errors and concerns without the fear of retaliation (Henriqson et al., 2014). ***Extrinsic and enforced*** through compliance of the safety working standards, operating procedures and reporting systems.

According to the IAEA (2002a, p. 17) “*probably the most important indication of a good safety foundation in an organization is the extent to which employees are actively involved in safety on a daily basis. If there is little involvement, with safety solely dependent on managers and safety specialists, it can be said that the organization has failed to win people over to the safety effort. Conversely, when safety issues are identified and acted on by all employees as part of their normal working routine, the organization can be said to have won over people’s hearts and minds to the safety cause*”.

Overall, it is important that safety be a core value within the company and that both managers and workers are committed to ensuring a strong safety culture that promotes communication and that encourages workers to report near misses and significant events, to ensure that underlying systemic issues are identified and addressed.

4.5. Fit of Contingency Variables in MCS and ERM

Numerous contingency models speculate that for the organization to be effective, both the context and the structure of the organization must “fit” (Burns and Stalker, 1961; Chenhall, 2003; Chenhall and Morris, 1986; Donaldson, 1995; Gordon et al., 2009; Hoque, 2004; David T Otley, 1980; Snow et al., 2006). In response to these contingency scholars, several classifications of fit have been proposed, at times with a variety of terms and conflicting definitions (Shields, 2003). The variance in definitions may lead to a non-consensus in the analytical and statistical methods used to carry out the empirical research. Additionally, these different understandings of fit may also lead to different views regarding multiple contingencies, referred to by Donaldson (1987) as *contingency imperative* and *equifinality*. In ***contingency imperative***, the contingency variable determines the fit that yields high performance (Donaldson, 1987). In the case of multiple contingencies, ***contingency imperative*** assumes that there is a single idyllic structure. In the ***equifinality*** idiosyncrasy, several idyllic structures may exist that are equally effective for any given context

(Drazin and Van de Ven, 1985). This is based on the idea that different management controls or designs of these MCS may yield a similar impact on the organizational performance for any one specific contingent variable.

Drazin and Van de Ven (1985) and Donaldson (2001) categorize three types of fit (*selection fit, interaction fit, and systems fit*) in management control systems, while Gerdin and Greve (2004) differentiate between *congruency approach and contingency approaches*. Later, Chenhall (2003, 2007) provided a summary of provided a summary of alternative methods to understand fit in the literature while adhering to the terms used by Drazin and Van de Ven (1985) and Donaldson (2001). This thesis will therefore also adhere to these first three terms while emphasizing their similarities between Gerdin and Greve's (2004) terminology. Specifically:

- **Selection fit** is associated with the “**Selection Approach**” where the firm design is dependent on the organizational conditions. In this case, a selection fit consists of an association between organizational factors (Selto, et al., 1995). The majority of contingency studies at the beginning of contingency research used the selection to identify the relationship between organizational context and design (Nedaei et al., 2015). Although according to Freeman (1973), the selection approach was *not concerned with performance*. As a result, selection fit studies investigate how contingency factors are associated with aspects of management control systems without intending to assess how these factors are linked to performance (Chenhall, 2003, 2006; Chenhall and Morris, 1986; Merchant, 1985). Selection fit closely parallels structural determinism, which states that “*there are structural elements or factors that deterministically affect outcomes, events, or processes. It is a concept that stresses rational, predictable outcomes and is suggestive of predetermined outcomes, given any particular structure or system of estimable factors*” (Mone in Clegg and Bailey, 2007, p.1477). This implies that contingency factors of the organization impact the firm's structures and hence its management controls in a unidirectional manner. Therefore, the performance of the firm is overlooked as according to selection fit, companies do not exist in a misfit to their environment. Instead, selection fit perceives the organizations to have extreme competitive pressures and therefore companies that are not in line with their environment will experience natural selection (bankruptcy, etc). As a result, organizations have no choice but to align and adapt to the dominant contingent variables of the organization. This is very similar to Gerdin and Greve's (2004) *congruency approach*.
- **Interaction fit** is synonymous with the “**Interaction Approach**” that is concerned with “*the influence of the interaction between the context variables rather than on the probable cause-and-effect relationship between organizational context and design*” (Drazin and Van de Ven, 1985 in Nedaei et al., 2015, p. 56). Unlike the selection approach, the interaction approach is concerned with both performance and organizational structure (Drazin and Van de Ven, 1985; Khandwalla, 1977), thereby investigating how organizational context impacts the relationship between management control systems and organizational performance (Brownell, 1983, 1985; Chenhall, 2003, 2006; Dunk, 1993; Govindarajan and Gupta, 1985). Unlike selection fit, interaction fit believes that companies in misfit

may exist as organizations with weak performance. This resembles Gerdin and Greve's (2004) *contingency approach*. Donaldson (2001) clarifies that the *contingency approach is a congruency study that takes into account performance*.

- **System fit** is associated with the "**Systems Approach**" and unlike the selection approach and the interaction approach that considers only a single variable at a time, it considers multiple variables of the design and the context at the same time, considering contingency factors simultaneously (Nedaei et al., 2015). Specifically, it considers how several facets of management control systems and multiple dimensions of organizational context interrelate to enhance performance (Chenhall, 2003, 2006; Chenhall and Langfield-Smith, 1998; Gerdin, 2005; Selto et al., 1995). Since the 1980s, "Systems fit" has been closely associated with configurational theory (Miller 1981) and modern management control theory. Systems fit employs a holistic view of management control systems, given that all of the components are considered to work together and hence must be aligned with each other. This can be referred to as the fit of an integrated whole, whereby the testing of fit consists of viewing multiple fits simultaneously in a larger context. This thesis is interested in systems fit.

As previously stated, Chenhall (2003, 2006) provides a summary of alternative variables that impact contingency fit in the literature via *structural relationships*, and variables derived from alternative theories such as *agency theory*, *Darwinian and natural selection (population ecology theory)*, and *individual personality fit (psychology theory)*. According to Chenhall (2006), these theories have much to say about the adoption and implementation of MCS in a contingency context, however this thesis solely considers the latter. *Fit based on psychology theory* considers that individual characteristics including personality or cognitive style impact how individuals react or respond to different management control systems. As a result, such personality characteristics may be important factors for the organizational contingency variables and the usefulness of the MCS (Chenhall, 2007). Specifically, empirical studies that assess the effectiveness of MCS such as budgetary participation based on the individual's locus of control (Brownell, 1981) or the levels of authoritarianism of the managers and their subordinates (Chenhall, 1986). In general, studies demonstrate that MCS success is dependent on the individual's commitment to the organization (Nouri and Parker, 1998), the level of trust between the employees and managers (Ross, 1994), and on the extent that the implementation of the MCS achieves organizational justice (Libby, 1999). Two new approaches, *person-environment fit* (Deci, 1980) and *person-organization fit* (Kristoff, 1996), have arisen from the application of psychology theory. Both approaches state that "*individual attributes can usefully be combined with organizational context by examining the compatibility between individuals and their work situation*" (Chenhall, 2003, p. 158). One strength of such alternative approaches is their ability to demonstrate potential struggles between individuals, groups and how the management control systems used by a firm are implicated amongst these conflicts (Chenhall, 2006). Several studies investigated the efficacy of MCS based on the level of environmental uncertainty and the workers' locus of control (Govindarajan

and Gupta, 1985); Gupta and Govindarajan, 1984). Surprisingly, workers with an external locus of control⁸ preferred a broad scope and timely information when they perceived environmental uncertainty compared to workers with an internal locus of control⁹ (Gupta and Govindarajan, 1984). According to Chenhall (2003, p. 158) it appears that *“personality, cognitive style and issues associated with commitment, trust and organizational justice could help explain the way individuals react to information in different contextual settings, and as such can be included readily within contingency-based frameworks. When combining different levels of analysis, care is required in theory development and method to ensure that combinations of individual and organizational variables are theoretically and empirically legitimate”*.

It is important to note that Contingency theory, the contingency variables and the concepts of fit are applicable for all contingency-based studies including both the contingency-based frameworks of MCS (detailed in 4.3) and ERM (detailed in 4.4).

Conclusion of Chapter 1

Management control is the process by which managers influence other members of the organization to implement the organization’s strategies. MCS have been described as a collection of control devices that serve as *“a system of organizational information seeking and gathering, accountability and feed-back designed to ensure that the enterprise adapts to changes in its substantive environment and that the work behaviour of its employees is measured by reference to a set of operational sub-goals (which conform to overall objectives) so that the discrepancy between the two can be reconciled and corrected for”* (D. Otley and Emmanuel, 2013, p. 8). Given this definition, MCS are useful in the management of both intra-organizational and inter-organizational actors (Dekker, 2004) such as the contractor-subcontractor relationship that due to the distance between firms requires resourceful management of systems and controls.

The development and implementation of formal control mechanisms and informal control mechanisms in an organization enable managers to strategically obtain results (Caglio and Ditilio, 2008; Eisenhardt, 1985). An organization has two types of formal controls (Reason et al., 1998; Ouchi and Maguire, 1975): behaviour and output controls. Behaviour controls i.e. Process Controls (Merchant and Van der Stede, 2007), standardize the work process using prescriptive rules, policies and procedures often measuring the behaviour to ensure the process is appropriate and performed according to the pre-determined specifications (Anderson et al., 2014; Das and Teng, 2001a; Eisenhardt, 1985a; Ouchi and Maguire, 1975). *Behaviour controls* ensure the subcontractor adheres to safety regulations by applying rules and behaviour prescribed by the contractor or the external regulatory authorities. Output controls measure the results of this behaviour

⁸ According to Govindarajan (1988, p. 831), external locus of control *“refers to perceiving positive and negative events as unrelated to personal behavior and therefore beyond personal control”*.

⁹ According to Govindarajan (1988, p. 831), internal locus of control *“refers to an individual's perceiving events, whether positive or negative, as a consequence of his or her own actions and thereby as potentially under personal control”*.

through a feed-back control process that contrasts output measures with performance and organizational objectives (Anderson et al., 2014; Das and Teng, 2001a; Eisenhardt, 1985a; Ouchi and Maguire, 1975). *Output control* serves as an accurate assessment of key performance measures, allowing contractors to adjust changes to those measurements thereby ensuring subcontractors implement their skills and resources to obtain results that comply with safety regulations. Finally, *informal or social controls* minimize goal discrepancies between the contractor and the subcontractor by establishing common culture, values and beliefs (Anderson et al., 2014; Das and Teng, 2001a; Ouchi and Maguire, 1975), thereby ensuring the convergence of objectives or the compatibility of non-convergent safety objectives. Given the complexity and the plethora of managerial controls, it is essential to explore the design of MCS using systems thinking approach, to identify the most suitable design components and their interactions at multiple levels of the organization. However, research indicates that the simple reinforcing of rules and procedures is insufficient to foster safe workplace behaviours; therefore, it is essential to complement MCS with other elements to ensure positive safety behaviour outcomes.

The concept of risk management involves two terms: control and risk. However, these two terms can be examined from two angles: the first looks at how management control systems support the management of risk- and hence “the *control of risk*”; and the second details the risks that are associated with management control systems –and hence “*the risks of control*”. *The control of risk* requires an organizational design for optimal Risk Management that takes into account organizational structures, procedures and strategies in the face of uncertainty. Galbraith (1977) proposes four organizational strategies to employ in the presence of increased uncertainty such as information uncertainty. By employing a combination of these strategies, the organization’s capacity to process information is improved thereby allowing the organization to function even at peaks of uncertainty, when the highest organizational performance expectations are imposed. *The risk of control* is heightened by the diminished levels of flexibility imposed by organizations during unexpected environmental changes. Management literature often assumes that the quantity of control that should be applied to a situation is directly proportional to the quantity of risk. Therefore, the greater the risk and the greater the consequences of such risk then the greater the quantity of control required to manage that risk. However, according to Berry et al. (2005), the contrary is often the case as exerting control in itself often carries a risk, and thus implementing a greater quantity of control to offset the perceived increased risk may impede or prevent the functioning of such risk management techniques. Specifically, these additional controls may diminish the organization actor’s ability of anticipation, contingency and flexibility which are essential components of risk management. Therefore, as plans, policies and budgets become more restricted and lack the flexibility to cope with unexpected situations, the organizational actors’ ability to navigate the turbulent climate is also restricted yielding an increase in risk rather than the intended reduction of risk. As a result, sensitive controls that allow for a flexible response to unexpected environmental changes (Berry et al., 2005, p. 299) are essential for managers, as they deal with variations of risks that fluctuate according to the internal characteristics (culture, size, maturity, etc) and external characteristics (competitors, environment) of the organization.

This thesis merges two theoretical frameworks of General Systems Theory and Contingency Theory, and is interested in their application to Management Control Systems (MCS) and Enterprise Risk Management (ERM) in Inter-Organizational Relationships (IOR). Previous studies that have merged both theoretical frameworks (Efferin and Hopper, 2007; Hewege, 2011; Hopper et al., 2009) have investigated deep-rooted cultural, social, political and anthropological contingency factors affecting management controls. Both General Systems Theory and Contingency Theory highlight the importance of analyzing MCS from a holistic approach that examines the effects of multiple elements or contingency factors on the system. Contingency theory further expresses that it is not the MCS that affect organizational performance, but rather the suitable fit between the MCS and the contingency factors (*environment, technology, size, strategy, structure, culture*) of the organization. As a result, both MCS and ERM should assess multiple factors specific to each scenario to determine the best risk management strategy that can be applied and ensure that the design of MCS or ERM takes into account such contingency factors. For example, Contingency Variables such as the *Structure, Size and Enterprise Resource Planning* and their link to the *sophistication of ERM methods and Organizational performance*. Therefore, no single universal solution to risk management exists. Instead, firms must evaluate their individual characteristics, while assessing the effects of such characteristics on the entire system in order to propose a tailored solution that best resolves the particularities of the specific risks.

The analysis of the contextual elements in the existing MCS, ERM and IOR literature, in combination with the empirical implications of subcontracting at the CEA (detailed in the introduction), reveals the need to address the following research question:

How does the CEA design Management Control Systems (MCS) that can effectively avert and mitigate subcontracting risks associated with quasi-integration, in the context of the specific characteristics of its nuclear facilities?

Furthermore, we acknowledge from this literature review there are additional questions in management that are not resolved in the literature. Specifically,

How do the MCS employed by CEA Managers (on subcontractors) avert and mitigate risks?

How do CEA managers balance MCS “as a package” to avert and mitigate subcontracting-related risks and events?

What dimension is implemented to orchestrate MCS as a package to enhance safety behaviours at the CEA?

What implementation approach(es) of MCS, following a near miss or a minor event, enable the controls to support and reinforce each other “as a package”?

A better comprehension of these aforementioned concepts will allow the CEA to understand the coupling of formal and informal controls, and their role in risk prevention in several Nuclear Facilities. The uniqueness of each Facility’s contingent variables (*environment, technology, size, strategy, structure, culture*) will also bring to light the influence between the contingent variables and the types of leadership and combination of management control systems that are employed.

Since organizations simultaneously use a wide range of control mechanisms to serve multiple purposes, Otley (1980) explains that this “makes it difficult, if not impossible, to isolate the effect of any specific means of control”. As a result, he states that “perhaps an initial research strategy would be to attempt to identify those combinations of controls that appear to be particularly suited to certain circumstances”. Therefore, the next chapter details the methodology used in this thesis to respond to the aforementioned research questions and attempt to identify the combination of controls suited in risk prevention and detection. Specifically, chapter 2, identifies the different particularities and contingency variables of several nuclear facilities and the analysis of the use of MCS to prevent and mitigate subcontracting related risks. It presents and justifies the choice of theoretical framework presented in this Chapter (General Systems Theory and Contingency theory) as well as the philosophical choices (paradigms), research approaches and use of two research methods grounded in abduction logic. The model centered process in conjunction with the systemic combining approach, used in this dissertation, led to the development of the initial and developed model of the use of Management Control Systems.

Chapitre 2 - Conception et méthodologie de la recherche

(Résumé en Français)

Un plan de recherche est "un cadre ou un plan directeur pour la conduite d'un projet de recherche, avec les détails des procédures nécessaires pour obtenir les informations requises pour structurer et/ou résoudre les problèmes de recherche" (Malhotra, 2012, p.102). Yin (2009) décrit un modèle de recherche comme un plan ou "un plan logique pour aller d'ici à là, où ici peut être défini comme l'ensemble initial de questions auxquelles il faut répondre, et là est un ensemble de conclusions (réponses) sur ces questions". Lors de la conception d'une étude de recherche, il n'existe pas de règles universelles, mais plutôt une série de directives visant à garantir une conception cohérente et logique dans laquelle tous les éléments de la conception sont complets. Ainsi, selon Hakim (1997), la conception de la recherche concerne le style et les préférences stylistiques du chercheur. Un aspect important de la conception de la recherche et de la sélection du cadre théorique découle de l'intention de fournir un angle de recherche holistique aux questions de recherche. Ferreira et Otley (2009) indiquent que la recherche sur les SCG bénéficierait d'un cadre qui offre une vue d'ensemble des aspects clés du SCG et qui permet aux chercheurs d'obtenir un aperçu holistique de la manière la plus efficace possible. En outre, la recherche qualitative adopte une vision holistique car elle s'appuie sur une description riche de la réalité de l'acteur pendant laquelle le phénomène est étudié dans le contexte (Denzin et Lincoln, 1994 ; Patton, 1980 ; Zawawi, 2018).

Le tableau 2 ci-dessous présente un aperçu des différents éléments de la conception de la recherche qui ont été utilisés pour définir, affiner et répondre à la question de recherche : ***Comment le CEA conçoit-il des systèmes de contrôle de gestion (SCG) qui peuvent prévenir et atténuer efficacement les risques de sous-traitance associés à la quasi-intégration, dans le contexte des caractéristiques spécifiques de ses installations nucléaires ?***

Tableau 2. Éléments de la conception de la recherche

Éléments de la conception de la recherche	
Cadre théorique	Théorie générale des systèmes et théorie des contingences
Paradigme épistémologique	Réalisme critique
Approches de la recherche	Combinaison systémique et processus centré sur le modèle
Mode de raisonnement	Logique d'abduction
Approche théorique	Développement de la théorie
Objet de l'analyse	Systèmes de contrôle de gestion
Stratégie de recherche	Une étude de cas unique (CEA) avec réplication théorique
Unité d'analyse embarquée	Trois installations nucléaires du CEA (installations A, B et E)

Pour répondre à cette question, deux *cadres théoriques*, la théorie générale des systèmes et la théorie de la contingence, ont été utilisés conjointement pour analyser les contrôles de gestion du CEA. Le chercheur utilise ici un paradigme épistémologique de *réalisme critique*, qui favorise l'utilisation de méthodologies mixtes. Selon Creswell (2007), une conception de la recherche qui mélange des approches méthodologiques améliore la force et la compréhension globales de l'étude, car les faiblesses individuelles d'une méthode particulière sont minimisées. Les deux choix méthodologiques utilisés dans cette thèse sont la *combinaison systémique* et le *processus de modélisation*, tous deux fondés sur une *logique abductive* itérative. Les deux méthodologies se complètent dans leur capacité à promouvoir le *développement théorique* de l'objet d'analyse (*les systèmes de contrôle de gestion*) à travers un processus itératif. La combinaison systémique compare continuellement le problème de recherche et le cadre analytique au monde empirique, dans son objectif de générer de nouveaux concepts et de développer des modèles théoriques (Dubois et Gadde, 2002). Selon Le Moigne (1987, p.3), "*un modèle [est une] représentation de la connaissance*", et le *processus de modélisation* sert d'instrument de production et d'exposition de la connaissance. Grâce à un processus conjoint de combinaison systémique et de modélisation, le chercheur affine continuellement la représentation des connaissances à chaque étape du "*mouvement continu entre un monde empirique et un monde modèle*" (Dubois et Gadde, 2002, p.554). Cela permet au chercheur d'implémenter les différents modèles observés sur le terrain au modèle théorique précédent ou préétabli, créant ainsi une représentation visuelle (processus de modélisation) qui évolue avec les nouveaux modèles observés à chaque retour sur le terrain. Ces représentations visuelles sont ensuite comparées à l'environnement empirique, et réévaluées à chaque retour sur le terrain (combinaison systémique). Ainsi, les modèles ont subi de nombreuses modifications au fur et à mesure qu'ils étaient formulés, détaillés, élaborés, réévalués et finalement validés dans trois Installations Nucléaires du CEA. Ces trois installations (Installation A, B et E) sont les sous-unités d'analyse d'une approche de recherche intégrée d'étude de cas du CEA.

Ce chapitre présente le plan de recherche et explique les choix méthodologiques utilisés dans cette thèse en quatre sections. La première section explique le cadre théorique de l'étude, les choix philosophiques (paradigmes épistémologiques), la démarche et le processus de recherche. La deuxième section présente l'analyse du système de construction de modèles, y compris la sélection des études de cas. La troisième section détaille la formalisation du modèle. La quatrième section décrit la validation *in situ* du modèle ainsi que la qualité de la recherche.

Dans l'ensemble, un point important de la conception de la recherche et de la sélection du cadre théorique est né de l'intention de fournir un angle de recherche holistique aux questions de recherche. Ferreira et Otley (2009) indiquent que la recherche en SCG bénéficierait d'un cadre qui offre une vue d'ensemble des aspects clés du SCG et qui permet aux chercheurs d'obtenir un aperçu holistique de la manière la plus efficace possible. En outre, la recherche qualitative adopte une vision holistique car elle s'appuie sur une description riche de la réalité de l'acteur pendant laquelle le phénomène est étudié dans le contexte (Denzin et Lincoln, 1994 ; Patton, 1980 ; Zawawi, 2018). La fusion de la théorie de la contingence et de la théorie des systèmes a en outre permis une observation et une analyse plus holistique des stratégies de gestion des risques des

trois installations et leur comparaison avec les stratégies de gestion des risques détaillées dans la littérature. La construction ou le développement de théories à partir d'études de cas présente de nombreux avantages, notamment la testabilité et la validité empirique, étant donné son lien étroit avec les preuves empiriques (Eisenhardt, 1989b ; Eisenhardt et Graebner, 2007 ; Siggelkow, 2007), étant donné qu'elle est "*dérivée des données, systématiquement recueillies et analysées à travers le processus de recherche*" (Strauss et Corbin, 1990:12).

Le chercheur emploie un paradigme épistémologique de *réalisme critique*, en utilisant la *combinaison* systémique, *une* approche de recherche ancrée dans une *logique abductive* itérative (Dubois et Gadde, 2002 ; 2014). Une deuxième approche de recherche, le *processus centré sur le modèle*, a également été employée comme outil de production et d'exposition des connaissances dans un "*mouvement continu entre un monde empirique et un monde modèle*" (Dubois et Gadde, 2002, p.554) à travers un processus itératif. Deux cadres théoriques, la *théorie systémique* et la *théorie de la contingence*, ont été utilisés pour analyser les systèmes de contrôle de gestion employés par trois installations qui ont recours à la sous-traitance de quasi-intégration au CEA. Les différentes représentations visuelles observées sur le terrain ont été comparées aux modèles théoriques préétablis avant de retourner sur le terrain. Cumulativement, *neuf phases de collecte de données* se sont déroulées sur 44 jours sur une période de deux ans et demi et ont donné lieu à un total de 36 entretiens, plus de 366 heures d'observations sur 44 jours dont 23 réunions documentées et 21 observations documentées. Au cours des quatre années qui ont suivi, des récits ont été construits à partir des 45 heures d'entretiens semi-dirigés et non-dirigés enregistrés, ainsi qu'à partir des 218 pages dactylographiées de notes de terrain et des 80 textes d'entreprise recueillis. Ces données obtenues in-situ de l'étude de cas ont ensuite été codées, analysées et déconstruites avec le logiciel d'analyse de données qualitatives n-VIVO pour identifier les risques de sous-traitance, les mécanismes de contrôle et autres éléments présents dans les trois installations nucléaires afin d'analyser leur interaction. Les données ont également contribué à générer une cartographie du contrôle de chacune des installations, ainsi que divers tableaux et diagrammes qui ont décrit l'utilisation des SCG et leurs méthodes d'implantation qui varient d'une installation à l'autre. Le développement de la théorie à partir des données, sous la forme de tableaux, de diagrammes et de conclusions générales, typique de la *combinaison systémique*, a ensuite été vérifié auprès de Jean-François Vautier et Guillaume Hernandez, les deux spécialistes des facteurs organisationnels et humains (FOH) de la Direction de la sécurité et de la sûreté nucléaire (DSSN) du CEA. Ils ont supervisé l'étude de recherche, ont grandement contribué à l'évolution du développement de la théorie des cas et ont diminué les biais des chercheurs. En conséquence, les modèles ont subi de nombreuses modifications au fur et à mesure qu'ils étaient formulés, détaillés, élaborés, réévalués et finalement validés dans l'Installation A et l'Installation B du CEA (et non invalidés dans l'Installation E). Ces trois installations (Installation A, B et E) sont les sous-unités d'analyse d'une approche de recherche intégrée d'étude de cas du CEA. Chaque installation a présenté un style différent de contrôle et de leadership qui semble être lié aux facteurs de contingence de l'installation, comme nous l'avons vu à la section 3 du chapitre 3. La nature variée des facteurs de contingence (caractéristiques) entre les trois installations a permis d'étudier la nature

contingente du SCG et des styles de leadership et d'utiliser l'installation E comme témoin entre l'installation A et l'installation B. De plus, les quatre manières de valider le processus abductif de David (1999) ont été utilisées pour valider le modèle développé, qui est le résultat de l'intégration de la nature antagoniste et contingente des SCG et du leadership au modèle initial. Ce modèle développé a également été confronté aux théories existantes dans les cadres de contingence SCG et GRE.

Le chapitre 3 expose les résultats de cette thèse qui présentent : *Comment le CEA conçoit des Systèmes de Contrôle de Gestion (SCG) qui peuvent prévenir et atténuer efficacement les risques de sous-traitance associés à la quasi-intégration, dans le contexte des caractéristiques spécifiques de ses installations nucléaires.*

Chapter 2 - Research Design and Methodology

A research design is “a framework or blueprint for conducting a research project, with the details of the procedures necessary for obtaining the information needed to structure and/or solve research problems” (Malhotra, 2012, p.102). Yin (2009) describes a research design as a blueprint or “a logical plan for getting from here to there, where here may be defined as the initial set of questions to be answered, and there is some set of conclusions (answers) about these questions”. When designing a research study, there are no universal rules, but rather a series of guidelines to ensure a coherent and logical design in which all of the elements of design are comprehensive. Thus, according to Hakim (1997), the research design is about the style and the stylistic preferences of the researcher. A significant focus of the research design and the selection of theoretical framework arose from the intention of providing a holistic research angle to the research questions. Ferreira and Otley (2009) indicate that MCS research would benefit from a framework that provides a broad view of the key aspects of MCS and that allows researchers to obtain a holistic overview in the most efficient way possible. Furthermore, qualitative research adopts a holistic view as it relies on a rich description of the actor's reality during which the phenomenon is under study within the context (Denzin and Lincoln, 1994; Patton, 1980; Zawawi, 2018).

Table 2 below, presents an overview of the different elements of the research design that were used to define, refine and respond to the research question: *How does the CEA design Management Control Systems (MCS) that can effectively avert and mitigate subcontracting risks associated with quasi-integration, in the context of the specific characteristics of its nuclear facilities?*

Table 2. Elements of the Research Design

Elements of the Research Design	
Theoretical Framework	General Systems Theory and Contingency Theory
Epistemological Paradigm	Critical Realism
Research Approaches	Systemic Combining and Model-Centered Process
Mode of Reasoning	Abduction Logic
Theoretical Approach	Theory Development
Object of Analysis	Management Control Systems
Research Strategy	A single case study (CEA) with theoretical replication
Embedded Unit of Analysis	Three CEA Nuclear Facilities (Facility A, B and E)

To answer this question, two *theoretical frameworks*, General Systems Theory and the Contingency Theory were used jointly to analyze the management controls of the CEA. The researcher employs a *critical realism* epistemological paradigm, that promotes the use of mixed methodologies. According to Creswell (2007), a research design that mixes methodological approaches enhances the overall strength and comprehension of the study, as the individual weaknesses of a particular method are minimized. The two methodological choices used in this dissertation consist of *systemic combining* and the *modelling process*; both grounded in an iterative *abductive logic*. Both methodologies complement each other in their ability to promote *theory*

development of the object of analysis (Management Control Systems) through an iterative process. Systemic combining continuously compares the research problem and the analytical framework to the empirical world, in its objective of generating new concepts and developing theoretical models (Dubois and Gadde, 2002). According to Le Moigne (1987, p.3), “*a model [is a] representation of knowledge*”, and the *Modeling Process* serves as an instrument of knowledge production and knowledge exhibition. Through a joint systemic combining and modelling process, the researcher continuously refines the representation of knowledge at each stage of the “*continuous movement between an empirical world and a model world*” (Dubois and Gadde, 2002, p.554). This allows the researcher to implement the different patterns observed in the field to the previous or a pre-established theoretical model, thereby creating a visual representation (modelling process) that evolves with the new patterns observed with each return to the field. These visual representations are then compared with the empirical environment, and reassessed with each return to the field (systemic combination). As a result, the models underwent numerous changes as they were formulated, detailed, elaborated, reassessed and finally validated in three Nuclear Facilities of the CEA. These three facilities (Facility A, B and E) are the sub-units of analysis of an embedded Case Study research approach of the CEA.

This chapter presents the research design and explains the methodological choices used in this dissertation in four sections. The first section explains the research study’s theoretical framework, philosophical choices (epistemological paradigms), research approach and process. The second section presents the Analysis of the System for Model Construction including Case Study selection. The third section details the formalization of the model. The fourth section describes the validation *in situ* of the model as well as the Quality of the Research.

1. Theoretical Framework, Paradigm Choices and Research

Approach

This first section of Chapter Two contains four subsections. The first subsection provides justifications for the choice of the theoretical framework used to analyze the object of analysis, while the second subsection details the epistemological paradigm of the study. The third subsection details the three scientific research approaches (*deductive, inductive and abductive*) including the study’s mode of reasoning. The fourth subsection presents the study’s two research processes (*Systemic combining Process and Model-centered Process*) both grounded in the study’s research approach.

1.1. Justification of the Theoretical Framework

In order to determine the theoretical framework that best aligned with the research objective of the thesis, several organizational theories were considered. Two theoretical frameworks were selected for this thesis by employing the proposed classification of Rojot (2003) and Plane (2012) in Lemaire (2013) that categorizes the theories according to the characteristics of the research objective. Figure 16 details this

classification according to two axes of the research object: (1) the dynamics of the research object, along the y-axis, that categorize the object as either process or as static structures; and (2) the level of granularity of the research objective, along the x-axis, that categorize the research object as either related to the organizational approaches or to the actor approaches.

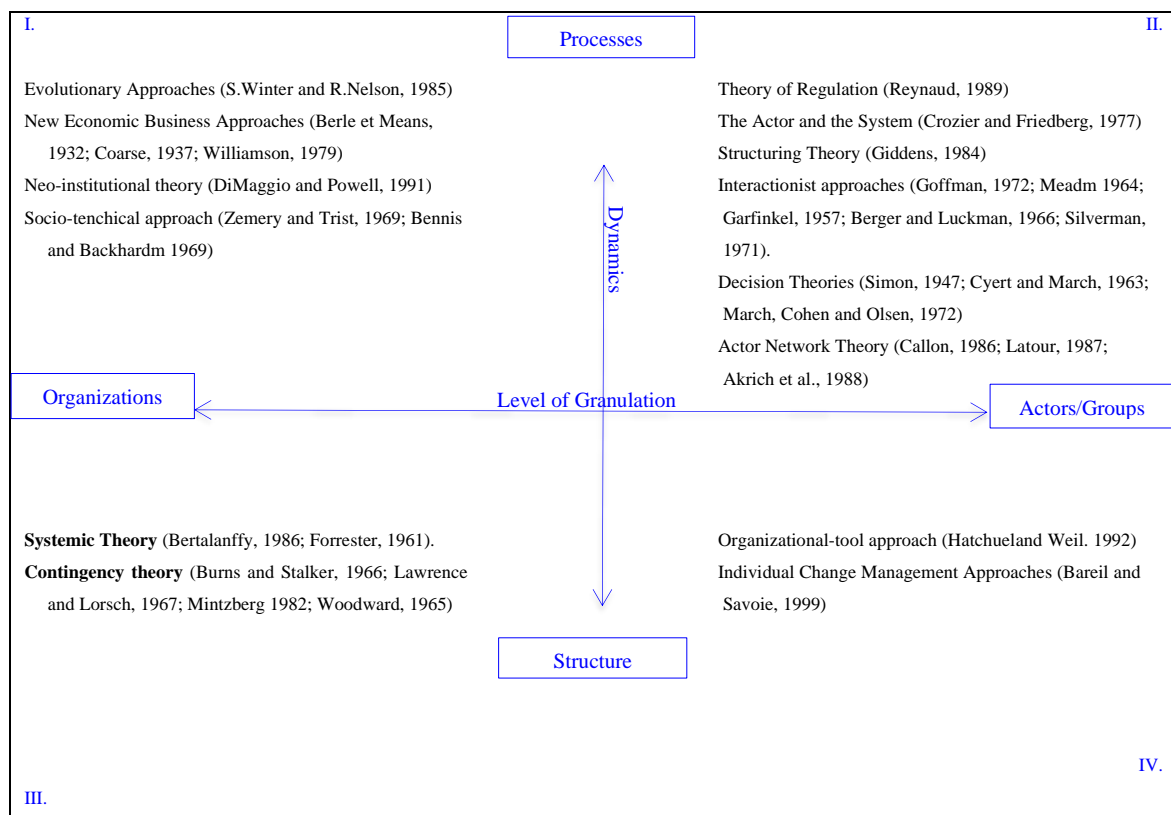


Figure 16. Classification of Organizational theories according to the dynamics and the granularity of the research objective (Adapted from Lemaire, 2013, original source: Rojot, 2003 and Plane, 2012).

The research framework was selected by first analyzing the level of granularity of the research object. Since this thesis is interested in studying management control theories and leadership factors at the organizational level, it was possible to exclude all of the theories that focused on the individual actors and groups. As a result, all of the theories in Quadrant II and IV were excluded, leaving only theories in Quadrant I and III. This thesis is mainly interested in the structural level of the risk management and the leadership aspects that occur in the Nuclear Facilities; and hence at the organizational and structural level. As a result, the theories in the Quadrant III, that favour a structure-based approach, are the most appropriate as per the research objectives of this thesis. The two theories in Quadrant III that remained, focus on the organization at a structural level: the *General Systems Theory*; and the *Contingency Theory*. These both emphasize the importance of the environment on the organizational structure of the firm. Specifically,

- **General Systems Theory** was first introduced by Von Bertalanffy in 1968. According to Rojot (1997, p.3347), originally written in French and translated hereafter, a system is very simply defined as ‘a complex of interacting non-random elements’. According to Koffka (1935) in Vautier et al. (2018, p.7), in General Systems Theory “the whole is other than the sum of its parts”, partly due to the interactions

between these elements as “*the properties of a system result only in part from the properties of its elements*”.

- **Contingency Theory** indicates that there is no one single best model. According to Rojot (2003), the theory emphasizes the importance of the environment and its impact on the organization. Several researchers have demonstrated how various environmental elements (size, age, strategy, activity sector) favour a variety of organizational structures. Lawrence and Lorsch in Rojot (1997, p.3346) state that “there is not a good structure of organization superior to all others but that some are more or less adapted to certain environments”.

According to Plane (2012, p.105), “a systems approach focuses more on the relationship between the building blocks of an entity of characteristics specific to each element”. This systems approach allows researchers to visualize the organization as a system, thereby identifying subsystems and the existence of feed-back phenomena. According to Rojot (2005, p.44), “*there is no point in correcting an undesirable element without simultaneously adjusting the elements to which it is linked to*”. Since the organization is seen as an open system, that is a system of interdependent individuals that can only fulfil their specific role if the other individuals do the same. These interdependent individuals exist within the system and are connected to the external environment.

Both the Systemic Theory and the Contingency Theory were chosen as a joint theoretical framework to analyze the research object. Both of these theories are detailed in Chapter 1. In this dissertation, the CEA is seen as the system, that is composed of a set or group of interdependent or temporary interacting parts (the different Nuclear Sites), that are in turn each composed of smaller parts (Nuclear Facilities). The Nuclear Facilities can be further broken down into the organizations that interact in an inter-dependent manner as is the case with the CEA Managers and the subcontracting group. Therefore, General Systems Theory allows the study of the interdependence of these relationships within the system, by contrasting a traditional analytical approach and instead highlighting the interactions and association of different elements in the system. Specifically, this thesis is interested in the management control systems used by the CEA to supervise the subcontractors. In the case of Facility A, this is restricted to CEA Managers, while in the case of Facility B and E, this is broadened to include both the CEA Managers and the Middle Manager from the subcontracting firm that are also responsible for monitoring the subcontractors (workers in the field). In comparing the different management parameters of the three Facilities, no specific universal best practices were identified. Instead, different practices were observed according to the size, the managerial configuration and the other contingent factors of each Facility. These results are detailed in Chapter 3.

1.2. Research Paradigms and Epistemological Assumptions of the Research Study

According to Guba and Lincoln (1994, p. 107), paradigms are “basic belief systems based on ontological, epistemological and methodological assumptions”. Piaget (1967) initially defined epistemology as “*the study of valuable knowledge constitution*”. Avenir and Thomas (2015, p. 3) define an epistemological framework as “*a conception of knowledge relying on a set of mutually consistent founding assumptions*

relative to the subjects that epistemology addresses". These assumptions rely on the researcher's beliefs of the "origin and nature of knowledge (*epistemic assumptions*), how [knowledge] is elaborated (*methodological assumptions*), and how it is justified", while most epistemological frameworks "also rely on founding assumptions that concern what exists (*ontological assumptions*)" (Avenir and Thomas, 2015, p. 3). Burrell and Morgan, (1979) adds assumption (human nature) and provides a schematic representation of all four assumptions as a continuum of two polarized perspectives, detailed in Figure 17 below. According to "Madill et al. (2000, p. 17), "qualitative researchers have a responsibility to make their epistemological position clear, conduct their research in a manner consistent with that position, and present their findings in a way that allows them to be evaluated appropriately".

There are several Paradigms in Management Science each with their own ontological, epistemological and methodological assumption. Table 3 below provides an overview of two of the most prominent Paradigms (Positivism and Interpretivist or Constructivist). For clarity the Post-Positivism under which this thesis inscribes itself has been included within this Table however, it will be discussed at the end of this subsection. The following paragraphs provide the ontology, epistemology and methodology of these Paradigms:

Positivism, found in the second column, believes that an apprehendable reality exists driven by immutable laws and mechanisms in the form of cause-effect laws (*Naïve Realism Ontology*) (Guba and Lincoln, 1994). The investigator and the investigated object are seen as independent entities, allowing the investigator to study the object without influencing it or being influenced by it; whereby enquiry takes place via a one-way mirror (*Dualist and Objectivist Epistemology*) (Guba and Lincoln, 1994). The hypotheses are formed in a propositional form and verified through empirical tests whereby confounding conditions are carefully manipulated (controlled) to prevent biases (*Experimental/ Manipulative Methodology*) (Guba and Lincoln, 1994).

Interpretivist/ Constructivist, found in the fourth column, believes that "realities are apprehendable in the form of multiple, intangible mental constructions, socially and experimentally based, local and specific in nature [...] and dependent for their form and content on the individual persons or group holding the construction" (Relativist Ontology) (Guba and Lincoln, 1994, p. 110). The investigator and the investigated object interact to "create the findings" during the investigation process (*Transactional/ Subjectivist Epistemology*) (Guba and Lincoln, 1994). Finally, the individual constructions are refined only through the interactions between the investigator and the subjects using hermeneutical techniques that are compared and contrasted through a dialectic exchange (*Hermeneutical/ Dialectical Methodology*) (Guba and Lincoln, 1994).

Table 3. Basic Beliefs of Positivism, Post-Positivism and Interpretivist/ Constructivist (Adapted from Guba and Lincoln, 1994)

Paradigm	Positivism	Post-Positivism	Interpretivist/Constructivist
Ontological Assumption	Naïve Realism	Critical Realism	Relativism
“form and nature of reality”	“Real”: reality is assumed to exist but apprehendable	“Real”: Reality is assumed to exist but only imperfectly and probabilistically apprehendable	“Not one reality” : Local realities that can be apprehendable in the form of mental constructions
Epistemological Assumption	Dualist/Objectivist	Modified Dualist/ Objectivist	Transactional/ Subjectivist
“origin and nature of knowledge”	“Replicable findings are true”	“Replicable findings are probably true”	Findings are “value-mediated and created”
Methodological Assumption	Experimental/ Manipulative	Modified Experimental/ Manipulative	Hermeneutical/ Dialectical
“how [knowledge] is elaborated”	Verification of hypothesis and mainly quantitative methods	Falsification of hypothesis and Inquiry in natural settings. May include qualitative methods	Transactional inquiry requiring a dialogue amongst the enquirer and the subject of inquiry,

This dissertation employs qualitative research and subscribes to a realist paradigm in its aim to determine: *How does the CEA design Management Control Systems (MCS) that can effectively avert and mitigate subcontracting risks associated with quasi-integration, in the context of the specific characteristics of its nuclear facilities?*

The realist perspective aims to use a more holistic process while aiming to describe and explain complex phenomena (Healy and Perry, 2000). Three realist epistemologies (*naive, scientific, and critical*) are defined by Madill et al. (2000, p.3): This thesis is interested in the last of these, the Critical realism, concerned with “*the way we perceive facts, particularly in the social realm, depends partly upon our beliefs and expectations*” (Bunge, 1993, p.231).

Specifically, this thesis subscribes to a *critical realism* that relies on a *realist ontology* and a *relativist* or anti-positivist *epistemology*. **Critical realism** has evolved over the past years following Roy Baskar’s (1978) work and exclaims that “*social sciences can be sciences in exactly the same sense as natural ones*” (Bhaskar, 1998a: 17). The term “critical realism” is the merger of two terms: “transcendental realism” and “critical naturalism” (Bhaskar, 1998a). Figure 17 below adapted from Burrell and Morgan (1979, p. 3) places critical realism on a philosophical and methodological continuum of two polarized perspectives mentioned above. The purple “X” denotes the position of this research study along each continuum. Each of these four perspectives is viewed from the critical realist perspective and further detailed in Appendix C.

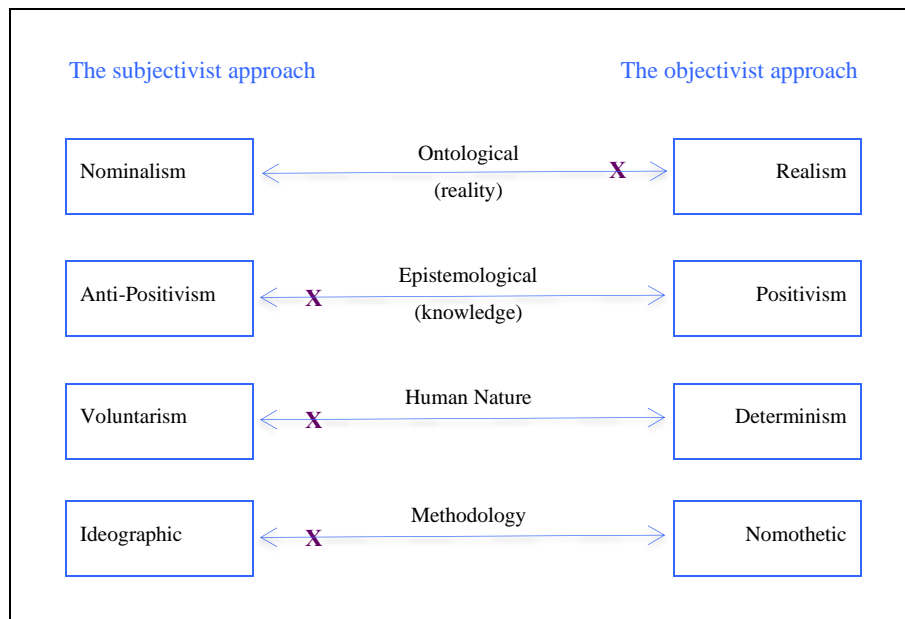


Figure 17. Philosophical and Methodological Continuum of this Study that is underpinned by a Critical Realist Paradigm (Adapted from Burrell and Morgan, 1982).

This dissertation’s subscription to critical realism is evident through the author’s ontology, the choice of multiple research methods, data sources and theories data collection and description. According to Healy and Perry (2000), in-depth interviews and instrumental case studies that aim to build theories fall under a critical realism paradigm. Multiple case studies also provide rich and abundant data to identify the generative mechanisms at the three nuclear facilities that emerge based on their contingent nature. Guba and Lincoln (1994) consider realism as enabling the discovery of the world even if it is imperfectly comprehensible. The researcher describes the use of MCS to mitigate subcontracting risks and the emergence of leadership at each Facility in a rich format. Through the use of multiple data collection techniques including rich observations and semi-directive interviews, it was possible to identify patterns of change specific to one facility, that had not been observed in the other (types of MCS used, leadership, trust mechanisms). Through the use of in-depth interviews, the proposed plausible underlying generative mechanisms for these differences could account for these changes. It was also possible to eliminate the alternative explanation of other potential mechanisms, initially observed in Facility A, that was not relevant to Facility B. For example, the element of trust was eliminated early on, as the concept of trust at Facility A consisted solely of inter-organizational trust (between the CEA and the subcontractors) while at Facility B, there was the presence of both intra-organizational trust (Middle managers and the subcontractors who belonged to the same company) and of inter-organizational trust (between the CEA and the subcontractors). After choosing to eliminate trust, the research focused on the other “puzzle pieces” so as to clarify the observed pattern. Specifically, different types of leadership were activated at selective times in combination with certain controls. Formal controls in Facility A appeared to activate transactional leadership¹⁰, while informal controls in Facility B appeared to activate transformational leadership. As a result, it was possible

¹⁰ Transactional Leadership (similar to *initiating leadership style*) and Transformational Leadership (similar to *consideration leadership style*) are both defined in Section 4.3.2.5 of Chapter 1.

to employ Tsoukas' (1989) abductive explanatory conception of the case study that intends to enrich the existing theoretical interpretation of generative mechanisms and the mode in which they are activated, through a comparative analysis of different contextual conditions in three Facilities. The generative mechanisms in each facility were contingent on the facility's size, their managerial configuration, leadership type, use of interactive controls, and a number of other contingency factors. The use of an embedded case study allows an improved understanding of the specific contingent conditions that the suggested generative mechanisms combine and operate (Tsoukas, 1989). As a result, it was possible to arrive at a theoretical explanation for the patterns that were initially observed and formulated in Facility A, later altered, validated in Facility B, then further detailed and elaborated in Facility B, to then be re-validated in Facility A. Additionally, the theoretical explanation of the patterns appear to be valid in Facility E, thereby not invalidating the theoretical explanation elaborated at Facility B.

1.3. Research Approach

According to Kovacs and Spens (2005), it is essential to differentiate between a research approach and a research process. A **research approach** is the way of conscious scientific reasoning, while a **research process** is the summary of all of the sequential steps that a researcher follows in order to carry out a specific scientific approach (Kovacs and Spens, 2005; Peirce, 1931). There exist three main approaches to Scientific Research and Scientific logic: *deduction logic*, *induction logic*, and *abduction logic*. However, in order to understand and explain the abductive approach, the choice of approach in this dissertation, it is essential to first understand the deductive and inductive approach. Additionally, according to Kirkeby (1990) and Kovacs and Spens (2005), the majority of Western research traditions entail the deductive and the inductive approach.

Kovács and Spens (2005 and 2006) proposed a Research Process Framework that recognizes three parameters to distinguish between the three research approaches. Specifically: (a) the initial state of the research process (theoretical advances or an empirical study); (b) the research aims (theory development or theory testing); (c) the point in time at which hypotheses or propositions (H/P) are developed and whether they are further applied (*ex-ante* vs *post hoc* hypotheses and their application). Their 2006 paper also included a fourth parameter, the type of research methods used.

This dissertation employs an abductive research approach, which in order to be described, first requires the understanding of a deductive and an inductive approach. Table 4 below provides an overview of the fundamental structure, the strengths, the limitations, the sequence of logic and the important researcher qualities of the deduction, induction and abduction logic. Each of these modes of logic (*deductive*, *inductive* and *abductive*) and the general research process specific to each of these approaches are detailed in the subsections below. The research processes used in this dissertation are detailed in subsection 1.4.

Table 4. Overview of Deduction, Induction and Abduction. (Adapted from Danermark et al., 2005).




	<i>Deduction</i>	<i>Induction</i>	<i>Abduction</i>
Fundamental Structure <i>Aims to...</i>	<ul style="list-style-type: none"> • derive logically valid conclusions from given premises. • derive knowledge of individual phenomena from universal laws. 	<ul style="list-style-type: none"> • draw universally valid conclusions about a whole population from several observations. • identify similarities in a number of observations and draw the conclusion that these similarities also apply to non-studied cases. • draw conclusions about law-like relations from observed co-variants. 	<ul style="list-style-type: none"> • interpret and recontextualize individual phenomena within a conceptual framework or a set of ideas. • understand a concept in a new manner by observing and interpreting the concept in a new conceptual framework.
Strength <i>Provides...</i>	<ul style="list-style-type: none"> • rules and guidance for logical derivations and investigations of the logical validity in all arguments. 	<ul style="list-style-type: none"> • guidance in connection with empirical generalizations, and the possibilities to calculate the precision of such generalizations. 	<ul style="list-style-type: none"> • guidance for the interpretative processes by which we ascribe meaning to events with relation to a larger context.
Limitations	Does not express anything new about reality beyond what is already in the premises. It is strictly analytical.	<i>Internal limitation:</i> inference can never be analytically or empirically certain. <i>External limitation:</i> restricted to conclusions at the empirical level.	Does not provide fixed criteria to assess in a definite way the validity of an abductive conclusion.
Sequence of Logic	Rule → Case → Result	Case → Result → Rule	Rule → Result → Case
Important researcher quality	Logical reasoning ability	Ability to master statistical analysis	Creativity and imagination
Research Process (Summary of Sequential steps)	(1)Theoretical Framework (from prior literature) (2)Theoretical conclusions (Hypothesis/Propositions reached through logic) (3a)Testing of conclusions (3b)Final conclusions(corroborating/abandoning theory)(accepting/discarding hypothesis or propositions)	(0)Existing theoretical knowledge from prior research (1)Real-life observations (2a)(Final) theoretical conclusions (framework)	(0)Prior theoretical knowledge (1)Deviating real-life observations (2)Theory matching (3)Theory suggestions (Final conclusions: hypothesis /propositions (4)Application of conclusions
Arrow Color in Figure.	Blue 	Yellow 	Red 

Figure 18 below provides a schematic representation of the research processes of all three modes of logic (*deductive, inductive and abductive*) and the general research process specific to each of these approaches. Please note that solely the abductive mode of logic is detailed below.

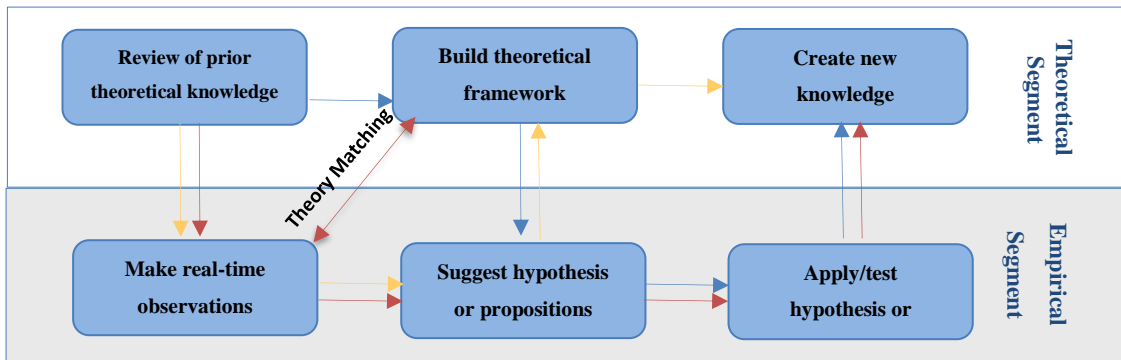


Figure 18. Comparison of the deductive (blue), inductive (yellow) and abductive (red) research processes (adapted from Kovács and Spens (2006)).

The **abductive research approach** differs from the deductive and inductive approach in its research process. Certain researchers see abduction as the systematized creativity or intuition in research to develop “new” knowledge (Andreewsky and Bourcier, 2000; Kirkeby, 1990; Taylor et al., 2002). This creativity is needed to step out of the limitations imposed by deduction and induction that limit the establishment of the relationship between previously acknowledged constructs (Kirkeby, 1990). In fact, advances in science are frequently reached through the instinctive jump known as abductive reasoning (Taylor et al., 2002). The abductive research approach has two different starting points: (1) a “surprising or puzzling” observation or an anomaly that cannot be explained using pre-existing theory; or (2) the intended application of an alternative theory to explain a phenomenon (Kovács and Spens, 2006). Both departing points, as detailed in Figure 19, begin with deviating real-life observations that in the *first case* consists of anomalies that cannot be explained by previous theoretical knowledge (Dubois and Gadde, 2002; Kirkeby, 1990; Kovács and Spens, 2006). Specifically, the nature and combination of MCS employed in Facility A differed entirely from those of Facility B. Additional elements linked to leadership style and timing of social MCS employed in Facility B were not present in Facility A. As a result, a “creative iterative process” (Lungberg, 2000; Taylor et al., 2002) of “theory matching” or “systemic combining” (Dubois and Gadde, 2002) was initiated; allowing to identify a matching framework that can extend the current theory utilized prior to their observations (Andreewsky and Bourcier, 2000). This use of systemic combining highlighted the link between Facility B’s leadership style to the Empowered Leadership Model and their use of social controls to a more preventive nature; results that appear contingent on the contextual characteristics of the facility. In the *second case*, creative elements can be consciously introduced by applying suitable theories of an already existing phenomenon to the research (Kirkeby, 1990; Kovács and Spens, 2006). This new theory or framework may have borrowed from both the current scientific discipline or from other scientific fields (Kirkeby, 1990; Stock, 1997). This was also carried out in this dissertation through the application of the Ago-Antagonistic Systems Theory borrowed from the Neuro-endocrine physiology discipline to help

explain the nature between Preventive and Detective Controls.

It is important to highlight that within the abductive research process, the empirical data collection phase and the theory-building phase occur simultaneously, thereby creating a “back and forth” direction between theory and empirical study in a learning loop (Dubois and Gadde, 2002; Kovács and Spens, 2006; Lungberg, 2000; Taylor et al., 2002; Wigblad, 2003); as was the case during the 9 Phases of Data Collection and Data Analysis. As a result, the sequence of logic used in abduction research is from *rule to result to case* (Danermark, 2001; Kirkeby, 1990; Peirce, 1932). Abduction is commonly used in both action research (Wigblad, 2003; Naslund, 2002) and case studies (Alvesson and Skoldberg, 1994; Dubois and Gadde, 2002), as this research method and research strategy (Yin, 2003) employs simultaneous data collection and theory development during the theory-building elements (Dubois and Gadde, 2002). The abductive approach aims to understand the new phenomenon (Alvesson and Skoldberg, 1994) and to suggest new theories (Kirkeby, 1990; Peirce, 1934) in the way of new hypothesis or propositions (Andreewsky and Bourcier, 2000).

While induction typically generalizes these hypotheses and propositions and creates new knowledge, abduction only generalizes them after additional empirical studies that corroborate the theory-testing phase (Kovács and Spens, 2006). Therefore, the abductive approach ends with the application of the hypotheses and propositions in an empirical setting (Alvesson and Skoldberg, 1994; Kovács and Spens, 2006; Wigblad, 2003), which can be considered as a deductive part of the research. As a result, abduction has elements of induction (at the beginning) and elements of deduction (at the end of the approach). Particularly as abductive research will derive hypotheses and propositions that may be thereafter verified in a deductive research phase (Kovács and Spens, 2006). Rather than only concentrating on generalizations, the **abductive approach** is interested in the peculiarities of specific situations that deviate from the general circumstances (Danermark, 2001; Kovács and Spens, 2006). According to Kovács and Spens (2006), it is essential to distinguish between situations that are generalizable and those that are specific, as is the case with situational environmental factors. In fact, “*the ability of a researcher to distinguish between general and particular features of a situation will depend on his or her previous experience and cultural setting*” (Kovács and Spens, 2005, p. 138).

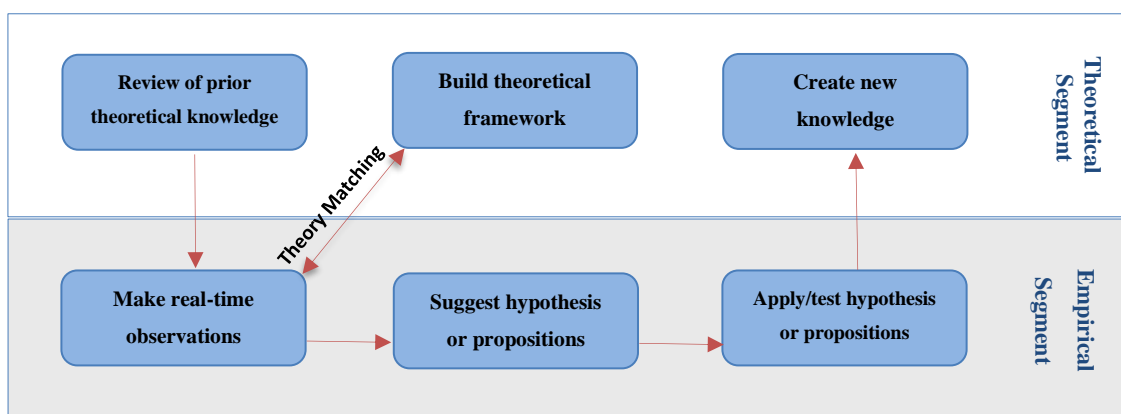


Figure 19. The abductive research process.

With regards to Kovács and Spens (2005 and 2006) proposed Research Process Framework, the **abductive research process**: (a) begins with deviating real-life observations (and not with empirical observations/facts nor with a strong theoretical grounding) (b) aims to understand the new phenomenon and to suggest new theories in the form of new hypotheses and propositions (and not develop or test the theories) and (c) following this research process, hypotheses and propositions are developed *post hoc* based on the empirical research and are only generalized after additional empirical theory testing phases (and not *post hoc* based on a single empirical test or *ex-ante* based on prior observations). Specifically, as detailed in Figure 19 above that compares all of the research approaches, the abductive process may begin with existing theoretical knowledge, although generally begins with deviating empirical observations, turns to the theoretical framework for theory matching, returning back and forth between theory and empirical observations, then suggests the hypotheses or proposals, and applies these conclusions thereby creating new knowledge. As previously described, two methods that use the abductive research process and that are used in this study are the systemic combining and the Model-centered Approach.

1.4. Research Process

As indicated above, a **research process** is the summary of all of the sequential steps that a researcher follows in order to carry out a specific scientific approach (Kovacs and Spens, 2005; Peirce, 1931). This dissertation uses two methods. The first of these two methods is the systemic combining process that is grounded in iterative abduction logic. The second method is the Model-Centered Process, which is used jointly with the first method to generate knowledge through visual representations during the multiple journeys between the empirical and theoretical world. It is important to note that systemic combining makes use of case studies. However, since Case Studies are a research strategy and not a research method (Yin, 2003), the case study is not detailed within this section, but rather can be found under section 2 “Analysis of the System for Model Construction”.

1.4.1. Systemic Combining

Systemic Combining “*is a process where theoretical framework, empirical framework, and case analysis evolve simultaneously, and it is particularly useful for the development of new theories*” (Dubois and Gadde, 2002, p.554). This process was first described by Dubois and Gadde as an “abductive approach to case research”, thereby providing a research method grounded in abduction logic to develop theory through the use of case studies. As detailed in the previous subsection, deduction aims to develop a proposition from current theory in order to test them empirically, while induction relies on ‘grounded theory’ (Glaser and Strauss, 1967) to systematically generate theory from data. Systemic combining resembles more closely to an inductive rather than a deductive approach, as similarly to “grounded theory” it is interested in “*the generation of new concepts and development of theoretical models, rather than confirmation of existing theory*” (Dubois and Gadde, 2002, p.559). Unlike grounded theory that accentuates theory generation, systemic combining stresses theory development and “*builds more on refinement of existing theories than on inventing new ones*” (Dubois and Gadde, 2002, p.559).

This dissertation employs a research approach based on *Systemic Combining* grounded in abductive logic that can be “[characterized by the] continuous movement between an empirical world and a model world” (Dubois and Gadde, 2002, p.554); in a process where the research problem and the analytical framework are continuously reoriented when confronted with the empirical world (Dubois and Gadde, 2002). As a result, the “*theoretical framework, empirical fieldwork, and case analysis evolve simultaneously*” thereby yielding a valuable approach to the development of new theories (Dubois and Gadde, 2002, p.554). The back and forth movement between empirical observations and theory, also allows to both expand the understanding of theory and the empirical phenomena (Dubois and Gadde, 2002). This “*continuous interplay between theory and empirical observation is stressed more heavily [in systemic combining] than in the ‘grounded theory’ approach*” (Dubois and Gadde, 2002, p.559). Systemic combining, as described by Dubois and Gadde (2002) consists of two processes (*matching theory to reality and the direction and redirection to other factors*), that are impacted and impact four main factors (framework, empirical world, theory, and case). The initial analytical *framework* permits to understand the ‘preconceptions’ of the literature, that will later evolve through the analysis and interpretation of the discoveries made in the *empirical world*. This evolving framework then *directs* the scope of the empirical study and expands the *theoretical model*. New empirical observations may yield new insights through the exploration of additional data collection methods. These findings may then *re-direct* and re-expand the recent framework and theoretical model. The resulting evolving framework further evolves when confronted with the evolving *case*. In systemic combining, the confrontation of theory and the empirical world (which is the objective of any research) occur continuously. Figure 20 below illustrates the four factors and two processes of systemic combining.

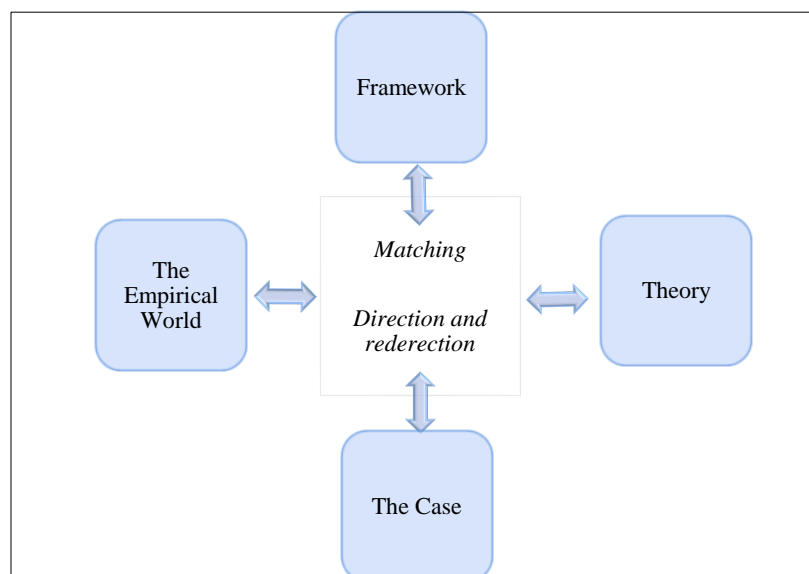


Figure 20. The two processes and four factors of Systemic Combining

Each of the four factors are further described below and where relevant, their application to this dissertation is depicted. Specifically:

Matching, entails the back and forth movement between framework, data sources, and analysis. Both Glaser (1978, p. 4) and Dubois and Gadde, (2002) ascertain “the importance of fit between theory and reality [as] that data should not be forced to fit preconceived or pre-existent categories, [but rather] the categories [should be] developed from data”. Matching of theory and reality does not employ a specific pattern, but rather is unique to the situational context. ¹¹

This dissertation aimed to initially understand the use of MCS by the CEA to mitigate subcontracting risks. The inter-organizational Risk Management Model by Das and Teng (2001) helped to categorize the different management controls, the subcontracting related risks, and which controls mitigate which risks. As a result, this Model served as an initial framework during the first field-immersion at Facility A. The empirical observations could not be completely explained by the initial theoretical framework. Therefore, alternative theories regarding inter-organizational control to complement this initial framework were sought out during the data collection phases at Facility A. Several inter-organizational trust and control models were identified to better explain some of the interdependencies of the control mechanisms observed between the contractors and the subcontractors that had been identified. As a result, the matching of the evolving observations and alternative theories yielded a newly evolved theoretical framework, thus concluding the *matching process*.

Direction and redirection pertain to the movement between the different sources of data and methods of data collection that help the researcher throughout the matching process. - combining employs multiple sources of information, not in an attempt to verify the data, but rather in an attempt to discover or reveal alternative features of the research problem (Dubois and Gadde, 2002). The majority of data collection is based on the scope provided by the current framework; nonetheless, as new finds appear and as the framework evolves the study may be *redirected*.¹²

This dissertation employed numerous sources of information, including: (1) semi-directed interviews of personnel from both the subcontracting and the contracting firm of three Nuclear Facilities, across multiple system levels (CEA Managers, subcontractors and Middle Managers) and across several disciplines (Engineers, Safety Officers, Technicians, etc); (2) technical, management and staff meetings throughout the Nuclear Facilities, including discussions with the participants after the meetings; (3) non-participative

¹¹ According to Eisenhardt (1989, p. 546), theory building from case studies consists of a “*frequent overlap of data analysis with data collection*” as “*creative insights often arise from the juxtaposition of contradictory or paradoxical evidence.... the process of reconciling these contradictions forces individuals to reframe perceptions into a new gestalt*”. Strauss and Corbin (1990) further describe this process as a constant move “*between asking questions, generating hypotheses, and making comparisons*”. As a result, systemic combining can be defined as “*a nonlinear, path-dependent process of combining efforts with the ultimate objective of matching theory and reality*” (Dubois and Gadde, 2002, p.556).

¹² According to Yin (1994, p.92), the use of multiple sources of information allow the researcher to address a wide range of issues from various viewpoints; as the study case findings and conclusion may be “*much more convincing and accurate if it is based on several different sources of information following a corroborative mode.*” As a result, deep probing case studies often combine several sources of data, while moving between analysis and interpretation as is the case with triangulation (Yin, 1994; Denzin, 1978). Triangulation allows the researcher to develop and converge multiple lines of inquiry (Dubois and Gadde, 2002), as researchers are “*self-consciously setting out to collect and double-check findings*” (Huberman and Miles, 1994).

observations of daily activities within the Nuclear Facilities; (4) documents of varying confidentiality including contracts, standard operating procedures, accident and event investigation reports, and other internal documents. The initial sources of information (meetings, observations, documents) provided a foundation for the development of additional questions that were then addressed during follow-up interviews and informal discussions. The results obtained following these discussions further contributed to the development of the framework and facilitated the pursuit of alternative theoretical concepts, and thus a new interpretation of the phenomenon. This was particularly the case with the emergent theme of “leadership” during the data collection phase at Facility B (see section 2.3 of this Chapter for further details). Dubois and Gadde, (2002, p.557) refer to the initial data the researcher “sets out to find” as “passive data” and the data “associated with discovery” as “active data”. As a result, the initial sources of information documents, meetings and observations led to the discovery of “active data”, which was then “passively enquired” during informal conversations and interviews.

Boundaries in the empirical world refers to the delimitation of the research terrain. The task of placing limitations or boundaries in the empirical world is an unusual task as open natural systems such as organizations have no natural boundaries (Dubois and Gadde, 2002). By expanding the initial boundaries, researchers may identify new interdependencies within the structure, thereby possibly generating a fresh understanding of the initial interdependencies. Time may also serve as a boundary, and the expansion of a narrow time frame (as is the case in longitudinal cases) may “provide insight into additional factors that were not initially considered” (Dubois and Gadde, 2002, p.558). As a result, “*the way boundaries are expanded is of major importance because it determines what will be found... therefore, the main issue is to choose among the multitude of dimensions available for expansion in order to make the most out of the case*” (Dubois and Gadde, (2002, p.558).

This dissertation was initially focused on Facility A, but as the initial boundary was expanded to include other Facilities, the scope of the research also evolved and a new focus on leadership and other contingent factors to explain the contrasting observations also developed. The interdependencies between the leadership aspects of the Facilities and the other contingency factors became a pivotal theme that further expanded the empirical and case boundaries. The time boundary of the case studies was initially determined from the start to follow the programmed duration of the thesis.

The role of the framework is an essential concept in the systemic combining process. Miles and Huberman (1994, p.16 and 17) distinguish between two types of frameworks: (1) a tight and pre-structured framework that, due to prior structurization, may “*blind the researcher to important features in the case or cause misreading of local informants’ perceptions*”; and (2) a loose and emergent framework that may lead to “*indiscriminate data collection and data overload*”. The first of these frameworks suggests a deductive study while the second alludes to an inductive study. According to Dubois and Gadde, (2002), the evolving framework is a foundation of systemic combining, and theoretical concepts should be used as a reference to guide the entry into the empirical world (Blumer, 1954), thereby acting as a set of evolving general

guidelines for the researcher (Bryman (1995). Therefore, the researcher must remain “*open to the multitude of meanings that a certain concept can give rise to*” (Dubois and Gadde, 2002, p.558), as these concepts represent the input and the output of the evolutive abductive case study.¹³

As previously described, this research study used an initial inter-organizational risk management framework that evolved throughout the Ph.D., as the empirical data was compared to the theory. This was in part due to unanticipated empirical findings and theoretical insights from other disciplines gained during the research process. Ago-antagonistic models and theories were borrowed from the field of endocrinology and applied to the research, that when reapplied to the empirical data in a back and forth movement, gave rise to an evolutive abductive case study. This approach gave rise to new combinations of concepts and relationships developed by the first convergence of established endocrinological and risk management theoretical models and second by the confrontation of this new interdisciplinary framework with the empirical world. Further details are provided in the data collection and data analysis section of each of the different Immersions (Pilot Study, Facility A, Facility B and Facility E).

The evolving case, in systemic combining, can be seen as a “tool” of the study that is sharpened throughout the research and as a “product” of the study that cannot be planned (Dubois and Gadde, 2002, p.558). Therefore, the design of the case study evolves throughout the study as the tool is “sharpened”, in part through discussions with other researchers. According to Dubois and Gadde (2002, p.558), “*the empirical language should be maintained [during the tool stage of the study, while the] theoretical language should be reserved for the end product. Otherwise, [not only will] the researcher be constrained in terms of their potential contributions to further systemic combining, [but the] reinterpretations will [also prove to be more challenging] for the researcher*”. According to the authors, data can be considered as confusing pieces of a puzzle that when combined with other puzzle pieces, allow a pattern to emerge. When multiple puzzle pieces are observed, the researcher must be selective in determining which puzzle pieces fit this pattern and which fit other patterns. This selection process may yield leftover pieces that fit other puzzles during the tool phase. However, once the case evolves into the product phase, there should be no confusing pieces that remain (Dubois and Gadde, 2002).

This research study benefited from the ongoing input of Dr. Jean-François Vautier and Guillaume Hernandez, the two a Human and Organizational Factors (HOF) Specialists from the Directorate of Nuclear Safety and Security (DSSN) of the CEA that oversaw the research study and contributed greatly to the evolution of the case. Intermittent meetings took place throughout the data collection and analysis phases of the research, to review emergent concepts and to readjust the case both at the tool and the production

¹³ Contrary to Miles and Huberman’s (1994) suggestion that framework is either tight and prestructured or loose and emergent, Dubois and Gadde, (2002) suggest that systemic combining has a “tight and evolving framework”. “*The tightness reflects the degree to which the researcher has articulated his ‘preconceptions’... and [the evolution of the framework] during the study is because empirical observations inspire changes of the view of theory and vice versa. Since there is more than one way in which empirical data and theory can be combined (Burke, 1992), there is always a need to clarify the choices made in the process*” (Dubois and Gadde, 2002, p.558).

stage. The evolution of the case study occurred at several points throughout the research study, notably in the addition of a third Facility (Facility E) that would later yield part of the embedded single case study.

The role of theory, according to Strauss and Corbin (1990), differs in research studies that aim to generate theory compared to those that aim to confirm it. Studies that aim to *confirm theory*, use theory to identify previous studies within the research field and to discover black holes or white spots in it. Theoretical and conceptual frameworks proposed by the theory in confirming studies, assist the researcher in defining important variables, suggesting relationships among them and interpreting the findings (Dubois and Gadde, 2002). In contrast, studies that aim to *generate theory*, as is the case with systemic combining, use theory that develops throughout the research study to discover new ideas, alternative variables and relationships; ensuring that the researcher does not constrain themselves to the original theory (Dubois and Gadde, 2002). According to Strauss and Corbin (1990), the researcher should enter the terrain with only background “technical literature” as extended theoretical knowledge may hinder the research process. In contrast, during Systemic Combining, the researcher is unable to identify all of the literature prior to commencing the study, since the empirical fieldwork occurs simultaneously to the theoretical conceptualization, thereby creating the “need” for theory throughout the entire research process (Dubois and Gadde, 2002).

This research study had extensive use of theory that evolved throughout the study. The initial pilot study allowed familiarity with the technical terms and general workings of the French Nuclear Industry, which highlighted key themes of inter-organizational relationships. As the data was carried out throughout the three Nuclear Facilities, new concepts, variables and relationships were identified in the field which were then compared to the literature yielding a new theoretical direction. Further details of the emergent themes, theoretical evolution and resulting adaptations to the framework are described for each of the four immersions (Pilot Study, Facility A, Facility B and Facility E).

1.4.2. The Model-centered Process

In addition to the systemic combining method, grounded in abductive logic, this dissertation also used a Model-centered approach. In this approach, models are used as an essential representation of the framework that integrates the theory, the empirical world and the case, thereby yielding “*a model [that is] strongly connected to experiments and observations*”. Therefore, the model is further refined through the *matching process* in Systemic Combining which entails the back and forth movement between the framework, data sources, and analysis. Both Glaser (1978, p. 4) and Dubois and Gadde (2002) ascertain “the importance of fit between theory and reality [as the] data should not be forced to fit preconceived or preexistent categories, [but rather] the categories [should be] developed from data”. Matching of theory and reality does not employ a specific pattern, but rather is unique to the situational context.

Pave (1994, p.26) defines a model as “*a symbolic representation of certain aspects of an object or phenomenon of the real world, that is to say, a written expression or formula that follows the rules of the symbolic system [at the origin] of this representation*”. Walliser (1977) in Guarnieri (1995) and Van Wassenhove (2004) provides a broader description of a model as a mental or physical representation of a

real system that can be expressed physically, verbally, graphically or mathematically. According to Walliser (1977) in Van Wassenhove (2004, p.149), any model aims to “*simulate the behaviour of a system according to certain objectives and given means, [thereby] supporting the subject’s knowledge of the object and supporting the subject’s actions on the object.*”

1.4.2.1. Typology and function of Models

Several scholars have provided typologies of models by distinguishing between the different functions of models. Schmidt-Laine and Pave (2002) and Walliser (1997) both propose three types and uses of models (*cognitive, normative, decision-making*), while Walliser (1977) identifies several additional functions (*forecasting, pedagogical, research*). Vassen (2016) further categorizes 20 functions of models into five major functions of models (*to facilitate observation and experimentation; to facilitate an intelligible presentation; to facilitate a theorization; to facilitate mediation between speeches; to facilitate mediation between representation and action*) that overlap with many of the functions detailed by both Schmidt-Laine and Pave (2002) and Walliser (1997). According to Vassen (2016, p.13) the same model can “*simultaneously ensure several of these specific functions [if they are compatible, although conventionally] the same model [generally] performs two or three of these functions, [as the] methodological constraints associated with each function often seem to contradict each other irremediably*”. Each of these models, their functions and their limits are detailed below:

- **A cognitive model** formalizes knowledge and assumptions in a scientific process (Schmidt-Laine and Pave, 2002). Its *cognitive (explanatory or descriptive) function*, allows the model to represent the relationships between the systems’ input and output variables (Walliser, 1977). Cognitive models that are explanatory, highlight the systems’ properties allowing the deduction of other properties (Walliser, 1977 in Van Wassenhove, 2004). However, the biggest issue with cognitive models arises from their flexibility, whereby the models may erroneously adjust to many experimental results. Conversely, numerous models can represent the same data, and should the researcher select an unsuitable model, this may lead to a loss of time during the research process (Schmidt-Laine and Pave, 2002). Examples include graphical models such as flow charts that reflect the structures and procedures of an organization.
- **A normative model**, highlights the fundamental elements of an ideal system (Walliser, 1997), presenting the precise reality of the object and establishing rules for the system (Schmidt-Laine and Pave, 2002). Its *normative (prescriptive, constructive) function*, allows the model to represent the desired relationships between the systems’ input and output variables (Walliser, 1977). However, the use of these models can be delicate as the use of an erroneous model may lead to ineffective and dangerous actions. As a result, these models must adhere to a strict validation process that include careful testing. Once the model has been validated, its use should be limited to solely within the area of validity (Schmidt-Laine and Pave, 2002). Examples include industrial processes for risk mitigation and medical optimization calculations.

- A **decision-making model**, intervenes in the decision-making process by providing several predictions based on the designated scenarios, although the final choice remains with the decision-maker (Schmidt-Laine and Pave, 2002). Its *decision-making (decision, optimization) function*, allows the model to define how to set the control variables in order to achieve the objectives of the output variables, while keeping in view the probable evolution of the external variables (Walliser, 1977). However, this model can only be validated *posteriori*, once the decision has been executed and its effects are discernable (Schmidt-Laine and Pave, 2002). Examples include decision-making models, economic-models and databases that provide information on the results of past actions, thereby providing the decision-maker with the information they require to implement a choice that will change the system (Walliser, 1977 in Van Wassenhove, 2004).
- A **forecast model** infers the future behaviour of a situation based on the knowledge of a system for a given situation (Walliser, 1977 in Van Wassenhove, 2004). Its *simulation or forecasting function*, allows the model to predict how the output variables of the system will evolve, according to the probable evolution of the external variables and the established control variables (Walliser, 1977). Examples include pilot experiments that predict the potential effects of certain changes in an organization.
- A **pedagogical model** serves as a convenient and simple support for the representation of a relatively complex phenomenon (Walliser, 1977).
- A **research model** has a “*heuristic*” function, that supports a systematic exploration of the analysis domain (Walliser, 1977).

1.4.2.2. Presentation of the General Modelling Approach

According to Varenne’s (2016) classification, the models generated throughout this thesis consist of “*models that facilitate intelligible presentation*”, by representing the target object via a mental figure or schema that displays how the concepts interact to facilitate the selection and classification of relevant entities within a domain. Additionally, these models can be classified as explanatory (*cognitive*) models that help to explain the phenomenon by illustrating the fundamental interactive mechanisms.

The Model-centered process employed in this thesis is adapted from Pave (1990, 2006) presented by Guarnieri (1995) and Van Wassenhove (2004). In this approach, **prior knowledge of the phenomenon** of study in conjunction with the purpose of the model allows the researcher to construct a model of the system of study (Guarnieri, 1995). Figure 21 shows an overview of the general Model-centered approach, where the researcher defines the **purpose and the objectives of the model** based on the finalities and needs of the model. The researcher then uses their theoretical **background** in combination with the **observations and measures of the real object or phenomenon** to **analyze the system**. This analysis provides the researcher with a **list of state and action variables, different types of data**, as well as the relationship between such variables. Once these factors are identified, the researcher through a **modelling process** can provide a **conceptual model** of the system. This conceptual model through an **ideal loop** (back and forth movement

between the theory and the fieldwork) is further refined so to yield alternative conceptual models that are tested and redefined. Once the refinement process is completed, a *formal model* is proposed (*Formalization of the Model*). This Formal model is then tested in adjacent settings through a series of *logical and analytical studies* in order to determine its *fit*, and *validity to the adjacent scenarios*. This can be carried out through the use of *selective experimentation*, and *sampling design* including embedded case studies or alternative case studies. By assessing this formal model in the new case study scenario, the researcher is able to observe the phenomenon in a new setting or a repetitive setting to determine if the model is an accurate representation (*interpretation*). And since “one of the main interests of the scientific research is to provide generic results, [it is essential to anchor the model] in a general theoretical framework” (Pavé, 2006, p.6). Additional *data or knowledge* may be identified that will further advance the model. Once the model is finalized, it may be applied in a *simulation* (initial field or a new field) in order to obtain *simulation results*, thereby confirming potential generalized results that build upon the initial theoretical framework. These results, in the form of a *generalized model*, can be used in a *practical application* to accomplish the intended aim of the model.

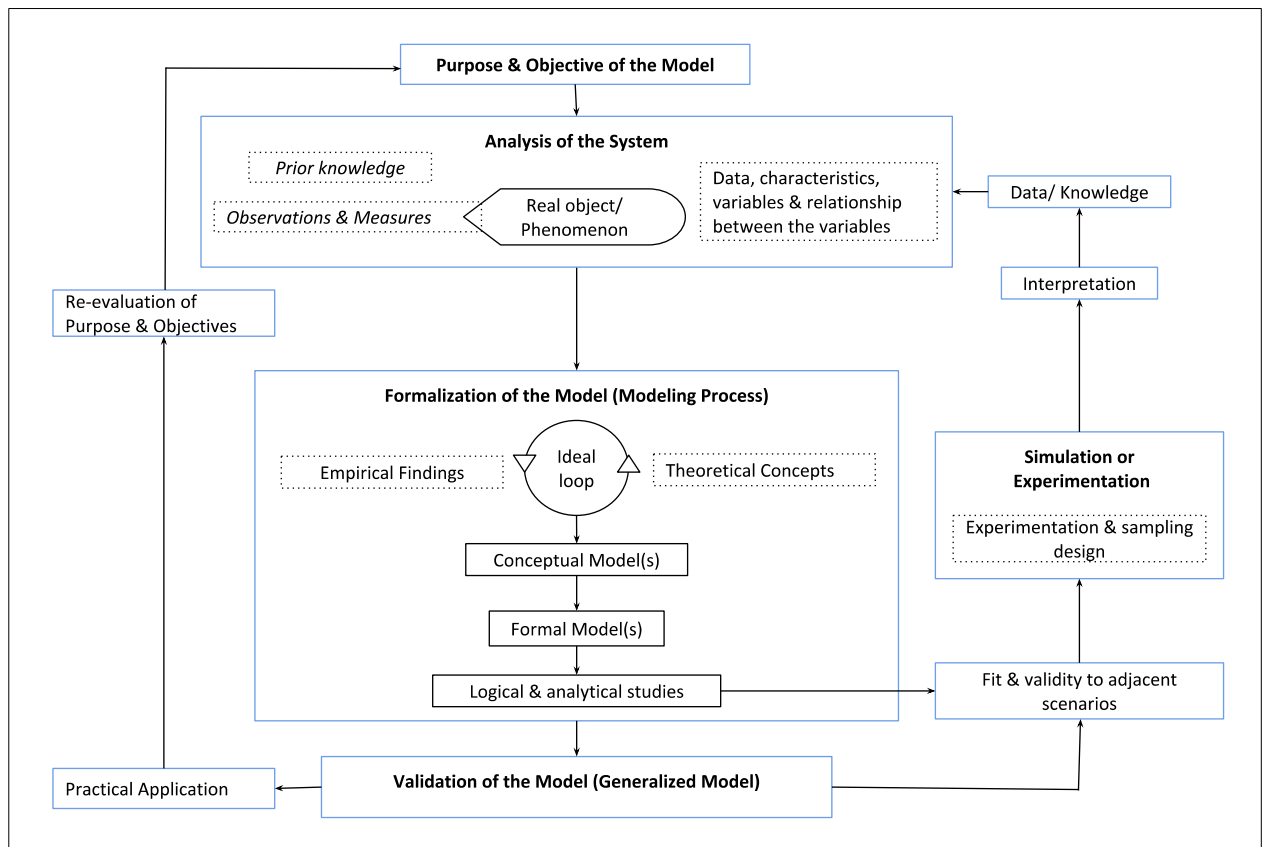


Figure 21. The model centered approach [Adapted from Pavé (1990) in Guarnieri (1995), Pavé (1990) in Van Wassenhove (2004), and Pavé (2006)].

Additionally, as indicated previously, this thesis integrates *Systemic Combining Process* throughout this Medialization process. As a result, the *theoretical framework*, the *empirical framework*, and the *case analysis* evolve simultaneously throughout the entire modelling process to develop the model. *Matching* occurs between the framework, the data sources and the analysis during the analysis of the system and the

formalization of the model thereby *redirecting* the modelling process. Two iterations of the “analysis, formalization and simulation” loop took place to formalize the model: the *first* began at Facility A, and the *second* began at Facility B.

This *first iteration* led to a *conceptual model* that represented the CEA’s use of management controls and trust to prevent and detect subcontracting related risks at Facility A. A decision was taken to not focus on the theme of the inter-organizational trust that emerged in this conceptual model, thus reducing the puzzle pieces, reframing and limiting the *formal model* to Risk and Control. This formal model integrated the theoretical concepts yielding the *formal initial model* following its authentication in Facility A, and its evaluation for fit and validity in the adjacent scenario of Facility B. However, once this model was implemented into this *new empirical framework* (Facility B), the results of the experimentation indicated that this model required *redirection*. Upon re-analyzing the system with the contrasting characteristics of Facility B, new variables were identified and the themes of leadership, balance and the contingent nature of MCS and leadership emerged. These new themes and their relationship to the other variables led to the expansion of the initial model into the *developed model*. As a result, the initial model is enclosed within the developed model.

The *second iteration* began at the expansion of the *developed model* at Facility B, initially with a *conceptual model* that integrated the themes of Control, Risk and Leadership. The expansion of the *theoretical framework* by the integration of additional theoretical concepts (Ago-antagonistic Systems) from other disciplines also further refined the model into a *formal model* that was authenticated at Facility B and then validated as the *formal developed model* at Facility A. This developed model was not invalidated during the Facility E interviews, thereby indicating a potential validity in Facility E. Additionally, the developed model was presented to various CEA Managers from all of the CEA Sites during the CEA’s 2019 HOF Day. The questions and comments indicate a potential validity in other CEA Facilities with a quasi-integration subcontracting style.

The process detailed in Figure 21 denotes the process used in this thesis and consequently the organization of this chapter. Section 2.1 details the purpose and the objectives of the model. Section 2.2. describes the Analysis of the System that occurred during the Pilot Study to determine the case selection. Section 2.3 details the Formalization of the Model during a first iteration beginning at Facility A and a second iteration beginning at Facility B. Section 2.4. describes the authentication and validation of the Model at Facility A and B, as well as the potential validity at Facility E and in other facilities that use quasi-integration. Its practical application will be discussed in Chapter 4.

1.4.2.3. Purpose and Objective of the Research’s Model

This research project is interested in the CEA’s use of MCS to mitigate subcontracting risks in the various CEA Facilities. Specifically, it aims to provide CEA managers with the knowledge and understanding of the current CEA practices used to mitigate subcontracting related risks in order to determine how to design efficient and effective MCS that are tailored for the characteristics of each facility. The CEA’s MCS were

identified, mapped out and defined according to the temporal aspects, the interactions and the role of the actors involved. Through the creation of cognitive models that represent the CEA's use of MCS and leadership styles to mitigate subcontracting risks, the relationship between several contingent variants and the control and leadership style was modelled. These contingent variants include: (1) External environment and information asymmetry; (2) Technology: work processes and interdependencies within and between system levels; (3) Organizational structure/managerial configuration and Systemic Level Interactions; (4) Size and ratio of Middle Managers and CEA managers to subcontractors; (5) Strategies and Methods to Achieve Results and Safety Objectives; (6) Implications of CEA Managers in Promoting Safety Culture. Through the creation of these models, a clearer understanding of the impact of middle managers on safety was identified.

These models employ several of the aforementioned functions, including Varenne's (2016) second, third and fourth major functions. *Firstly*, these models *facilitate intelligible presentation*, by providing a *descriptive and explanatory* schema that displays and explains the MCS, leadership styles used by the CEA Facilities according to the specific contextual parameters or characteristics of each Facility (size, managerial configuration, levels of control, activity). As the models evolved from Facility to Facility, the models illustrated the essential interactive mechanisms and allowed to identify and extrapolate missing concepts (trust, leadership) that were later omitted from and added to the evolving model. *Secondly*, these models *facilitate a theorization* through the use of the automobile analogy to depict the ago-antagonistic nature between preventive and deductive controls and the IAEA's Level of Defense in Depth. *Thirdly*, these models *facilitate mediation between speeches* by allowing a visual representation of the processes to encourage dialogue between actors of this research (CEA, etc.), enabling the co-construction of the system. *Fourthly*, the models also contain a *heuristic function*, similar to a *research model*, that helps identify the systematic exploration of the input and output variables at each of the three facilities explored. This includes the understanding of the type of MCS and leadership used (input variable), and the type of risks that are mitigated (output variable).

2. Analysis of the System for Model Construction

This second section of Chapter 2 presents the method used to analyze the system and determine the characteristics and variables emanating from the analysis of the system such as the flow of communication. These include: the analysis of the empirical setting: The CEA (2.1), the use of Case Studies and Case Selection Strategies for theoretical replication (2.2), the data collection methods (2.3), and the data analysis methods (2.4).

2.1. The empirical Setting: The CEA

The research context is the nuclear energy sector, specifically within the French Alternative Energies and Atomic Energy Commission (CEA). The French Alternative Energies and Atomic Energy Commission (*Commissariat à l'énergie atomique et aux énergies alternatives*) or CEA is a French governmental agency and a public body established in October 1945 by General de Gaulle. The CEA is a leader in research,

development and innovation. It has four main activities, which include: low-carbon energies, defence and security, information technologies and technologies for health across nine research centers/sites spread across France (including Site 1 and Site 2 which are the focus of this dissertation). According to the CEA mission statement, it endeavours: (1) to become the leading technological research organization in Europe and (2) to ensure that the nuclear deterrent remains effective in the future. The CEA has particular status, which classes it as a public establishment of an industrial and commercial aspect also known as EPIC (*Etablissement Public à caractère Industriel et Commercial*). In other words, this is a legal entity for the purpose of running a public service of industrial and commercial activity. Generally, EPIC meets the needs of production and marketing of goods and services that could not be properly carried out by a private business enterprise subject to competition. In addition, EPIC are subject to the obligation to be specialized, limiting their activities to only those public services they are responsible for ensuring.

All of the aforementioned research centres subcontract a percentage of their work to numerous subcontractors, by way of public tender, but the history and the type of subcontracting differs from Facility to Facility and from Site to Site. This dissertation focuses on three Nuclear Facilities that are located on Site 1 (Facility A) and Site 2 (Facility B and E) and that all use a quasi-integration type of subcontracting to carry out a variety of tasks that include:

- reception/dispatch of waste barrels; and storage of waste barrels for Facility A and Facility E;
- reception/dispatch of waste barrels; storage of waste barrels; and treatment/modification of waste for Facility B.

For all three facilities, these aforementioned tasks require additional tasks surrounding the maintenance of the equipment associated with each of the elements of nuclear waste operations. Each of the 24 MCS reviewed in this thesis apply to each of the aforementioned tasks.

These three facilities also have a varied history of subcontracting:

In Facility A on Site 1, the CEA has always been the nuclear operator of the facility and subcontracts a percentage of their work. The contract duration is generally of three years with the possibility of two one-year renewals, for a maximum of five years. After this time, a new call for tender is published and the exiting subcontractor is contractually obligated to train the incoming firm. This training period, referred to as the transition process between two subcontractors, is included in the price of the subcontractors' service and is specified within the contract.

In Facility B and E's on Site 2, the CEA became the nuclear operator of the facilities historically operated by AREVA in 2005. Therefore, the CEA needed to re-learn operating procedures in order to exploit its facilities by way of subcontractors. Initially, the operation remained with AREVA NC, but later on, this reorganization allowed the CEA to on one hand exploit their facilities by way of a competitive tender, thus yielding a more competitive market, but on the other hand, this also increased subcontracting practices and hence potential risks associated with these practices. In 2011, the CEA conceived "The transition process between two subcontractors" to ensure that "knowledge and know-how essential in the operation of a facility be transferred from the outgoing subcontractor [AREVA] to the CEA and then eventually to his

successor. This process was first implemented in 2013 and since then has been implemented in various nuclear facilities. It consists of two hand-over and training periods, one at the beginning and one at the end of the contractual period, each lasting 3 to 6 months. Details of the “transition process between two subcontractors” are stipulated in the contract. At the beginning of the contract, the subcontractor is trained by his predecessor and at the end of the contract, he trains his successor. Prior to the end of the contractual period, lasting 3 to 5 years, a call for public tender is published. The current subcontractor may re-apply but if they do not successfully re-acquire the contract, then they are legally obligated to train the incoming subcontractor. Given the context, it is essential to adequately monitor and control not only the change of contractor process but also the ongoing operations during the entire contractual period.

With both Site 1 and Site 2, the CEA has experienced several drawbacks due to long-term subcontracting and a continual transition process between two subcontractors over a lengthy period of time. These drawbacks include: loss of technical knowledge competencies; loss of control in supervising, as nuclear knowledge and know-how of certain tasks has been directly transferred from one subcontractor to the next. As a result, the CEA has employed a strategic change to re-appropriate such knowledge-base in order to better supervise the subcontractor, using both formal and informal mechanisms of control. This change consists of a period of time during which knowledge is transferred from the previous industrial or technical operator to its successor. It consists of numerous activities, seminars, hands-on training, quizzes and assessments to assure the knowledge has been transmitted and acquired. As a result, the exiting subcontractor finds himself in an unusual situation: contractually forced to train the successor that will take over his job, a successor that he or she did not request. The subcontractor now must bestow all of his knowledge, skills and personal capacities onto his replacement over a short period of time. As a result, effective control measures during the transition process between two subcontractors are of utmost importance to ensure this operation occurs with the utmost efficiency and safety; and to mitigate the possible risk of being met with resistance during this endeavour.

Given the context and the “multifaceted, turbulent and dangerous task environments” of the CEA in addition to its endeavour for “continuous, error-free operations” (Roberts, 1990), it is considered an organization that succeeds in avoiding catastrophes despite a high level of risk and complexity. Their use of subcontractors to carry out a percentage of their work thereby requires a strong element of inter-organizational control.

2.2. Use of a Case Study and Case Selection Strategies

The *pilot study* (Phase 1) that took place over four days from March 14 -18, 2016 at the Safety Support Department at Site 2 of the CEA, was intended to: *firstly*, acclimatize to the institution’s managerial practices and use of language often riddled with acronyms; *secondly*, provide preliminary information regarding the nuclear sector and the CEA in order to analyze the system that makes up the case study; *thirdly*, begin to identify a theoretical framework for the study; *fourthly*, understand the transition process between two subcontractors and of the types of risk and control mechanisms used by the CEA; *fifth*,

understand the different levels of control used in the Facilities of the CEA; and *sixthly*, define the limits of the case study and identify potential units of analysis (the Facilities).

According to Yin (2009, p.18), a *case study* is “an empirical inquiry about a contemporary phenomenon (e.g. a “case”), set within its real-world context – especially when the boundaries between the phenomenon and the context are not clearly evident”. Piekkari et al. (2009, p.569), propose an alternative definition to a case study as “a research strategy that examines, through the use of a variety of data sources, a phenomenon in its naturalistic context with the purpose of ‘confronting’ theory with the empirical world”. The research questions studied within this research are very specific and strongly linked to the context and its backdrop in the nuclear sector. As a result, the case study strategy is appropriate for examining phenomena that are difficult to study outside of their natural setting. According to Stake (1995), Yin (2003; 2009) and Creswell (2007), case studies based on a qualitative research paradigm can be categorized according to the size of the case study (*single-case design* or a *multiple-case design*) and on the number of units of analysis (*holistic subcase with a single-unit of analysis* or *embedded subcases with multiple-units of analysis*). This dissertation consists of a **single case study** that studies the variations within a single organization, the CEA. This single case study can further be classified as an **embedded single case study** as it “involves more than one unit of analysis” (Yin, 2009, p.50). Figure 22 below provides an overview of the single-case study (at the CEA that includes the interactions between the CEA and the subcontractors) containing the three embedded case-study units (Facility A, Facility B and Facility E). Each unit of analysis (each facility) was studied at three levels of analysis: the CEA Managers, the Middle Managers that belong to the subcontracting firm and the subcontractors.

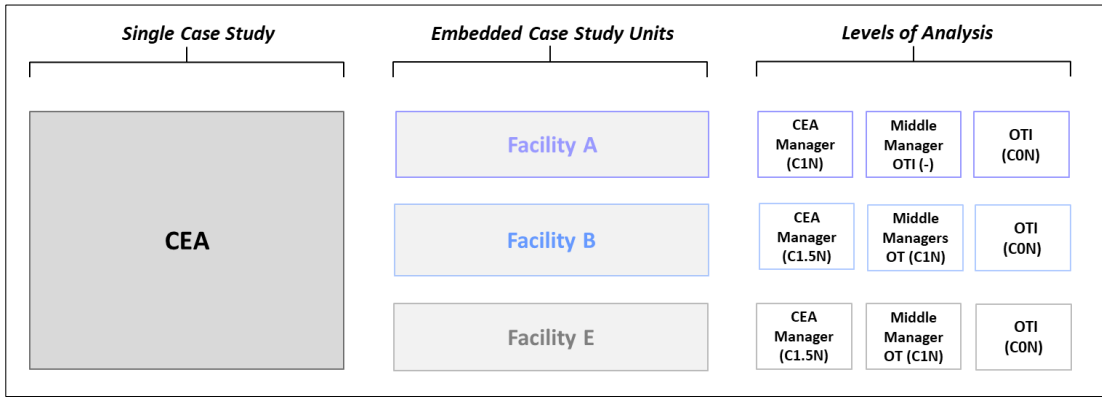


Figure 22. Single case-study at the CEA, with three Embedded Case Units (Facility A, Facility B, and Facility E) each with three levels of analysis (CEA Managers, Middle Managers and Subcontractors).

This dissertation investigates the Management Control Practices of both CEA Managers and Middle Managers at the CEA. The aim of this design was not to compare the levels of analysis between case-study units, but rather to comprehend and analyze the effects of the variations in characteristics of the facilities on their use of MCS. These variations were better understood through the study of a single setting, the CEA, allowing these dependent case-study units to contribute individually to the total case. As a result, the propositions and theoretical constructs in the Models detailed in Chapter 3 originate from an embedded single-case study of the CEA’s Facility A, Facility B and Facility E.

2.2.1. Case Selection Characteristics

The Facilities were selected based on the difference in five characteristics that include: *the size of the facility* (total number of actors), *the managerial presence* (total number of CEA and Middle Managers), *the type of activity* (waste storage or waste treatment/modification), *the managerial configuration* (Middle Management present or not present on-site), and *the levels of control* (1 or 2 levels). Figure 23 provides a summary of the aforementioned characteristics used for case selection in each Facility. Each of these characteristics is self-explanatory with the exception of the levels of control. As a result, we will first establish the difference in levels of control, prior to proceeding to detail the Facilities' other characteristics. Controls that are carried out within the same organization (Middle Managers to subcontractors) are considered *intra-organizational* controls, while those carried out between organizations (CEA to subcontractors) are considered *inter-organizational* controls. These controls are found in the aforementioned figure:

Facility A has *one official level of control within the facility: Level 1 (C1N)* which is carried out by the CEA Managers: Chief and the supporting staff on the subcontractors (*inter-organizational control*).

Facility B and Facility E, both have similar managerial configurations with *two official levels of control within the facility*. This facility is led by an RCI, has a **Level 1 (C1N)** control that is carried out by subcontracting middle management on the subcontractors of their own firm (*intra-organizational control*). Following this initial control, an intermediate **Level 1.5 (C1.5N)** control is carried out by the CEA Managers on the subcontractors (*inter-organizational control*); an equivalent control to the **Level 1 (C1N)** in Facility A.

Each of these facilities has two additional controls. *The first additional control* is a **Level 2 (C2N)** control that is conducted by the Internal Audit Department (“la cellule”) at the Centre level and hence outside of the facility. The cellule conducts both *inter-organizational* (on the subcontractors) and *intra-organizational controls* (on the CEA Managers). *The second additional control* consists of the **Auto-controls** employed by the subcontractors at all three facilities to ensure they carry out the procedures according to the specifications. Given that these auto-controls are carried out by the subcontractors themselves and that they are not considered an official level of control at the CEA, they have thus been labelled “**Level 0 Controls (CON)**”. Figure 23 below details each of these levels of control for each of the three facilities.

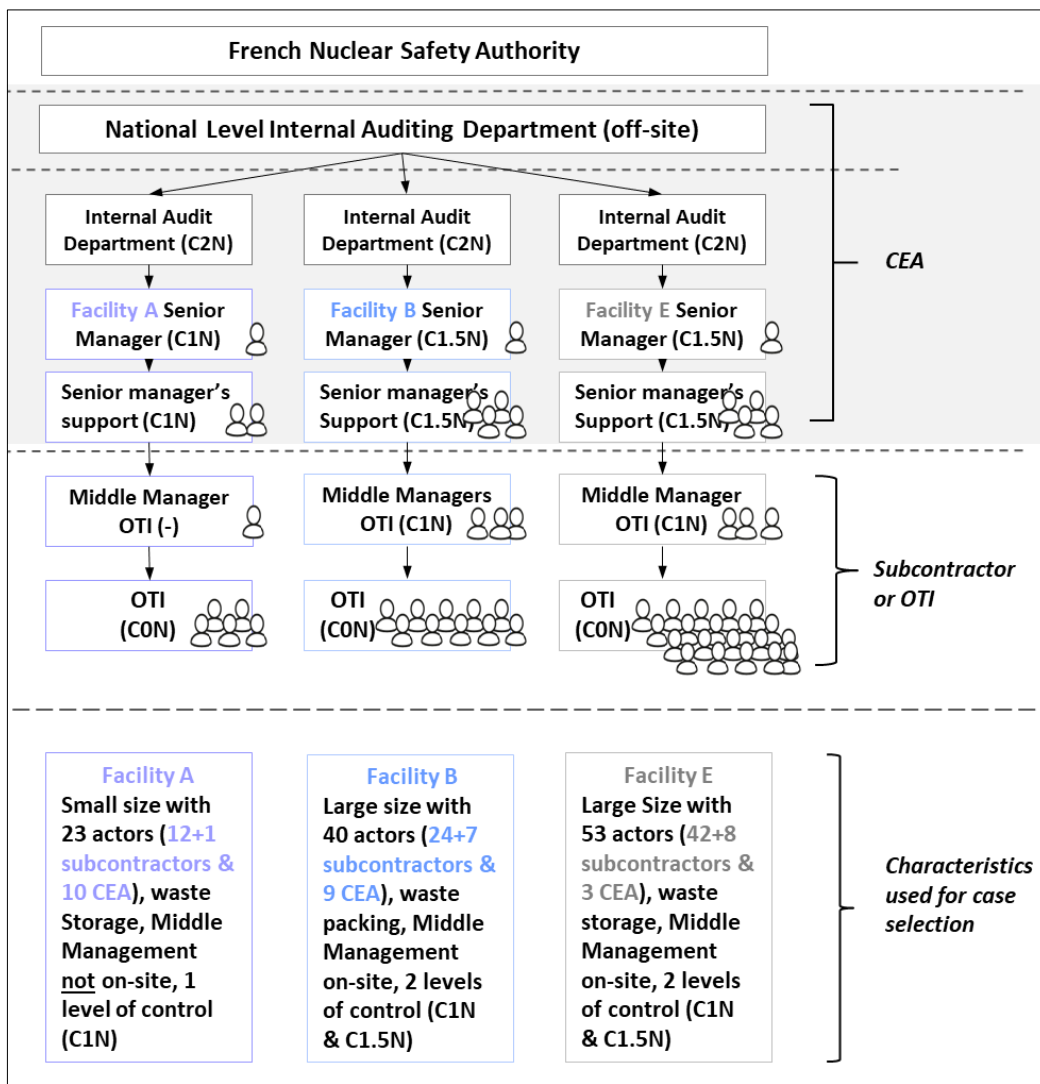


Figure 23. Levels of Control and characteristics of the three Facilities of the CEA (Facility A¹⁴, Facility B, and Facility E).

Initially, Facility A and Facility B were selected as case-study units as they were exact opposites on each of these five aforementioned characteristics. Specifically:

- **Facility A and Facility B** have a difference in *the size of the facility* (a small number of actors vs. a large number of actors), *the managerial presence* (a small number of both CEA and Middle Managers vs a large number of both CEA and Middle Managers), *the type of activity* (waste storage vs waste packaging), *the managerial configuration* (no Middle Manager vs. Middle Manager), and *the levels of control* (1 level vs 2 levels).

Figure 23 demonstrates these differences. As a result, all of the five characteristics could be compared but none could be used as a control. As a result, an additional Facility E was chosen to serve as a control to the

¹⁴ At the time that Facility A was visited (t=0), solely the storage function was observed during this transition process between two subcontractors.

results obtained in comparing Facility A and Facility B, as Facility E shared some of the characteristics with Facility A while at the same time sharing other characteristics with Facility B. Specifically:

- **Facility A and Facility E** both share two characteristics: *the managerial presence* as both have a small number of CEA and Middle Managers and *the type of activity* as both conduct waste storage. As a result, Facility A and Facility E could be compared for *the size of the facility, the managerial configuration* and *the levels of control* (the characteristics that they contrast) while controlling for the *managerial presence* and *the type of activity* (the characteristics they share).
- **Facility B and Facility E** both share three characteristics: *the size of the facility* as both have a large number of actors), *the managerial configuration* as both have Middle Managers on-site, *the levels of control* as both have two levels of control. As a result, Facility B and Facility E could be compared for the *managerial presence* and *the type of activity* (the characteristics that they contrast) while controlling for *the size of the facility, the managerial configuration* and *the levels of control* (the characteristics they share).

Despite being a single-case study, the choice of both similar and opposing characteristics of the three embedded facilities was carried out to mimic the literal replication and theoretical replication often used in multiple case-studies, particularly, as it is the general opinion that the replication in multiple cases provides better explanation than in the case of a single case (Yin, 1994; Eisenhardt, 1989, Miles and Huberman, 1994). As a result, each facility was carefully selected to predict a similar outcome due to shared characteristics similar to *literal replication* and at other times to predict contrasting results due to contrasting characteristics similar to *theoretical replication* (Yin, 2009).

Due to the opposing nature of Facility A and Facility B, a theoretical replication could be carried out for all five characteristics. An ideal situation would have been to find a fourth Facility that has the opposing nature to Facility E, including the same managerial presence (a large number of both CEA and Middle Managers) and that carries out the same type of activity (waste packing) as Facility B, but with the same number of actors (small number), the same levels of control (1 level) and the same managerial configuration (no Middle Manager) as Facility A. This fourth facility, would have provided additional characteristics to control. An alternative would also have been to find other Facilities that replicate Facility A and Facility B providing further insight into these particular combinations of characteristics.

2.3. Data Collection Methods

Cumulatively, *nine phases of data collection* took place over 44 days in a two-and-a-half-year period. Figure 24 below indicates the pilot study (Nuclear Safety and Occupational Safety Support Department in orange), and the case study units that include Facility A in lilac, Facility B in blue and Facility E in grey. Each data collection phase was followed by its data analysis phase, that was completed prior to embarking on the next data collection phase. Table 7 at the end of this subsection details the data collected including the actors interviewed, the relevant findings from the observations and meetings during the nine phases of data collection. Further details of the interviews conducted, the meetings assisted, the observations

conducted, and the interview guide can be found in three tables in Appendix A and in Appendix B. These tables detail the CEA site, the date, the type of meeting or observation, the duration of the interview, the given interviewee code, the role of the interviewee (CEA or subcontractor), their alias, their interview number, and the N-vivo File Name.

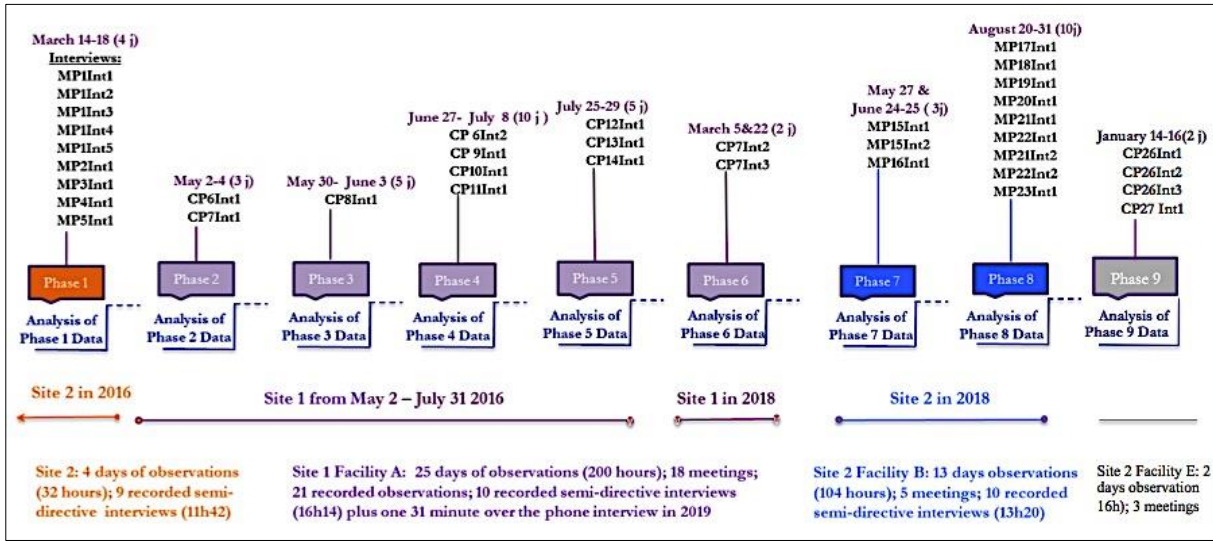


Figure 24. The nine data collection and the nine data analysis phases of the research.

Data for this dissertation were collected from five out of Yin’s (2009) six sources of evidence for a case study (*documentation, archival records, interviews, direct observations, and physical artifact*) omitting the sixth source as *participative observations* were not conducted. Table 5 below provides the general strengths and weaknesses of each of these types of data as per Yin (2009, p. 103-120) as well as a description of the presence of each type of data in this study.

Table 5. Six sources of Evidence Adapted from Yin (2009. P 103-120)

Sources of Evidence	Strengths	Weaknesses	Presence in Study
Documentation	<ul style="list-style-type: none"> Stable -allows for a continuous reveal Unobtrusive- created independently of the case study Exact- contains precise names, references and details of an event Broad coverage of context- numerous events and settings along a span of time 	<ul style="list-style-type: none"> Retrievability- may be difficult to locate Biased selectivity- if the collection is incomplete Reporting bias- reflects (unknown) bias of the author. Access- may be deliberately withheld 	<ul style="list-style-type: none"> Over 80 internal documents, Meeting minutes, online articles, written internal reports provided evidence of the context.
Archival Records	<ul style="list-style-type: none"> (Same as above for documentation) Precise and qualitative 	<ul style="list-style-type: none"> (Same as above for documentation) Accessibility due to privacy issues. 	<ul style="list-style-type: none"> Contracts, 20 ASN Letters and CEA Responses.
Interviews... ...are guided by a line of inquiry	<ul style="list-style-type: none"> Targeted- focus directly on the object of research and case study topic 	<ul style="list-style-type: none"> Bias due to poorly articulated questions 	<ul style="list-style-type: none"> 37 Semi-directed interviews of personnel from several system

<i>linked to the research topic</i>	<ul style="list-style-type: none"> • <i>Insightful- provides perceived causal inferences</i> • <i>Accessibility- multiple means to the actors (telephone, face-to-face, internet)</i> 	<ul style="list-style-type: none"> • <i>Response bias- withholding information</i> • <i>Inaccuracies- poor recall</i> • <i>Reflexivity-interviewer answers that the researcher wants to hear</i> 	levels (subcontractors, Middle Managers, CEA Managers). This accounts for 46 hours and 42 minutes of recorded interviews.
Direct Observations	<ul style="list-style-type: none"> • <i>Reality- provides real-time data</i> • <i>Contextual-covers context of the case</i> 	<ul style="list-style-type: none"> • <i>Time Consuming and Costly- multiple hours needed by human observers</i> • <i>Selectivity- access to the field is not always possible and broad coverage is challenging without a team of observers.</i> • <i>Reflexivity- event may proceed different due to observation</i> 	Access to fieldwork allowed for 44 days (253 hours) of observations. 26 Meetings and 21 recorded observations.
Participant Observations	<ul style="list-style-type: none"> • <i>(Same as above for direct observation)</i> • <i>Insightful into interpersonal behaviour and motives.</i> 	<ul style="list-style-type: none"> • <i>(Same as above for direct observation)</i> • <i>Bias due to participant-observer's presence and subsequent (un)intentional manipulation of the events.</i> 	Not employed due to the potential bias.
Physical artifacts	<ul style="list-style-type: none"> • <i>Insightful into cultural features and technical operations</i> 	<ul style="list-style-type: none"> • <i>Selectivity challenges</i> • <i>Availability issues</i> 	Minor Event Reports detailing control changes.

Over 80 internal **documents**, meeting minutes, online articles, intranet documents, organizational charts, written internal reports, Incident reports and annual reports were obtained during the Pilot Study, and during the immersions at the three facilities. These documents provided additional insight into the industrial context, the details of past events, allowing not only to gain insight of the organization, but also to facilitate the analysis of data that originated from alternative sources. For example, the Standard Operating Procedures (SOP) documents detailing the procedures observed during the observations clarified certain tactical maneuvers such as the stop points and the relay controls. Similarly, the **archival records** such as Facility Contracts, and the 20 ASN Letters and CEA responses also provided insight into the context as well as the monitory controls and infractions in place within the contracts. **Physical artifacts** such as the Minor Event reports for a similar event that took place in Facility A and Facility B provided insight into the cultural features and technical operations at each of the facilities and their potential connection to the Facilities Safety Culture practices.

A total of 37 in-depth, semi-structured **interviews** of 27 personnel were conducted totalling over 46 hours and 42 minutes of recordings. This includes 27 CEA Manager and Support Staff interviews, 5 Middle Manager (OTI) interviews and 5 subcontractor interviews as indicated in Table 6 below. The interview guide is provided in Appendix B. The researcher's access to the field allowed for multiple interviews with

nearly all of the three levels of analysis in order to better assess the implementation practices of MCS in each of the Case Study Units. Access to each of the different position levels (CEA managers, Middle Managers and subcontractors) permitted a different viewpoint of the MCS practices from those actors that were carrying out the controls (CEA and Middle Managers) and the actors that were receiving the controls. Additional spontaneous conversations, not counted within the interviews, were carried out with subcontractors from Facility A and Facility B in order to gain insight into the subcontractors' practices in a more casual setting. The interviews were conducted in French, the interviewees' native language and the official language of the CEA. Welch and Piekkari (2006) emphasize the importance of using the interviewees' native language, as it provides the respondent to produce more authentic answers that exhibit subtler nuances. The duration of the interviews varied and all of the interviews were recorded with 3 exceptions at the request of the interviewees. Overall, the interviews were carried out in a comfortable environment, often their office that allowed the respondents to express their views and opinion openly.

Table 6. Interviews conducted broken-down into the Levels of Analysis.

Pilot Study and Case Study Unit	CEA Managers and Support	Middle Managers (OTI)	Subcontractors (OTI)	TOTAL
(Pilot Study)	9	0	0	9
Facility A	8	0	5	13
Facility B	7	4	0	11
Facility E	3	1	0	4
Total Number	27	5	5	37

A total of 366 hours of *direct non-participatory observations* over 44 days including 23 documented meetings and 21 documented observations were carried out through the nine phases of data collection. The extended immersions at each of the three facilities allowed to observe the participants in their natural context in order to understand the manner that the MCS were carried out and the connection between these controls and other variables (trust, leadership, contingency factors). As the immersion took place all day over several days, this allowed actors of the research to socialize during lunchtimes, organized breakfasts, and coffee breaks providing the opportunity to get to know the personnel on a more social and relaxed atmosphere. The interactions outside the working hours provided insight into how the actors in different position levels interact with one another. Such details provided complementary perception to interpret the data.

Finally, daily reflection notes in a field diary were recorded as suggested by Eisenhardt (1989) while the events were fresh, detailing the data collected on that day, its relation to the data collected during previous data collection phases, as well as new data that could be collected either the following day or in upcoming immersions in order to facilitate its analysis.

Table 7. Key Elements of the 9 phases of the Data Collection Process at Pilot Study, Facility A, B and E

Phase	Dates (duration)	Nuclear Site or Facility	Data collected (n-VIVO file name)	Actors interviewed (n-VIVO file name)	Relevant Observations, Meetings or Interviews (Types of Risk and Control System Observed)
1	2016-03-14 until 2016-03-18 (4 days)	Site 2/ Service S (Pilot Study)	<ul style="list-style-type: none"> 48 internal documents studied, classified and indexed 16 hours and 18 minutes of observations 11 hours and 42 minutes of recorded semi-directed and non-directed interviews 	<ul style="list-style-type: none"> HOF Specialist at Site 2 (2P01Int1, 2P01Int2, 2P01Int3, 2P01Int4, 2P01Int5) Reversibility Project Chief (2P02Int1) RCI of the liquid effluent treatment plant (2P03Int1) RCI of the materials decontamination workshop (2P04Int1) Facility B Chief: solid-waste packaging site (2P05Int1) 	<ul style="list-style-type: none"> Interview 2P02Int1 with Suor: Reversibility Project Chief (<i>the importance of control methods and cartography of Control of Facility A at Site 2</i>) Interview 2P03Int1 with Gotterdamm: RCI of the liquid effluent treatment plant (<i>the paradoxical nature and risks of reversibility</i>) Interview 2P04Int1 with Dardanus: Facility A Chief, a material decontamination workshop (<i>definition of “the transition process between two subcontractors” from CEA documents, its nature and risks</i>)
2	2016-05-02 until 2016-05-04 (3 days)	Site 1/ Facility A	<ul style="list-style-type: none"> 17 hours of observations 4 hours of interviews 3 meetings (1FM-1, 1REV-1, 1FM-2) 	<ul style="list-style-type: none"> Facility A Occupational Safety Engineer (1P06Int1) Facility A Chief (1P07Int1) 	<ul style="list-style-type: none"> Interview 1P06Int1 with Elektra: Facility A Occupational Safety Engineer (<i>Relational Risk and Behaviour Control</i>) Meeting 1FM-2 with Edgar : First Meeting with Facility A Chief (<i>Performance Risk and Output Control</i>)
3	2016-05-30 until 2016-06-03 (5 days)	Site 1/ Facility A	<ul style="list-style-type: none"> 34 hours and 32 minutes of observations (1TO-1, 1TO-2, 1TO-3, 1TO-4, 1TO-5) 28 minutes of interviews 3 meetings (1PRES-1, 1PRES-2, 1REV-2) 	<ul style="list-style-type: none"> Facility A Occupational Safety Assistant (1P08Int1) 	<ul style="list-style-type: none"> Interview 1P08Int1 with Manon: Facility A Occupational Safety Assistant (outsourcer) (<i>Performance, Behavioural, Compliance and Regulatory Risk, and Social Control</i>) Technical Observation 1TO-1 : Lowering and removal of the Tower (<i>Performance Risk and Output Control</i>)
4	2016-06-27 until 2016-07-08 (10 days)	Site 1/ Facility A	<ul style="list-style-type: none"> 67 hours and 16 minutes of observations (1TO-6, 1TO-7, 1TO-8, 1TO-9, 1TO-10, 1TO-11, 1TO-12) 2 hours and 44 minutes of recorded semi-directed and non-directed interviews 9 meetings (1PRES-3, 1REV-3, 1QCM-1, 1QCM-2, 1REV-4, 1COA-1, 1REV-5, 1COA-2, 1LM-1) 	<ul style="list-style-type: none"> Facility A Occupational Safety Engineer (1P06Int2) Technical Correspondent of New Outsourcer at Facility A (1P09Int1) In charge of Facility A's Exploitation Contract (1P10Int1) Facility A Nuclear Safety Engineer (1P11Int1) 	<ul style="list-style-type: none"> Part 1 of Interview 1P10Int1 with Aida: In charge of Facility A's Exploitation Contract (<i>Relational Risk and Behaviour Control</i>) Part 2 of Interview 1P10Int1 with Aida: In charge of Facility A's Exploitation Contract (<i>Relational Risk and Behaviour Control</i>)
5	2016-07-25 until 2016-07-29 (5 days)	Site 1/ Facility A	<ul style="list-style-type: none"> 32 hours and 50 minutes of observations (1TO-13, 1TO-14, 1TO-15, 1TO-16) 2 hours and 13 minutes of recorded semi-directed and non-directed interviews 3 meetings (1CM-1, 1TM-1, 1COA-3) 	<ul style="list-style-type: none"> TQRP of Exiting Outsourcer (1P12Int1) TQRP of New Outsourcer (1P13Int1) Replacement of Facility A Occupational Safety Assistant (outsourcer) (1P14Int1) 	<ul style="list-style-type: none"> Technical Observation 1TO-14: 1st level (TQRP) and 2nd level (SPR) control of radioactivity on the uniforms (<i>Performance Risk and Output Control</i>) Interview 1P12Int1 with Amadis: TQRP of Exiting Outsourcer (<i>New Potential Risks Identified</i>)

6	2018-03-05 and 2018-03-22 (2 days)	Site 1/ Facility A	<ul style="list-style-type: none"> 6 hours and 52 minutes of recorded semi-directed and non-directed interviews 	<ul style="list-style-type: none"> First Facility A Manager (1P07Int2, 1P07Int3) 	<ul style="list-style-type: none"> Validation of the initial model from Facility A detailing preventive and detective controls contrasted with the levels from Defence in Depth and French Legal texts Identification of Contingency Factors influencing the use of Control Mechanisms
7	2018-05-27, 2018-06-24 and 2018-06-25 (3 days)	Site 2/ Facility B	<ul style="list-style-type: none"> 15 hours of observations 5 hours and 20 minutes of recorded semi-directed and non-directed interviews 	<ul style="list-style-type: none"> Second Facility B Manager (2P15Int1, 2P15Int2) Facility B QSE Support (2P16Int1) 	<ul style="list-style-type: none"> Presentation of the “Initial MCS Model” from Facility A, using a Driving analogy to describe the detective and preventive controls.
8	2018-08-20 until 2018-08-31 (10 days)	Site 2/ Facility B	<ul style="list-style-type: none"> 61 hours of observations (2TO-17, 2TO-18, 2TO-19, 2TO-20, 2TO-21) 9 hours of recorded semi-directed and non-directed interviews 5 meetings (2APR-1, 2COA-4, 2COA-5, 2COA-6, 2COA-7) 	<ul style="list-style-type: none"> Facility B Production Manager (2P17Int1) Facility B Health and Safety Animator (2P18Int1) Facility B Nuclear Safety Engineer (2P19Int1) Facility B Deputy Facility Manager (2P20Int1) HOF Site Specialist 2 (2P21Int1) HOF Site Specialist 3 (2P22Int1) Facility B Quality Manager (2P23Int1) Facility B Quality and Environment Manager (2P24Int1) 	<ul style="list-style-type: none"> Identification of 5 additional MCS (present in Facility A but not observed due to the timing of the transition process between two subcontractors) Coupling of MCS into a Package during the Co-activity Meetings in a Morning Daily Ritual Description of the cycle of control and timing of the controls Identification of Empowerment Leadership Factors through Middle Managers’ implication and link to contingency factors Identification of Ago-antagonistic Forces between Detective and Preventive Controls
6*	2019-01-03		<ul style="list-style-type: none"> Telephone Interview (31 minutes) with the Second Facility A Manager (1P25Int1) 		<ul style="list-style-type: none"> Validation by Facility A Manager of the 5 additional MCS found in the “Refined Facility B Model” Validation by Facility A Manager of the Facility B Model with Leadership, ago-antagonistic and contingency factors Presentation of the “Developed MCS and Leadership Model” from Facility B, using a Driving analogy to describe the leadership, preventive, and detective controls by a clutch, brake and accelerator.
9	2019-01-14 until 2019-01-15 (2 days)	Site 2/ Facility E	<ul style="list-style-type: none"> 11 hours of observations 3 hours and 15 minutes of recorded semi-directed and non-directed interviews 3 meetings (2COA-8, 2PRES-4, 2-PRES-5) 	<ul style="list-style-type: none"> Facility E Nuclear Safety Engineer (1P26Int1, 1P26Int2, 1P26Int3) 	<ul style="list-style-type: none"> Re-evaluation and Validation of the “Refined Facility B Model”
9*	2019-09-25		<ul style="list-style-type: none"> Telephone Interview (42 minutes) with the Facility E Production Manager (1P27Int1) 		<ul style="list-style-type: none"> Creation of an internal electronic form (software tool) that allows all subcontractors to provide abnormal findings, which are then reviewed by 3 Middle Managers to determine if it will be escalated to the CEA Managers.
TOTAL			<ul style="list-style-type: none"> 44 days in a 3-year period 3 Facilities and 1 Service in 2 Sites 		<ul style="list-style-type: none"> 37 interviews, 46 hours and 42 minutes of recorded semi-directed and non-directed interviews 26 meetings and 21 recorded observations or 253 hours of observations

2.4. Data Analysis Methods

Theoretical propositions and constructs emerged following nine phases of empirical data collected, separated by a period of analysis during which there was “*constant movement back and forth between theory and empirical data*” (Wodak, 2004, p.200). This iterative approach was used to make sense of the observations (Dubois and Gadde, 2002; Dumez, 2016) by creating a learning loop (Taylor et al., 2002), typical of *abductive reasoning*. During this iterative back and forth aspect, the empirical data collection and theory building occur simultaneously, which accentuates the exploration for suitable theories to “match” an empirical observation; a process that Dubois and Gadde (2002; 2014) refer to as “theory matching”, or “systemic combining”. According to Dubois and Gadde (2002), systemic combining is an abductive approach where the researcher’s comprehension of the phenomenon develops as the empirical data are observed against the intermediate conceptual models. Theory building or development from case studies has numerous strengths including testability and empirical validity given its close linkage to empirical evidence (Eisenhardt, 1989b; Eisenhardt and Graebner, 2007; Siggelkow, 2007) given that it is “*derived from data, systematically gathered and analyzed through the research process*” (Strauss and Corbin, 1990:12). This dissertation is concerned with theory development or refinement, that occurred during the data analysis phases where the empirical evidence and the theoretical concepts facilitated the construction of these intermediate models (initial model and developed model).

The data obtained in-situ from the nine data collection phases coded, analyzed and deconstructed with n-VIVO qualitative data analysis software to identify subcontracting risks, control mechanisms and other elements present in the three nuclear facilities in order to analyze their interaction. Each interview was transcribed in French in its entirety and identified with an n-VIVO File code that was comprised of the CEA Site, the person code, and the interview number. Meeting, observation and the daily reflection notes in the field diary were written in English and identified with their individual n-VIVO File code. N-VIVO, a qualitative analysis software facilitated the identification, grouping and comparison of the data. Data was coded in English, the language of the research, the dissertation and the literature, while important interview passages were later translated in English. Content analysis was conducted using open and axial coding (Strauss and Corbin, 1998), whereby text passages sentence by sentence are attributed keywords and then are categorized by themes and primary patterns in the data (Ayache and Dumez, 2011). This allowed to remain open to new theoretical insight and perspectives, as data should not be forced into pre-determined categories, allowing new categories to develop from the data (Glaser, 1978). The emerging themes were then contrasted with themes from previous theoretical frameworks, in line with the systemic combining approach (Dubois and Gadde, 2002) and pattern-matching (Yin, 2009). Figure 25 below presents a coding example of a passage concerning the Co-activity Meetings in Facility A.

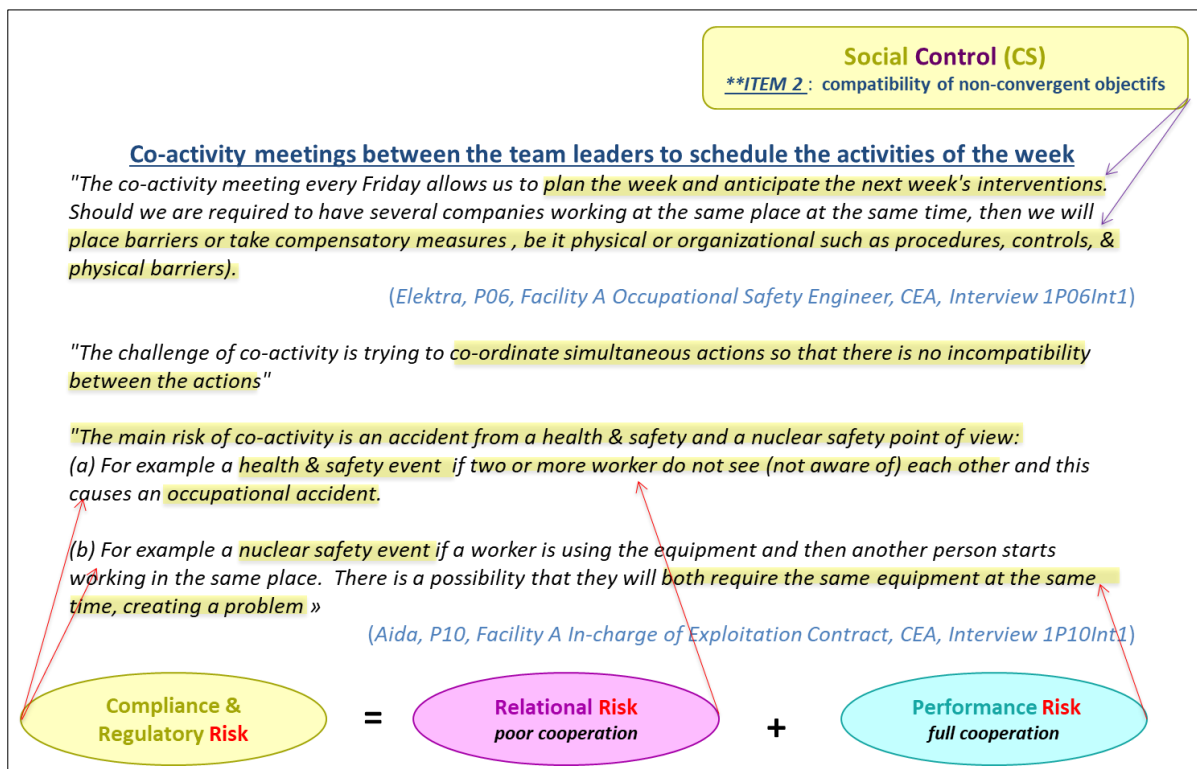


Figure 25. Coding example concerning a Co-activity meeting.

The coding process allowed several new categories to emerge including “Trust” from Facility A data and “leadership” from Facility B data. New theoretical frameworks were introduced at different Phases of the Data Analysis, to analyze the new categories and to build the intermediate models. For example, following Phase 2-6 at Facility A, the Defense in Depth framework aggregated the data yielding the *initial model*. Similarly, following Phase 7-8 at Facility B, the Empowerment Leadership Model and Ago-antagonistic systems provided insight into the contingency factors and helped to build the analysis across the case-study units (Facility A, Facility B) from multiple levels of analysis perspectives (CEA Managers, Middle Managers and subcontractors) for the *developed model*.

The development of a model from data, in the form of charts, diagrams and general findings, was discussed with discussed and verified with the Facility Managers (Lincoln and Guba, 1985). Additionally, the models were reviewed on an ongoing basis by Dr. Jean-François Vautier and Guillaume Hernandez, the two a Human and Organizational Factors (HOF) Specialists from the Directorate of Nuclear Safety and Security (DSSN) of the CEA. They oversaw the research study, contributed greatly to the evolution of the case theory development and decreased researcher bias. Such exchanges also allowed for the emergence of driving analogies that complement each of the models. These analogies provided a means to communicate new concepts to the actors at the facilities allowing them to guide perceptions and interpretation of reality (Cornelissen, 2005) thus making sense of the underlying themes and conversely express their views using these analogies. Further information on these elements of the Formalized Model is detailed in the next section.

3. Formalization of the model

This third section of Chapter 2 presents the formalization of the model in two sub-sections. The first subsection details the formalization of the *initial model* that emerged from the data collected from the Pilot Study (Phase 1) and the immersion at Facility A (Phases 2-5, Phase 6). This section also details the emergent themes and the theoretical concepts that contributed to the *Modelization of the Initial MCS and Risk Model*, and the automotive driving analogy that complements this initial model. The second subsection details the formalization of the *developed model* that emerged from the expansion of the initial model with the data collected at the immersion at Facility B (Phases 7-8), the emergent themes and theoretical concepts that contributed to the modelization of the developed MCS, Risk and Leadership Model, as well as to the creation of the Ago-antagonistic driving analogy that complements this model. Figure 26 below provides an overview of the themes and theoretical concepts of each of these models. The authentication and validation of each of these models are discussed in Section 4 of this chapter.

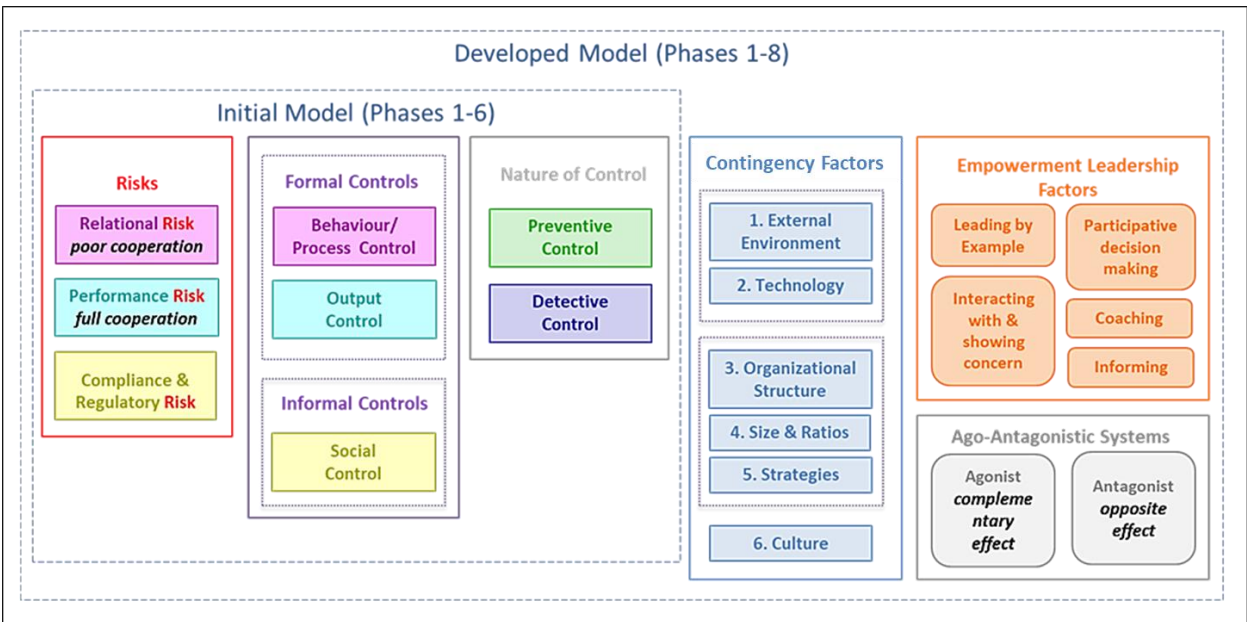


Figure 26. Stages in the formalization of the Initial Model (Phase 1-6) and the Developed Model (Phase 1-8).

3.1. Formalization of the Initial Model at Facility A

3.1.1. Immersion at Facility A

Facility A is a "Packaging and Radioactive Waste Storage Facility¹⁵" equipped with handling and high-performance surveillance systems at Site 1. Facility A replaces another facility, which was built in the 1960s. Facility A benefits from the feed-back and the operating experience of another facility thus incorporating the latest technological advances in storage. Facility A contains two types of warehouses:

¹⁵ At the time that Facility A was visited (t=0), solely the storage function was observed during this transition process between two subcontractors.

a warehouse that stores Long lived Radioactive Waste Low Radiation Level Packages (up to up to 2 mGy/h) deposited in 4 levels on the floor of the hall; and a warehouse that stores Long lived Radioactive Waste Intermediate Radiation Level Packages (up to up to 3 Gy/h) that are stored in a sealed alveolus. The buildings are built to be able to withstand an earthquake. The waste packages are stored provisionally until they are shipped to a national storage site, that at the time of writing this thesis, has yet to be defined and is currently under review. This facility underwent the transition process between two subcontractors during the months of May, June and July of 2016 (Phase 2-5) during which observations and interviews were held and during which the first Facility A Manager (P07) was in charge. Facility A has had two Facility Managers during the duration of this research project: Edgar (P07) the “First Facility A Manager” from 2015 – 2017 (Phase 2-5, Phase 6) and Rossini (P24) the “Second Facility B Manager” thereafter (Phase 6*).

The *immersion at Facility A* was carried out in three main segments (Phase 2-5, Phase 6, and Phase 6*). An initial 23 days immersion over a three month period during 4 data collection phases (Phase 2 to phase 5) allowed the creation of the initial model, followed by an additional fifth data collection phase with the First Facility A manager which would take place nearly 2 years later (Phase 6) to authenticate the proposed initial model that included preventive and detective MCS, and then finally a sixth data collection phase six months after that (Phase 6*) at the end of the Facility B immersion (Phase 7-8) to validate the proposed developed model that showed the ago-antagonistic relationship between leadership and the preventive and detective MCS. The last of these segments (Phase 6*) will be discussed in Section 4 of this chapter (Validation of the Model).

3.1.2. Emergent Themes from Phases 2-5 and Phase 6

Following the data analysis of phases 2-5, complemented by the analysis from the Pilot Study (Phase 1) using a systemic combining approach, several *themes emerged*. Certain themes confirmed the initial results from the literature review (*typologies of risk and control*), while other new themes emerged notably *trust* and particularly *inter-organizational trust* yielding the creation of an *initial risk, control and trust model* detailed in the conceptual model in Figure 27 below. However, following the identification of the trust “puzzle pieces”, a decision was made to reframe the *conceptual model* without the use of the trust concept. Another theme of *prevention* and *detection* also emerged that was later incorporated into the *formal initial model* from the integration of the theoretical concepts detailed below.

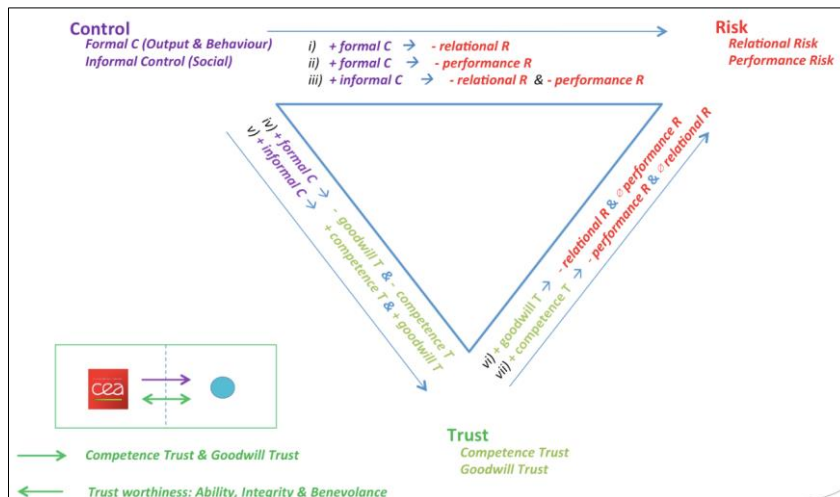


Figure 27. Conceptual model from Phases 2-5 at Facility A, detailing the emergent themes of risk, control and trust.

3.1.3. Theoretical Concepts that contributed to the Initial Model (Phases 1-6)

Having omitted trust, all of the 23 (18+5) control and risk couplings observed at Facility A were analyzed *using two theoretical concepts*: (1) *INSAG-10 Defense in Depth in Nuclear Safety* from the IAEA and the *Decree from February 7, 2012, general rules for Nuclear Facilities*, and (2) *Chiapello's (1995) and Dambrin's (2005) Dimension's of Organizational Control*.

Upon inspection of the *INSAG 10* and the *Decree from February 7, 2012*, it was apparent that both of these texts detail the safety framework to be respected by nuclear operators and the levels of defence. This research study is interested in these first 2 levels of each (in grey) in Figure 28 below -The incident portion– before the accident occurs. The *first* level focuses on the *prevention of incidents*, while the *second* level focuses on the *detection of incidents*. As a result, each control-risk coupling was analyzed through this emerged *preventive and detective* theme.

INSAG-10 Defence in Depth in Nuclear Safety, IAEA: levels of defence.

Levels of Control				
1 st level	2 nd level	3 rd level	4 th level	5 th level
Prevention of abnormal operation	Control of abnormal operation and detection of failures	Control of accidents within the design basis	Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Mitigation of radiological consequences of significant releases of radioactive materials

Decree from February 7 2012, general rules for Nuclear Installations

Levels of Control				
1 st level	2 nd level	3 rd level	4 th level	5 th level
Prevent incidents	Detect incidents and implement actions allowing, on the one hand, to prevent them from leading to an accident and, on the other hand, to restore a normal operating situation. Should this fail, then maintain the installation in a safe state	Control accidents that could not be avoided. Should this fail, then limit their aggravation, by regaining control of the installation in order to bring it back and keep it in a safe state.	Manage uncontrollable situations so as to limit the consequences, in particular for people and the environment.	

Figure 28. Levels of Control from INSAG-10 Defense in Depth and France's Decree from February 7, 2012.

Each control was categorized according to the 12 Dimensions of Control that included four of six Chiapello’s (1996) dimensions of control (*attitude of the person being controlled, and control process were omitted*) and Dambrin’s (2005) two dimensions of control. The controls were then re-grouped by the type of control (Social Control, Behaviour Control and Output Control) and were detailed in each of the three facilities. Figure 29 below details each of the dimensions of control including the link between the type of control and the risks it mitigates. A definition of preventive and detective controls at the CEA is proposed in section 2 of Chapter 3.

Twelve Dimensions of Control	
Medium: <i>What is controlled and how? (tools, special procedures)</i>	[Subject and means of the control from Chiapello (1996)]
Location: <i>Where? (Office / field)</i>	
Frequency: <i>How often? (frequency of control)</i>	
Timing: <i>When are the controls performed with reference to the task?</i>	[Time of controls from Chiapello (1996)]
Human Resource: <i>Who controls? (only one person, one team)</i>	[Controller’s identity from Chiapello (1996)]
Direction: <i>Is the control descending, ascending or lateral?</i>	[Direction of control from Dambrin (2005)]
Technical Resource: <i>What technical resources are used to control?</i>	[Instrument of control from Dambrin (2005)]
Type or Nature of Control: <i>Prevention or Detection of which task?</i>	
Why the control: <i>What are we trying to avoid? What risk? (RNC, RR or RP, other?)</i>	
Effectiveness of the control: <i>Does it limit the risk? How efficient is the control in mitigating the risk?</i>	
Improvements Proposed: <i>What resources (human, technical, and budgetary) are missing to resolve the limits of current control?</i>	
In reference to other risks and controls: <i>Is there a second or third risk that is avoided with this control? How is this control linked to the other risks? Is this control linked to the other two controls?</i>	

Figure 29. Categorization of a Task according to its Twelve Dimensions of Control.

3.1.4. Modelization of the Initial MCS and Risk Model and Complementary MCS Analogy

Following the systemic combining process that reframed and refined the model, several elements of the initial model emerged: *firstly* the capacity of social controls to mitigate all three subcontracting related risks, *secondly* the link between the nature of control (preventive or detective) and the type of control (social, behavioural or output) as certain controls can be both preventive and detective, *thirdly* the link between the type of control (preventive or detective) and the timing of the control (before, during and after the event), *fourthly* the cyclical nature of all controls, with social controls as the Alpha and the Omega (beginning and the end of the control loop), and *fifthly* the temporal aspects of adverting an event. Each of these elements of the Initial Model are detailed in the models found in Section 1 of Chapter 3 (risk and control couples) and in Section 2 of Chapter 3 (preventive and detective controls). In order to present each of these elements of the model to the actors at the CEA, an automotive driving analogy of the MCS model was developed with the help of Jean-Francois Vautier, a Human and Organizational Factors (HOF) Specialist at the CEA. This analogy given in Figure 30 below provides a complement to the initial model describing the automotive experience in terms of the exploitation and support activities and categorizing each of the controls (preventive, detective, social, behavioural or output controls) in terms of their timing and the person performing the control. For example, preventive controls are performed by the driver while detective controls are performed by another actor. Learning

the rules of the road and driving lessons are all carried out by the driver (preventive controls) and take place before the action (driving) thereby being considered social control (CS). Driving the car and taking the driving exam occur during the action and can both be categorized as behaviour/process control (CC), however the first is carried out by the driver (preventive) while the second is carried out by an examiner (detective). A garage tune-up and a technical CO2 inspection are performed by someone other than the driver (detective control) after the action (driving) and are both a type of output control (CR).

These elements allow the actors to identify these concepts with their everyday driving tasks including the prevention of relational, performance and compliance and regulatory risks. The analogy also provided an illustration of each of the five elements detailed above that emerged in the original MCS Model. This analogy was also presented at the beginning of each immersion in both Facility B and Facility E.

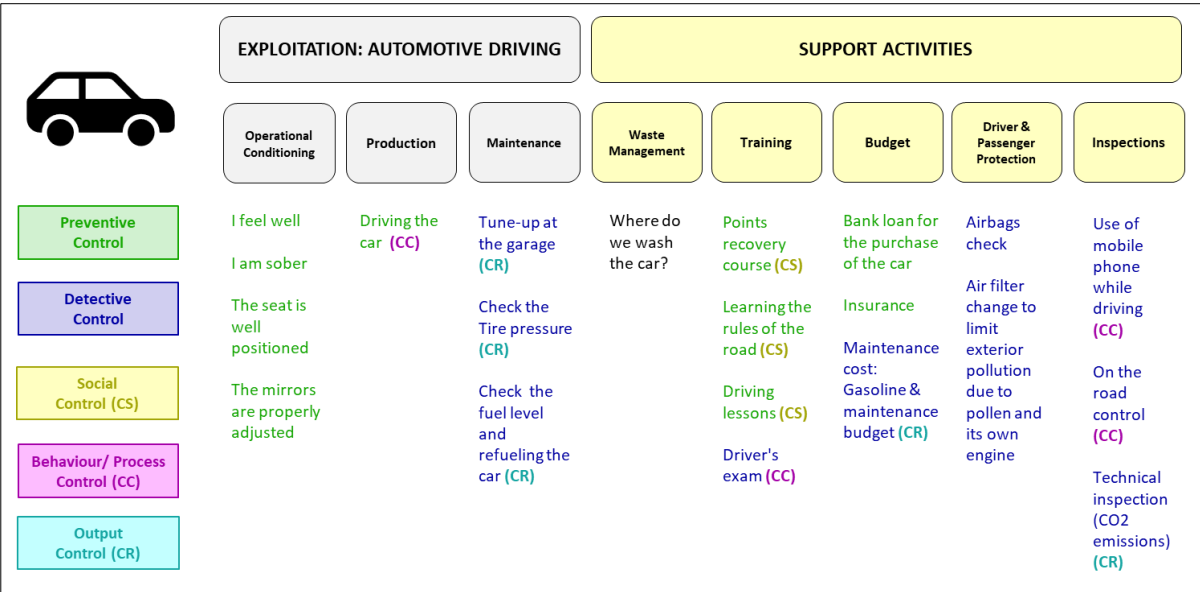


Figure 30. MCS Analogy: Controls during Automotive Driving Activities (as a complement to the Initial (Facility A) Model).

3.2. Formalization of the Developed Model from Facility B

3.2.1. Immersion at Facility B

Facility B is a “Solid Radioactive Waste Packaging Facility” that specializes in the treatment of nuclear waste at Site 2. It was commissioned in 1961 and was created to condition low activity radioactive waste collectively produced from all of the Site 2 facilities. This facility has been modernized and adapted in the early 1990s to meet the new norms set by the National Agency for the Management of Radioactive Waste (ANDRA). The facility is managed by the CEA and underwent the transition process between two subcontractors prior to the commencement of this research project beginning on the 1st of October 2015. Facility B has had two Facility Managers during the duration of this research project: Boris (P05), the “First Facility B Manager” from 2015-2017 (Pilot Study during Phase 1) and Gutterdamm (P03 and P15), the “Second Facility B Manager” thereafter (Phase 7-8). Gutterdamm (P03) was interviewed

during the Pilot Study in his position as Health and Safety Manager of Safety Support Department (Phase 1), thereafter he was given a new code (P15) as Facility B Manager (Phase 7-8).

The *immersion at Facility B* was carried out over two segments (Phase 7, Phase 8). An initial 3-day immersion (Phase 7) allowed to gain insight into this new Facility and to present the aim of the study as well as the *initial model* from Facility A and its complementary driving analogy. A second 10-day immersion (Phase 8) allowed to identify new themes and mechanisms that would contribute to the *developed model*.

3.2.2. Emergent Themes from Phases 7-8

Following the data analysis of phases 7-8 using the systemic combining approach, complemented by the analysis from the Pilot Study and Facility A (Phase 1-6), several new *themes emerged*. This includes the theme of *leadership, balance, and contingent nature of MCS and leadership on the Facility's contingency factors*. These new concepts that emerged from Facility B, in combination with the integration of the theoretical concepts detailed below, constitute a key reframing and refinement factor of the *developed model*.

3.2.3. Theoretical Concepts that contributed to the Developed Model (Phases 1-8)

The emergence of leadership at the two system levels of control (Middle Manager and CEA Manager) was analyzed using *two theoretical concepts*: (1) Arnold *et al.*, 's (2000) *Empowerment Leadership Model (ELM)* and (2) Bernard-Weil's (1978) *Ago-antagonistic Systems (AAS)* which are based on *Systems Thinking*.

The **ELM** distinguishes five dimensions of empowering leaders (*leading by example, coaching, informing, participative decision making, showing concern and interacting*) and has been shown to embrace leadership behaviours especially relevant for nuclear power plants (Martinez-Corcoles *et al.*, 2011; 2012; 2013). As a result, each control throughout the control cycle from Facility A and Facility B was analyzed in terms of the five dimensions of ELM. The Control Cycle, presented in subsection 2.6 of Chapter 3, shows how each of the controls interact with each other in a cyclical manner.

The French Endocrinologist E. Bernard-Weil (1978) formalized **AAS**, during his work on adrenal-post-pituitary interrelations to analyze couples whose forces have both “opposite, *antagonistic effects*” and “parallel positive, *agonistic effects*”, which are inseparable for the understanding of the phenomenon (Bernard-Weil, 2003). This theoretical concept allowed to illustrate how CEA Managers mitigate risk through ago-antagonistic couples, by considering the forces of preventive and detective controls collectively rather than separately. This approach incites managers to balance ago-antagonistic tensions between prevention and detection controls by learning to identify when agonistic-antagonistic unbalances have occurred. Further details of the developed model are provided in Section 2.4 of Chapter 3.

3.2.4. Modelization of the Developed MCS, Risk and Leadership Model and Complementary Ago-antagonistic Analogy

Following the emergence of new themes in Facility B and the integration of additional theoretical concepts, the initial model developed in Facility A was reframed and refined a developed model. Additionally, several changes in the use of MCS in Facility B (compared to Facility A) to increase safety culture were linked to the five dimensions of the ELM. The developed model had several new elements, notably: *first* the link between leadership and interactive nature of social controls, *second* the impact leadership in the cycle of control, *third* the link between the 5 dimensions of the ELM and each type of control, *fourth* the identification of ago-antagonistic forces between preventive and detective controls, *fifth* the impact of the facility's contingency factors (environment, technology, organizational configuration, size, strategy and culture) on the control and leadership style used by managers. Each of these elements are detailed in the developed models found in section 3 of Chapter 3.

This research proposes a new approach to risk management, based on "Systems Thinking", that applies the principles of safety leadership to develop and overcome the limits of MCS. It combines a systems approach to MCS with a systems approach to safety leadership, through an Ago-Antagonist model to balance the types of control. In order to explain these new ago-antagonistic forces in the developed model, an automotive driving analogy was used that explained how a car, as an Ago-antagonistic System (AAS), balances its brake and accelerator. This analogy provided in Figure 31 below also details an analogy for the clutch of the car.

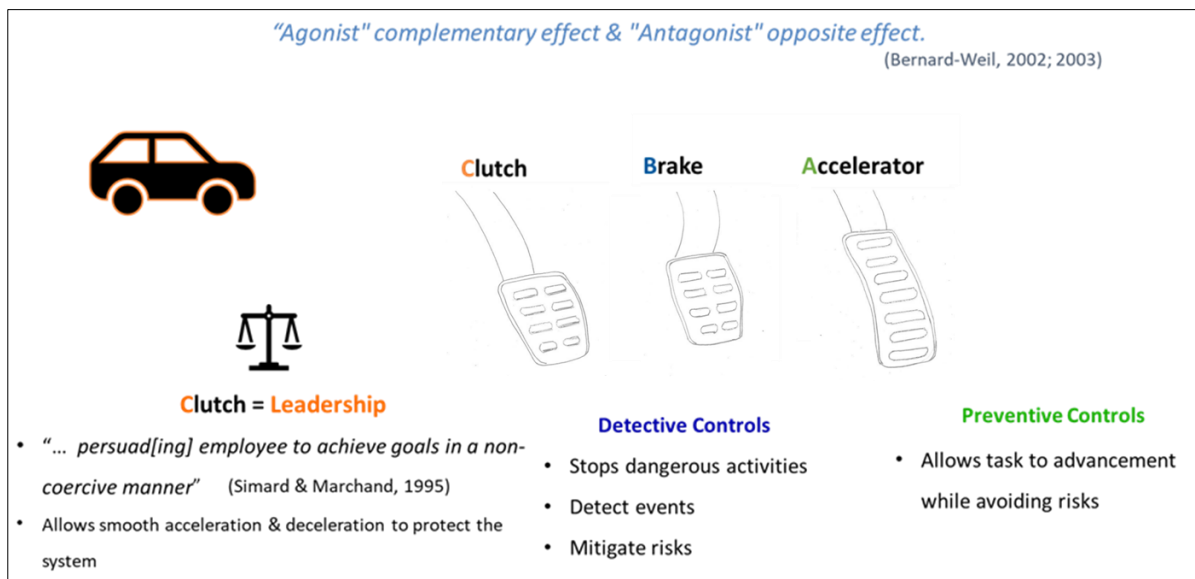


Figure 31. Control and Leadership Analogy: Balance through Ago-Antagonistic Systems (as a complement to the Developed (Facility A and Facility B) Model.

More precisely, systems thinking indicates that a car on a highway is connected to the surrounding cars. Therefore, changing one element will have an effect on the whole system, as a tire explosion may yield a traffic accident or traffic thereby impacting other cars. In this example, the brake and the accelerator are the ago-antagonistic poles, whereby if a car has strong brakes but a weak accelerator then the car

will not advance. In contrast, a car with a strong accelerator but a weak brake could result in an accident if the driver does not adapt their driving style. This is particularly the case with bumper cars. In the analogy, the accelerator refers to preventive controls, which allow the advancement of the activities while avoiding risks. The brakes refer to detective controls that stop dangerous activities, detect the event and mitigate risks. In order to improve the balance of the car system, we can add the clutch which allows the driver to change gears, accelerate or brake gently, protecting the system. In the example, leadership is exemplified by the clutch that impacts preventive controls much like how the clutch affects the accelerator. So, therefore, if the cars on the highway all have the correct brake, accelerator and clutch configuration or balance, and if traffic is moving smoothly then the driver only requires the use of the accelerator (Preventive Controls). However, during an event, the driver will release the accelerator and brakes (Detective Controls) or in the case of rain, can downshift the gears with the use of the clutch (Leadership).

This analogy as a complement of the Developed Control, Risk and Leadership Model was presented to numerous academics and CEA personnel throughout the research study, as well as during the validation of the model in situ at Facility A (Phase 6*) and Facility B (Phase 7-8). It was also discussed with actors at Facility E and presented to CEA Managers and FOH personnel from several CEA Facilities during the 2019 HOF Day.

4. Validation of Model in Situ (in the field)

When researcher use abduction to generate hypothesis or propositions, they do not stop at the “pre-theoretical stage”, but instead continue by submitting their hypothesis or propositions to scientific debate. According to David (1999) the abductive research process consists of two stages: the initial process that develops the three elements of a recursive loop (data, hypothesis or propositions, theory) and the second process that validates those hypotheses or propositions (David, 1999). This validation process can be conducted by any of these four manners: “[the first], by verifying the quality of the empirical observations and the rigor of the adductive reasoning itself; [the second] by comparing the hypothesis [or proposition] themselves to other hypotheses [or propositions] relating to the same class or phenomena or other classes of phenomena; [the third] by comparing the consequences deduced from the theories with other empirical data, either observed in other fields, or deduced from other theories, [and finally] by confronting the theories induced with existing theories (David, 1999. p. 8).

This fourth section of Chapter 2 presents the “*Validation of the Model in Situ*” in three sub-sections using elements from David’s (1999) validation of an abductive research process. The first subsection details the authentication of the *initial model* at Facility A (Phase 6) and its validation at Facility B (Phase 7-8). The second subsection details the authentication of the *developed model* at Facility B (Phase 7-8) and its validation at Facility A (Phase 6*). The third subsection presents the potential validation of the developed model at Facility E (Phase 9, Phase 9*) and other CEA Facilities with a quasi-integration style of subcontracting. Finally, the fourth subsection details the Quality of the Research.

4.1 Authentication and Validation of the Initial Model

The authentication and validation of the *Initial Model* occurred at the end of the first “analysis of the system, formalization and simulation” loop that began in Facility A.

4.1.1 Authentication of the Initial Model at Facility A (Phase 6)

The *authentication of the initial model* took place at Facility A during the 2-day immersion of Phase 6 nearly 2 years following the initial Facility A immersions (Phase 2-5). During this immersion, each of the 12 dimensions of the 19 control-risk couplings found in Facility A were reviewed with the First Facility A Manager. Elements of prevention and detection and their link to the levels of Defense in Depth were also discussed. Edgar (P07), the First Facility A CEA Manager, validated all of the elements obtained. As a result, this resulted as per David’s (1999) *first* manner of validating the abductive process in the verification of quality of the empirical observations (from Phases 2-5) and the verification of the adductive reasoning directly from the First Facility A CEA Manager.

4.1.2. Validation of the Initial Model at Facility B (Phase 7-8)

The *validation of the initial model* took place at Facility B throughout the 13-day immersion in Phase 7-8 a few weeks following its authentication at Facility A (Phase 6). Facility B was chosen to verify the fit and validity of the model in an adjacent scenario given the contrasting characteristics between Facility A and Facility B. Each of the 18 control-risk- couplings identified in Facility A and their preventive and detective nature were also observed in Facility B. An additional 5 control-risk couplings were identified that were also present at Facility A but due to the timing of the immersion (the transition process between two subcontractors) they were not observed. After confirmation of these additional 5 controls with the Second Facility A Manager, the initial validation model contained 23 control risk couplings. These controls-risk couplings were also observed in Facility E. All of the findings from Facility B were validated by Gotterdamm (P15), the second Facility B Manager as well as by his second in command. Several of David’s (1999) aforementioned proposed manners of validating the abductive process were employed. The *first* manner, also used in Facility A, was obtained by the verification of quality of the empirical observations (from Phases 7-8) and the verification of the adductive reasoning directly from the second Facility B CEA Manager with regards to the control-risk couplings and the nature of Preventive and Detective Controls. Additionally, David’s (1999) *second* manner of validation of the abductive process, was achieved by comparing the hypothesis or proposition obtained in Facility A (23 control-risk couplings, temporal nature of Preventive and Detective controls) to other hypotheses or propositions to the same class of phenomena such as those of Facility B. As a result, the propositions from Facility A regarding the 23 control- risk couplings and the temporal elements of preventive and detective controls were validated in Facility B. Furthermore, David’s (1999) *third* manner of validation was attempted unsuccessfully, as the consequences deduced from the theories in Facility A were compared and contrasted to other empirical data in Facility B. However, upon this comparison and upon further observation at Facility B, it was apparent that new variables and themes identified

(leadership and contingency variables) were missing from the initial model, requiring its expansion and thereby reframing, re-evaluating and authenticating these new elements in a more developed model. As a result, this initial model did not represent a complete picture of Facility B and instead was expanded into the developed model which encompasses some elements of the initial model (Risk, Control), while adding the missing elements (Leadership and Contingency Variables) of the developed model.

4.2. Authentication and Validation of the Developed Model

The authentication and validation of the *Developed Model* occurred at the end of the second “analysis of the system, formalization and simulation” loop that began in Facility B.

4.2.1 Authentication of the Developed Model at Facility B (Phase 7-8)

The *authentication of the developed model* took place at Facility B throughout the 13-day immersion in Phase 7-8 Phase. During this Facility B immersion, the five dimensions of the Empowered Leadership Model were observed in conjunction with changes that were made to Management controls in order to promote safety culture given its managerial configuration. The ago-antagonistic nature between preventive and detective controls and their link with leadership was also perceived and showed to be taken into account by both CEA Managers and Middle Managers to balance preventive and detective controls. All of the findings were presented to and validated by the Facility B Manager, his second in command and several of the Middle Managers.

Once again, several of David’s (1999) aforementioned proposed manners of validating the abductive process were employed. *First* the Facility B Manager, his second in command and several of the Middle Managers verified of quality of the empirical observations (from Phases 7-8) and the verification of the adductive reasoning with regards to the ago-antagonistic nature of Preventive and Detective Controls. *Second*, the emergent propositions (Preventive and Detective controls as ago-antagonistic couples, the link between leadership and contingency factors of the Facilities in the use of MCS) were compared to other propositions to other classes of phenomena (neuro-endocrine studies, MCS and ERM Contingency Frameworks). The consequences deduced from these theories in the developed model, were able to authenticate the developed model in Facility B that would later require validation in Facility A.

4.2.2 Validation of the Developed Model at Facility A (Phase 6*)

Given these new elements in the developed model, it was essential to validate that these changes also apply to Facility A. As a result, following its authentication during Phase 7-8, the *validation of the developed model* looped back to Facility A via the telephone with Trovatore (P25), the second Facility A Manager, during a Phase that has been designated as Phase 6*. This phone call assisted in David’s (1999) *third* manner of validating the abductive process, as the consequences deduced from the theories in Facility B related to ago-antagonistic nature of control, and the link between control-risk- leadership and the Facility’s Contingent Variables, were compared and contrasted to the empirical data from Facility A and discussed openly with the Facility A manager. However, Facility A did not employ the

same control and leadership style as Facility B but had their individual leadership elements, confirming the contingent nature of both MCS and the leadership dimensions.

An alternative control and leadership style was also observed in Facility E. The impact of the contingent variants on the use of MCS and leadership style in Facility A, Facility B and Facility E is discussed in Section 3 of Chapter 3. The varied nature of the contingency factors (characteristics) between Facility A, Facility B, and Facility E allowed to validate the contingent nature of MCS and leadership styles. Additionally, Facility E was able to serve as a control between Facility A and Facility B, as Facility E shares 2 contingent variants (*managerial presence, type of activity*) with Facility A while it shares three contingent variants (*size, managerial configuration, levels of control*) with Facility B. As a result of the contrast in the three Facilities, David's (1999) *fourth* manner of validating the abductive process was achieved as the *theories induced* regarding the ago-antagonistic and contingent nature of MCS and leadership *were confronted with existing theories* in both the MCS and ERM Contingency Frameworks. The merger of Contingency Theory and Systems theory further allowed for a more holistic observation and analysis of the Risk Management Strategies of all three facilities and their comparison to the Risk Management strategies detailed in the literature.

4.3. Potential Validation of the Developed Model at Facility E and other CEA Facilities with quasi-integration

The developed model was presented both at Facility E and during the CEA's 12th Annual Human and Organizational Factor (HOF) Day in 2019.

4.3.1. Presentation of the Developed Model at Facility E (Phase 9, Phase 9*)

Facility E is a "Radioactive Waste Storage Facility" at Site 2 that implements various treatments to eliminate the majority of radioactive substances attached to the materials either approved for re-use or to be uncategorized as radioactive, prior to being discarded as waste. These treatments are carried out in several specific units, depending on the mechanical and radiological features of these materials. The treated pieces are either returned to the original facility or oriented towards the different disposal routes. The facility is also responsible for the decontamination of lead via fusion, the maintenance of radioactive effluent transport packages, the sizing of waste into the appropriate dimensions. The facility is managed by the CEA and underwent the transition process between two subcontractors at the end of 2018, a few months prior to the visit in January 2019. The managerial configuration and hence the two levels of control in this Facility mimics those of Facility E. In the first level of control, being carried out by the Middle Manager (C1N), the middle level of control by the CEA Managers (C1.5N) as with all of the facilities, there is a final second level of control (C2N) that is carried out by the internal department outside of the Facility ("La Cellule").

The *immersion at Facility E* was very brief (Phase 9, Phase 9*), but allowed to observe several meetings and processes within the Facility. Following the validation of the *developed model* in Facility A during the Phase 6*, the 2-day immersion at Facility E (Phase 9) and the telephone conversation (Phase 9*),

allowed to present the model to Derk (P26), the Facility E Nuclear Safety Engineer and Foscari (P27), the Facility E Production Middle Manager. The general consensus was that the elements presented in the developed model were not invalidated during the Facility E interviews, thereby indicating a potential validity in Facility E. Given the limited immersions in Facility E further data collection at this Facility is required prior to validating the developed model in this setting.

4.3.2. Presentation of the Developed Model at the CEA's 12th Annual Human and Organizational Factors (HOF) Day in 2019

On November 5th, 2019, the CEA organized their Annual Human and Organizational Factors (HOF) Day, titled "HOF in the extended organization: training subcontractors and controlling their activities" to provide additional knowledge and to exchange experiences on HOF through testimonials from CEA employees and external orators from other high-risk industries. The researcher presented their research including the initial and developed model to various CEA Managers and HOF liaisons from several Facilities across all of the CEA Sites. Specifically, the models illustrated how CEA managers and Middle Managers across the three nuclear facilities observed, executing similar subcontracting activities (but varying in size, managerial configurations, and other characteristics), implement contrasting management and leadership styles in their management of safety and HOF. The proposed developed model thereby proposes a new approach to risk and safety management, underpinned by systems thinking, which applies safety leadership principles to re-enforce risk prevention by balancing the controls to overcoming the limits of MCS. It integrates safety leadership practices into the application of a series of informal controls, thus creating a significant impact on the organization's safety management practices. The questions and comments indicate a potential validity in other CEA Facilities with a quasi-integration subcontracting style. Further research is required to validate the model in these alternate settings.

4.4. Quality of Research and Methodological Reflections

This research study employs a *critical-realist* epistemological perspective that, through abductive reasoning, aims to develop specific suppositions of the underlying plausible generative mechanisms of the phenomena under study (Avenir and Thomas, 2015). In critical realism, the social phenomena are believed to be shaped by humans that act with intention and are able to learn, thereby rendering it difficult to measure the reliability of the social phenomenon (Avenir and Thomas, 2015). Additionally, since the social phenomenon occurs within open systems, this makes replication difficult (Bhaskar, 1998b). As a result, researchers must endeavour to demonstrate how they have formulated the research question, analyzed the data, controlled and verified their interpretations, and reported the results (Sandberg, 2005). The pursuit of research quality in qualitative research is based on the rigorous nature of four fundamental principles: *reliability*, *inferences quality*, *construct quality* and *generalization* (Avenir and Thomas, 2015; Gibbert *et al.*, 2008). For each of the four fundamental principles a definition is provided below, as well as the strategies adopted in this study to ensure each of these elements:

Reliability is often referred to as “truthfulness (Sandberg, 2005), “trustworthiness” (Guba and Lincoln, 1989; Schwarcz-Shea, 2006), “credibility” (Charmaz, 2006) depending on the epistemological framework of the research. Lincoln and Guba (1985) propose four criteria of trustworthiness or reliability: *credibility, transferability, dependability and confirmability*. Table 8 below details each of these as well as the strategies applied within this study to ensure rigour.

Piekkari *et al.* (2010) highlights the importance of the researcher’s *self-reflexivity*, that is, ensuring they are aware of their influence on the data and their role in the process, particularly as qualitative research is impacted by the researcher’s skills, their training, their experience, their capabilities and their competencies (Patton, 2002). Consequently, the data collection and analysis, the case description, the fact construction and the models that emerge will forever be based on the interpretations of the researcher (Alvesson and Skoldberg, 2000). The researcher’s previous Bachelor and research experience in Neuroendocrine Physiology was beneficial in the implementation of the Ago-Antagonistic System, which was initially applied to the field of Endocrinology.

The research was financed by the CEA, which allowed access to the CEA Facilities and provided an “insider” view of the company thus encouraging personnel to openly share their perceptions. Nonetheless, certain personnel felt uncomfortable sharing their perceptions during a recorded interview; which is why the interviewees requested not to be recorded.

Table 8. Strategies used in the study to achieve Lincoln and Guba (1985)’s four criteria of trustworthiness (or reliability).

Criteria of Reliability	Description	Strategies to achieve Rigour in this study
Credibility	The degree of confidence that the results, from the participant’s perspective, are accurate and credible.	Nine immersions over a 3-year period were spent at the CEA to engage with participants. The interview protocols were tested during the pilot study and all interviews were transcribed for accuracy. The findings were presented in debriefing sessions with key HOF specialists at multiple CEA Sites. Multiple interviews were conducted with several participants providing a summary of the past interview to ensure their viewpoints were correctly understood.
Dependability	The degree to which findings are repeatable given the same research design and variables (participants, context, etc.)	The same data collection methodology was carried out at all three Facilities and all of the data obtained was carefully registered (see Appendix A). Detailed (thick) description of each Facility allows the reader to make their own conclusions as to the degree of fit of the findings to alternative settings. The study’s protocols, detailed in Chapter 2, were validated with the CEA HOF specialist.
Confirmability	The degree to which the results may be confirmed or corroborated by other researchers.	Daily reflexive journal entries allowed to review the day’s themes as well as determine the questions that should be asked the following day. Multiple sources of data including internal documents, observations and interviews were used to corroborate the data.
Transferability	The degree to which the results may be generalized or transferred alternative scenarios.	Thick description of the case study’s context, and participant’s daily comments and actions, as well as the complete transcription of all 37 interviews. The results obtained in one Facility were confirmed in the other facilities to determine standardization across the other facilities with a Quasi-integration style of subcontracting. The embedded case units confirmed the results were generalizable within the CEA to Facility A, Facility B and Facility E. The HOF Day presentation indicates a potential that the results may also be valid other CEA Facilities employing quasi-integration.

Construct quality refers to the capacity to generate clear classifications of the phenomenon, allowing for the experiences to be structured into meaningful categories (Avenir and Thomas, 2015; Suddaby, 2010). According to Glaser (2004), a construct's quality depends on the explanatory power of the model elaborated. As a result, the construct's quality is *firstly* related to the quality of the data collection and the *quality of inferences* (*internal validity*) (Tsoukas, 2011), and *secondly* related to the logical connections between the proposed new construct and other existing constructs (Suddaby, 2010). As a result, researchers must indicate the rigour and pertinence of the data collection and analysis that has allowed to abstract inferences and constructs, as well as what literature they have leaned on and what literature they are contributing to (Avenir and Thomas, 2015; Suddaby, 2010).

The case setting (CEA), the three embedded case units (Facilities) and the emergent themes were described in a thick rich detail. Additionally, the data analysis process includes a thick description of the data sources (quotes, observations, notes) allowing the reader to draw their own conclusions.

Multiple sources of data (Standard Operating Procedures, internal documents, observations) were used to verify the comments obtained during the 37 interviews, thereby confirming the chain of evidence. Additionally, several levels of analysis (CEA Manager, Middle Manager and subcontractor) were interviewed to capture multiple voices (Welch and Piekkari, 2016) and multiple perspectives of the phenomenon particularly as multiple voices allowed to explore the different facets of the phenomenon thereby deepening the understanding and ensuring strong internal validity (Tracy, 2010). All of the results and the models that emerged from the combination of these multiple levels of analysis were verified with the Facility Managers at each Facility.

Confirmation of the same 23 control-risk couplings in all of the multiple embedded units (Facility A, Facility B, Facility E) confirmed the chain of evidence and highlighted the difference in the type of leadership and control style used to mitigate them. The difference in contextual characteristics between Facility A and Facility B confirms a contingent relationship between the Facility's contextual characteristics and their MCS and leadership practices. Additionally, pattern matching of the empirical results and the theoretical concepts (Trust, ELM, AAS, application of Contingency Theory to MCS) helped to identify categories already in the literature as well as the creation of new categories of insights that could not be classified into the existing categories). Additionally, the use of the systemic combining process encouraged to match the evolving case, with the framework, the data sources and the analysis, which early on eliminated certain themes (trust, inter-organizational trust) from the evolving case results.

Generalization, often referred to as *external validity*, refers to the validity of the knowledge claims beyond the study's empirical setting. It concerns the degree of abstraction of the explanatory model (Avenir and Thomas, 2015), as generality is not seen as an element of the empirical domain but rather a property of the structures operating in the real domain (Tsoukas, 2011). According to Smith (2006, p.205), "*generalization does not come from a movement of empirical events in one context to empirical events in a novel context, but rather it results from the uncovering of the underlying essence of things,*

a movement from surface to depth”. As a result, case studies can be generalizable if they can provide an explanation of the causal powers at work that generate the observed phenomenon (Tsoukas, 2011).

The initial model and the developed model that emerged from this case study were modified and enriched numerous times throughout the research process. The models were tested in the adjacent settings of all three Facilities, allowing for continuous comparison with more and more data (Glaser, 2004). The embedded case study design facilitated the exploration of the richness of a single case, and allowed the testing of the models in each Facility with their own unique characteristics, eventually elaborating the explanation of the case as a whole. The results obtained at each of the Facilities and the models that emerged are discussed in Chapter 3.

Conclusion of Chapter 2

A significant focus of the research design and the selection of theoretical framework arose from the intention of providing a holistic research angle to the research questions. Ferreira and Otley (2009) indicate that MCS research would benefit from a framework that provides a broad view of the key aspects of MCS and that allows researchers to obtain a holistic overview in the most efficient way possible. Furthermore, qualitative research adopts a holistic view as it relies on a rich description of the actor's reality during which the phenomenon is under study within the context (Denzin and Lincoln, 1994; Patton, 1980; Zawawi, 2018). The merger of Contingency Theory and Systems theory further allowed for a more holistic observation and analysis of the Risk Management Strategies of all three Facilities and their comparison to the Risk Management strategies detailed in the literature. Theory building or development from case studies has numerous strengths including testability and empirical validity given its close linkage to empirical evidence (Eisenhardt, 1989b; Eisenhardt and Graebner, 2007; Siggelkow, 2007) given that it is “*derived from data, systematically gathered and analyzed through the research process*” (Strauss and Corbin, 1990:12).

The researcher employs a ***critical realism*** epistemological paradigm, using systemic ***combining***, a research approach grounded in an iterative *abductive logic* (Dubois and Gadde, 2002; 2014). A second research approach, ***Model-Centered Process***, was also employed as a tool of knowledge production and knowledge exhibition in a “*continuous movement between an empirical world and a model world*” (Dubois and Gadde, 2002, p.554) through an iterative process. Two theoretical frameworks, ***Systemic Theory*** and the ***Contingency Theory*** were used to analyze the management control systems employed by three Facilities that employ quasi-integration subcontracting at the CEA. The different visual representations observed in the field were compared to pre-established theoretical models prior to returning to the field. Cumulatively, ***nine phases of data collection*** took place over 44 days in a two-and-a-half-year period and yielded a total of 36 interviews, over 366 hours of observations over 44 days including 23 documented meetings and 21 documented observations. Throughout the four years that ensued, narratives were constructed from the 45 hours of recorded semi-directed and non-directed

interviews, as well as from the 218 typed pages of field notes, and the 80 company texts collected. These data obtained in-situ from the case study were then coded, analyzed and deconstructed with n-VIVO qualitative data analysis software to identify subcontracting risks, control mechanisms and other elements present in the three nuclear facilities in order to analyze their interaction. The data also contributed to generating a cartography of control of each of the facilities, as well as various charts and diagrams that outlined the use of MCS and their methods of implantation that varied from facility to facility. The development of theory from data, in the form of charts, diagrams and general findings, typical of *systemic combining* were then verified with the Facility Managers (Lincoln and Guba, 1985). Additionally, the models were reviewed on an ongoing basis by Dr. Jean-François Vautier and Guillaume Hernandez, the two Human and Organizational Factors (HOF) Specialists from the Directorate of Nuclear Safety and Security (DSSN) of the CEA. They oversaw the research study, contributed greatly to the evolution of the case theory development and decreased researcher bias. As a result, the models underwent numerous changes as they were formulated, detailed, elaborated, reassessed and finally validated in Facility A and Facility B of the CEA (and not invalidated at Facility E). These three facilities (Facility A, B and E) are the sub-units of analysis of an embedded Case Study research approach of the CEA. Each Facility displayed an alternative control and leadership style that appears to be linked to the Facility's contingency factors, as discussed in Section 3 of Chapter 3. The varied nature of the contingency factors (characteristics) between the three Facilities, allowed to study the contingent nature of MCS and leadership styles and use Facility E as a control between Facility A and Facility B. Additionally, David's (1999) four manners of validating the abductive process were used to validate the Developed Model, which is the result of integrating the ago-antagonistic and contingent nature of MCS and leadership to the initial model. This developed model was also confronted with existing theories in both the MCS and ERM Contingency Frameworks.

Chapter 3 presents the Results of this Dissertation that present: ***How the CEA design Management Control Systems (MCS) that can effectively avert and mitigate subcontracting risks associated with quasi-integration, in the context of the specific characteristics of its nuclear facilities.***

Chapitre 3 - Résultats empiriques

(Résumé en Français)

La recherche se déroule dans trois installations nucléaires¹⁶ du CEA et étudie les interactions de trois acteurs situés à différents niveaux de l'organisation : Les opérateurs de terrain des entreprises sous-traitantes, les managers de ces dernières (managers dits intermédiaires « middle managers » en anglais) et les chefs d'installation et ingénieurs du CEA (CEA managers en anglais). La recherche se concentre sur **trois types de systèmes de contrôle de gestion** : *d'une part le contrôle comportemental et le contrôle par les résultats et d'autre part le contrôle social*. Dans le domaine de la gestion, ils sont classés respectivement en contrôles formels et informels, et, concernant le champ des concepts de sûreté tels que la "défense en profondeur", ils sont décrits comme des modes de contrôle de prévention et de détection, c'est-à-dire des contrôles qui évitent versus détectent un événement (ce dernier étant l'expression d'un risque lié à la sous-traitance qui s'est produit). La recherche examine comment ces trois contrôles préviennent et/ou atténuent **trois types de risques liés à la sous-traitance** : *le risque relationnel, le risque lié à la performance et le risque de non-conformité*. Il est important de noter que ces risques sont accentués par la distance organisationnelle existant entre le CEA et les entreprises sous-traitantes. La recherche identifie ensuite des **stratégies de gestion supplémentaires** [Leadership en matière de sécurité et le *Model de Leadership par Responsabilisation* d'Arnold et al. (2000)] qui favorisent le comportement de sécurité. Elle montre comment les stratégies multiples (en combinaison avec les systèmes de contrôle de gestion) interagissent dans un système complexe pour renforcer la performance de sécurité. La figure 32 (cf. texte en anglais) donne un aperçu de la thèse qui vise à répondre à la question : *Comment le CEA conçoit-il des Systèmes de Contrôle de Gestion (SCG) qui peuvent efficacement éviter et atténuer les risques de sous-traitance associés à la quasi-intégration, dans le contexte des caractéristiques spécifiques de ses installations nucléaires ?*

En utilisant la théorie des contingences et la théorie systémique, une série de modèles systémiques sont produits qui appliquent les concepts de facteurs de contingence et de systèmes ago-antagonistes. Ces modèles systémiques contribuent à apporter des contributions managériales et académiques :

- *premièrement* en identifiant le cycle de contrôle commun aux trois installations nucléaires et en classant les différents contrôles sur la base de l'aspect temporel des contrôles (par rapport à la tâche) et de la position de l'acteur qui exécute la tâche ;
- *deuxièmement* en illustrant comment l'aspect temporel des contrôles détermine leur capacité à éviter et/ou à détecter un événement ;

¹⁶ Comme indiqué dans l'introduction de cette thèse, les noms des installations (de l'installation A à l'installation E) ont été choisis à la demande du CEA afin que les deux thèses réalisées dans ces installations aient la même lettre. Par conséquent, la dénomination des installations est cohérente avec celle utilisée dans la thèse d'Amaury Bazalgette.

- *troisièmement* en identifiant les apports des contrôles ago-antagonistes et en montrant comment équilibrer les contrôles ago-antagonistes pour une meilleure prévention et atténuation des risques et des événements liés à la sous-traitance ;
- *quatrièmement*, en illustrant comment le leadership promeut la sécurité en aidant à surmonter les limites des systèmes de contrôle de gestion ;
- *cinquièmement*, en montrant comment le type de contrôle et le style de leadership dépendent des facteurs de contingence de l'installation (environnement externe, technologie, structure organisationnelle, taille et ratio, stratégie et culture) ;
- et *enfin*, en soulignant la relation entre le style de leadership et l'application et la promotion de la culture de sûreté par le manager.

Pour plus de simplicité, dans ce chapitre, le terme "Middle Manager" est écrit en vert et le terme "CEA Manager" est écrit en rouge. Par conséquent, le contrôle intra-organisationnel a également été écrit dans le même vert que les managers de l'entreprise sous-traitante pour rappeler que le contrôle intra-organisationnel a lieu entre les managers de l'entreprise sous-traitante et les personnels de terrain de l'entreprise sous-traitante qui font donc tous deux partie de la même entreprise. De même, le contrôle inter-organisationnel a été écrit dans le même rouge que les Managers du CEA pour rappeler que le contrôle inter-organisationnel a lieu entre les Managers du CEA et les personnels de l'entreprise sous-traitante (managers ou personnels de terrain) qui font partie de deux entreprises distinctes.

Ce chapitre présente les résultats empiriques obtenus tout au long des 9 phases de collecte de données en trois sections, comme le montre la Figure 33 (cf. texte en anglais). La première section identifie les risques liés à la sous-traitance au CEA ainsi que les couplages SCG-risques utilisés pour éviter et atténuer ces risques dans les trois installations. Les risques et les contrôles ont été codés en couleurs primaires, comme indiqué plus en détail dans la section 1.1. La deuxième section analyse les SCG employés dans les 3 installations, en proposant des définitions de la nature de ces contrôles (*contrôle de prévention* en vert et *contrôle de détection* en bleu), du moment où ils permettent d'éviter les événements, de leur nature ago-antagoniste et de leur contribution au cycle de contrôle. La troisième section oppose six variantes contingentes aux trois installations et montre comment ces variantes contextuelles ou contingentes (*environnement externe, technologie, structure organisationnelle, taille et ratio, stratégies, culture*) ont un impact sur les styles de contrôle et de leadership préférés. Dans la figure 33, les six facteurs de contingence sont organisés selon les conclusions de la section 3 de ce chapitre. Le facteur de contingence de la structure organisationnelle est considéré par les chercheurs comme contenant des éléments de leadership. Tous les éléments liés au leadership dans ce chapitre sont écrits en orange.

Plus précisément, cette thèse évalue la relation entre les risques de sous-traitance, les systèmes de contrôle de gestion et les facteurs de contingence dans trois installations du CEA. Comme le montre la Figure 33 ci-dessous, nous pouvons observer deux directions de relations :

- De gauche à droite (→), les risques sont influencés par les systèmes de gestion des risques. Les types et la nature des systèmes de gestion des risques mis en œuvre sont conditionnés par les facteurs de contingence de l'installation. Parmi les facteurs de contingence, le style de leadership de l'installation (les facteurs du modèle de Leadership par Responsabilisation) est influencé par les autres facteurs de contingence.
- En allant de droite à gauche (←), plusieurs facteurs de contingence influencent le style de leadership des managers, ce qui conditionne les types de SCG mis en œuvre, lesquels influencent à leur tour la capacité à prévenir et à atténuer les risques de sous-traitance.

Plus précisément, le style de leadership des trois installations est dû à : (1) *l'implication des managers (managers du CEA et de l'entreprise sous-traitante)* et (2) *la manière dont les managers (managers du CEA et de l'entreprise sous-traitante) promeuvent la culture de sûreté* ; ces deux facteurs sont à leur tour liés aux facteurs de contingence de chaque installation. Les trois premiers facteurs de contingence (*technologie, structure organisationnelle et taille & ratio*) influencent *l'implication des managers* (1) ; tandis que les deux autres facteurs de contingence suivants (*environnement externe et stratégies*) influencent *la manière dont les managers promeuvent la culture de sûreté* (2). Enfin, le dernier facteur de contingence, la *culture*, influence à la fois *l'implication et la manière dont les Managers promeuvent la culture de sécurité*. Enfin, le style de leadership est une autre façon d'exprimer l'ensemble des facteurs de Leadership par Responsabilisation.

Ce chapitre présente les résultats de la recherche en trois sections. La première section traite de l'utilisation des SCG pour prévenir et atténuer les risques liés à la sous-traitance au CEA. La deuxième section présente les caractéristiques des 24 SCG du CEA. Enfin, la troisième section détaille l'impact des variantes de contingence sur l'utilisation des SCG et les styles de leadership dans les trois installations du CEA.

Dans l'ensemble, la gestion du risque au CEA peut être décrite comme un système dynamique avec des interactions complexes entre divers sous-systèmes, y compris le contractant CEA - le sous-traitant, les outils de gestion du risque de sous-traitance et les *contrôles de prévention - détection*, entre autres. L'utilisation de la pensée systémique pour modéliser les forces de l'ago-antagonisme (AA) présentes dans le système de gestion des risques, permet aux managers d'identifier et d'équilibrer les *contrôles de prévention et de détection* utilisés dans les pratiques de gestion des risques des trois installations observées ; en particulier parce que chaque installation met l'accent sur un ou plusieurs pôles antagonistes (de prévention ou de détection). Après avoir analysé plusieurs exemples empiriques de pratiques actuelles de CEA, un système de contrôle hybride de prévention (niveau 1) et de détection (niveau 2) synonyme de stratégie de *défense en profondeur* peut être identifié dans les trois installations par le biais des contrôles relais et du cycle de contrôle. Les Contrôles Relais qui consistent en un auto-contrôle non interactif du *pôle de prévention ago-antagoniste* suivi d'un contrôle vérificateur interactif du *pôle de détection ago-antagoniste*. Le cycle de contrôle qui semble être le plus efficace commence par un *contrôle social de prévention avant la tâche*, suivi d'un *contrôle comportemental de prévention*

ou de détection pendant la tâche, d'un contrôle de sortie de détection après la tâche, et enfin suivi d'un *contrôle de prévention* qui a lieu entre la fin de cette activité et la prochaine fois que la même activité sera réalisée; prévenant ainsi les événements futurs. De cette façon, les contrôles *de prévention* servent à la fois d'alpha et d'oméga de la prévention des risques, renforçant ainsi l'approche classique de la sécurité qui se concentre sur la prévention des barrières et la réduction de la probabilité d'occurrence des événements. Ces procédures existent pour prévenir les événements potentiels et imaginables mais négligent les événements inconcevables. Par conséquent, le développement d'un modèle/outil ou d'un méta-modèle pour comparer les événements permettrait de mieux comprendre les événements qui se produisent soit parce que les barrières de prévention n'ont pas fonctionné (bien que l'événement ait été imaginé), soit parce que les barrières de prévention n'existaient pas (parce que l'événement était inimaginable et inattendu).

Chaque installation utilise des SCG pour atténuer les risques de sous-traitance liés à la sûreté, mais leur utilisation des pratiques de leadership varie. Le type de contrôles et le style de leadership semblent être influencés par la combinaison des six variantes contingentes (*environnement, technologie, structure organisationnelle, taille et ratio, stratégie et culture de sûreté*) des installations. Un total de 24 catégories de SCG, communes aux installations A, B et E, ont été cartographiées sur plusieurs niveaux de systèmes, ce qui a permis de comprendre la distance entre les éléments et leur lien avec les cinq dimensions du modèle de Leadership par Responsabilisation (*diriger par l'exemple, encadrer, informer, prendre des décisions participatives, se montrer concerné et interagir*). Plus précisément : Les contrôles sociaux (de prévention et interactifs) et les résultats de sortie interactifs (de détection) ont encouragé l'ensemble des cinq facteurs de leadership, tandis que les contrôles de comportement ont permis d'obtenir certains facteurs de leadership. Seuls, les contrôles de sortie non interactifs n'ont permis d'attribuer aucun des facteurs de leadership.

L'évolution des pratiques SCG dans l'installation B montre comment, à la suite d'une série d'événements, le CEA et les managers intermédiaires utilisent leur leadership pour renforcer la prévention des risques par la mise en œuvre de plusieurs changements de procédure afin d'obtenir des résultats en matière de sécurité qui, à leur tour, équilibrent les mécanismes des contrôles de détection et de prévention. Les changements observés modifient la séquence des contrôles en allant vers une augmentation des *contrôles de prévention*, équilibrant ainsi les deux pôles antagonistes. Plus précisément, ces changements :

- (1) permettre aux managers de *donner l'exemple et de* démontrer leur engagement en matière de sécurité ;
- (2) servir de plate-forme de communication pour les problèmes de sécurité et les rappels, et identifier les domaines qui nécessitent un *accompagnement*, renforçant ainsi l'engagement de l'organisation en matière de sécurité et responsabilisant les sous-traitants par le biais des connaissances et de la formation.

- (3) Fournir une période de temps pour *informer* ou diffuser des références cruciales en matière de sécurité et pour exprimer des préoccupations concernant les nouvelles directives, encourageant ainsi de nouvelles idées et initiatives, tout en améliorant les comportements de participation à la sécurité et la conformité des pratiques de sécurité à travers les multiples niveaux du système de l'organisation.
- (4) Augmenter *l'interaction avec les employés*, en permettant aux sous-traitants d'exprimer des suggestions pour les opérations quotidiennes ;
- (5) Augmenter la *prise de décision participative*, en facilitant les discussions sur les contingences en cas de changements opérationnels inattendus, encourageant ainsi de nouvelles suggestions de sécurité et renforçant un environnement pour signaler les événements évités de justesse/les événements mineurs.

En promouvant les 5 dimensions du leadership, les managers peuvent détecter les comportements ou les résultats inadéquats en matière de sécurité (par le biais du SCG) et les transformer en utilisant des pratiques de leadership en matière de sécurité. Ces connaissances incitent les managers à concevoir des systèmes de contrôle de gestion qui équilibrent les tensions agonistes-antagonistes entre les *contrôles de prévention et de détection* en apprenant à identifier quand des déséquilibres agonistes-antagonistes se sont produits. La figure 56 du chapitre 4 présente un diagramme de décision sur la manière de traiter les déséquilibres agonistes-antagonistes dans les installations du CEA et des suggestions sur la manière de rééquilibrer et d'éviter ces déséquilibres. Les contributions universitaires et managériales de ces pratiques sont détaillées au chapitre 4.

Chapter 3 – Empirical Results

The research takes place at three nuclear facilities¹⁷ of the CEA and studies the interactions of three actors found at different levels of the organization: Subcontractors, Middle Management both part of the Subcontracting Firm, and the Contractors who are CEA. The study focuses on **three types of Management Control Systems**: *Social Control*; *Behaviour Control*; and *Output Control*. In management, they are categorized as informal and formal controls, and in safety concepts like “Defence-in-Depth”, they are described as preventive and detective modes of controls, that is controls that avert – and detect the event (the latter being the expression of a subcontracting related risk that has occurred). The study investigates how these three controls mitigate **three types of subcontracting-related risks**: *Compliance and Regulatory Risk*; *Relational Risk*; and *Performance Risk*. It is important to note that these risks are exacerbated by the organizational distance between two entities of the contractor-subcontractor relationship. The Study then identifies **additional management strategies** [Safety Leadership and Arnold et al.’s (2000) Empowerment Leadership Model] that promote safety behaviour and observes how multiple strategies (in combination with the Management Control Systems) interact in a complex system to strengthen safety performance. Figure 32 details an overview of the thesis that aims to determine: *How does the CEA design Management Control Systems (MCS) that can effectively avert and mitigate subcontracting risks associated with quasi-integration, in the context of the specific characteristics of its nuclear facilities?*

Using Contingency Theory and Systemic Theory, a series of systemic models are produced that apply the concepts of Contingency Factors and Ago-Antagonists Systems. These systemic models contribute to make managerial and academic contributions: *Firstly* by identifying the cycle of control common to all three nuclear facilities and classifying the different controls based on the temporal aspect of the controls (in relation to the task) and the position of the actor performing the task; *Secondly* by illustrating how the temporal aspect of the controls determines their ability to avert and/or detect an event; *Thirdly* by identifying the ago-antagonistic virtues of the controls and demonstrating how to balance ago-antagonistic controls for an improved prevention and mitigation of subcontracting-related risks and events; *Fourthly* by illustrating how leadership promotes safety by helping to overcome the limits of management control systems; *Fifthly* by exhibiting how control preference and leadership style are contingent on the Facility’s contingency factors (external environment, technology, organizational structure, size and ratio, strategy and culture); and *finally* by highlighting the relationship between the leadership style and the manager’s application and promotion of safety culture.

For simplicity, **Middle Manager** from hereon in this chapter is written in green and **CEA Manager** is written in red. As a result, **Intra-organizational control** has been also written in the same green as the

¹⁷ As indicated in the Introduction of this thesis, the names of the Facilities (Facility A through to Facility E) have been chosen at the request of the CEA to ensure the two theses carried out at these Facilities share the same letter. As a result, the nomination of the Facilities is mirrored in the thesis of Amaury Bazalgette.

Middle Managers as a reminder that intra-organizational control takes place between the Middle Managers and the subcontractors who are both part of the Subcontracting Firm. Similarly, Inter-organizational control has been written in the same red as the CEA Managers as a reminder that inter-organizational control takes place between the CEA Managers and the subcontractors who are part of two separate firms.

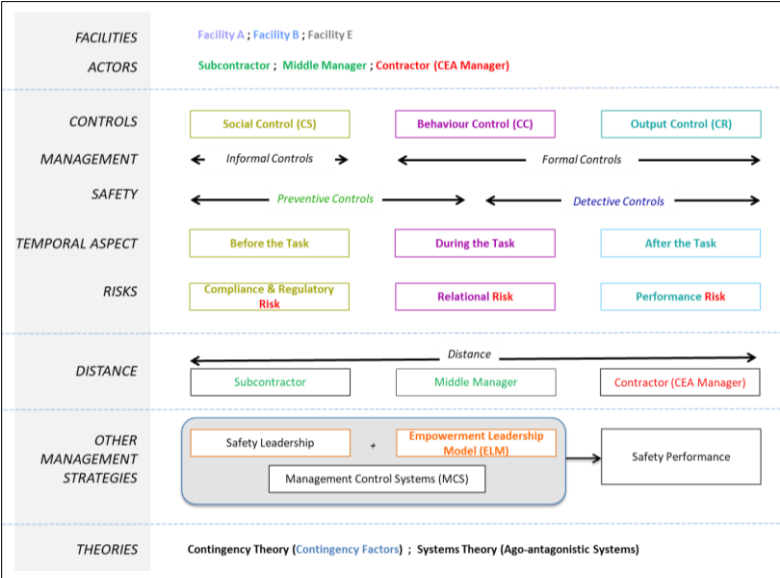


Figure 32. Overview of the research

This chapter presents the empirical results obtained throughout the 9 Phases of Data collection in three sections as detailed in Figure 33 below. The *first* section identifies subcontracting related risks at the CEA as well as the MCS- risk couplings used to avert and mitigate these risks in the three Facilities. Both the risks and controls have been colour-coded in primary colours as further detailed in section 1.1. The *second* section analyses the MCS employed across the 3 facilities, proposing definitions of the nature of these controls (*Preventive control* in green and *Detective Control* in blue), the timing in averting events, their ago-antagonistic nature, and their contribution to the cycle of control. The *third* section contrasts six contingent variants across the three Facilities and shows how these contextual or contingent variants (*external environment, technology, organizational structure, size and ratio, strategies, culture*) impact the preferred control and leadership styles. In Figure 33, the five Contingency Factors are organized according to the finding in section 3 of this chapter. The Contingency Factor of organizational structure is discussed by scholars as containing elements of Leadership. All of the leadership-related elements throughout this chapter are written in orange.

More precisely, this thesis evaluates the relationship between subcontracting risks, Management Control Systems and the Contingency Factors across three Facilities of the CEA. As depicted in Figure 33 below, we can observe two directions of relationships:

- Going from left to right (→), the risks are influenced by MCS, and the types and nature of MCS implemented are conditioned by the contingency factors of the Facility. Within the contingency factors, the leadership style of the Facility (the factors of the Empowerment Leadership Model) are influenced by the other contingency factors.
- Going from right to left (←), several contingency factors influence the leadership style of Managers which conditions the types of MCS implemented, which in turn influences the capacity to avert and mitigate subcontracting risks.

More precisely, the leadership style of the three Facilities are due to: (1) *the implication of Managers (CEA Managers and Middle Managers)* and (2) *the manner in which Managers(CEA Managers and Middle Managers) promote safety culture*; both of which are in turn linked to the Contingency Factors of each Facility. The first three contingency factors (*technology, organizational structure, size and ratio*) influences the *implication of Managers* (1); while the next two contingency factors (*external environment and strategies*) influences the *manner in which Managers promote safety culture* (2). Finally, the last contingency factor of *culture* influences both *the implication and the manner that Managers promote safety culture*. Finally, leadership style is another way to express the set of Empowerment Leadership Factors.

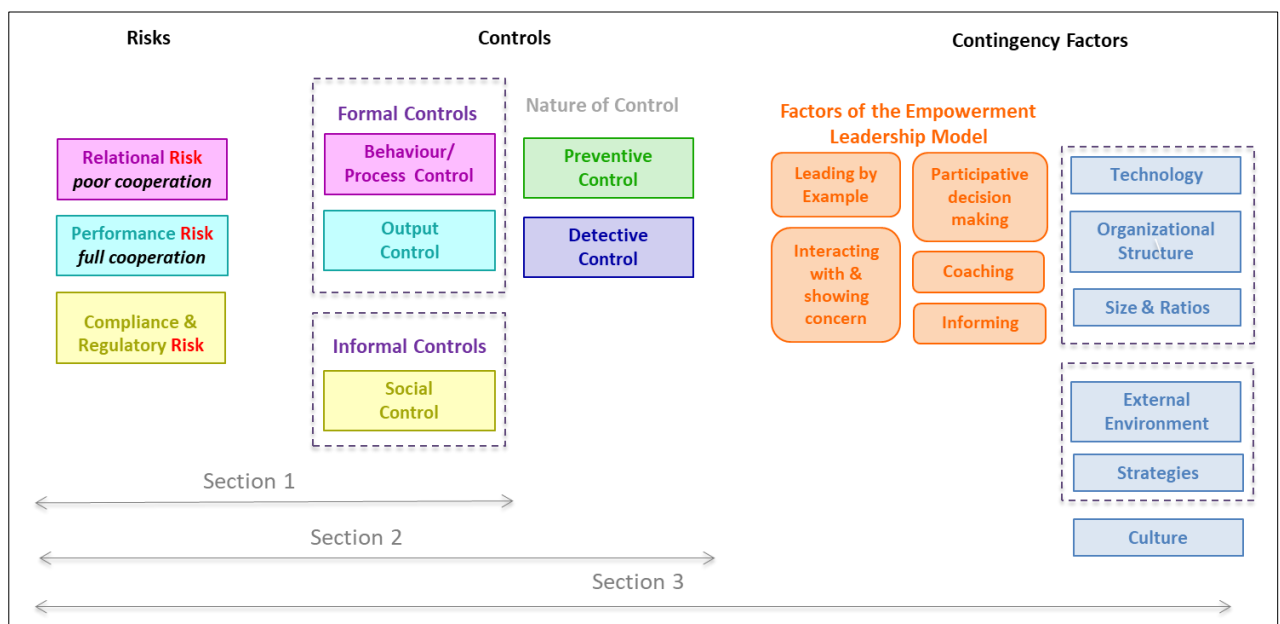


Figure 33. Components of the three sections of Chapter 3

This chapter presents the research results in three sections. The first section discusses the use of MCS to avert and mitigate subcontracting related risks at the CEA. The second section presents the characteristics of the 24 MCS at the CEA. Finally, the third section details the impact of contingency variants on the use of MCS and leadership styles in the three facilities of the CEA.

1. The use of MCS to Avert and Mitigate Subcontracting related risks at the CEA

The first section of this chapter explores the use of MCS to avert and mitigate subcontracting risks at the CEA in five subsections. The first sub-section defines and details subcontracting risks at the CEA, the second sub-section identifies the 24 MCS used to avert and mitigate these risks, the third sub-section proposes a new definition to the three types of MCS specific to the nuclear context, the fourth sub-section identifies control-risk couplings used in the CEA, and finally, the fifth sub-section explores the effectiveness of the MCS in detecting risks and the actors involved in the changes made to the MCS during near misses or nearly significant events.

The acronyms for each of the controls and risks used in this chapter are taken from the French translation and hence do not appear to resemble their English counterpart. For example, *Social Control*'s acronym "CS" comes from its French translation (*Contrôle Social*) and each type of Social Control is nominated using the French acronym (*CS1, CS2, CS3* etc.). Table 9 below recapitulates all of the French-English translations, for the three types of controls and the three types of risks, including their acronyms and designated primary colours (yellow, magenta and cyan). Finally, it is important to note that the Anglo-Saxon term "Control" corresponds to the French term "Maîtrise" or management in English used within the CEA.

Table 9. Recapitulation of the English and French terms used in this chapter, their acronyms and designated colour

English Term	French Term	Acronym	Designated Color
Social Control	<i>Contrôle Social</i>	CS	Yellow
Behaviour Control	<i>Contrôle Comportemental</i>	CC	Magenta
Output Control	<i>Contrôle par les Résultats</i>	CR	Cyan
Compliance and Regulatory Risk	<i>Risque de Non-Conformité</i>	RNC	Yellow
Relational Risk	<i>Risque Relationnel</i>	RR	Magenta
Performance Risk	<i>Risque lié à la Performance</i>	RP	Cyan

1.1. Subcontracting related risks at the CEA

Numerous subcontracting related risks were identified and the strategies that CEA personnel employ to avert and mitigate these risks were discussed with CEA and subcontracting personnel during the 9 phases of immersion at Facility A, B and E. These risks can be categorized into *three types of clusters* that follow the same lines indicated by risk management literature: (1) Procedures are not performed in line with specifications of CEA and external regulatory authorities (*relational risk*); (2) Results are not obtained in accordance with commitments of the subcontractor (*performance risk*); (3) Compliance

with nuclear safety and occupational safety standards is not met (*compliance and regulatory risk*). These risks are not mutually exclusive and thus at times, a situation or event can be categorized as several of the pre-defined risks.

Numerous subcontracting-related risks were highlighted by both CEA and subcontracting personnel. It is important to note that often a situation can be categorized as more than one risk, depending on the reason why the rules were not applied including the motivations of the subcontractor (cooperative/ non-cooperative) and the outcome of the situation (conformity with regulations). The following are a non-exhaustive list of the subcontracting related risks which could occur or risks that were encountered in the facilities we studied. It is important to note that these five risk examples below can be categorized as more than one category of the three aforementioned general risk categories:

Risk 1: Non-transfer of Information

As experienced by Elektra (P06, Facility A Occupational safety Engineer, CEA, Interview 1P06Int1, *1; Interview 1P06Int2) and discussed by Manon (P08, Facility A Occupational safety Assistant 1, Subcontractor, Interview 1P08Int1); Pagliacci (P11, Facility A Nuclear Safety Engineer, CEA, Interview 1P11Int1), Nicholas (P09, Facility A Technical Correspondent, Subcontractor, Interview Int09Int1), and Foscari (P27, Facility E Production Manager, Middle Management- Subcontractor, Interview 3P27Int, *14) there is a risk in the transfer of information during the transition process between two subcontractors. The reluctance or lack of time for the exiting subcontractor to transfer the required knowledge and skills required to operate the facilities to his successor and to the prime contractor [the CEA] is a form of *relational risk* (on the part of the exiting subcontractor in the case of reluctance) and a *performance risk* (incurred by the incoming subcontractor in the event he is not provided with all of the knowledge and know-how essential in running the facility). This second type of risk is detailed in the example below.

Risk 2: Non-transfer of knowledge and know-how

The difficulty in transferring information and skills between the exiting and incoming subcontracting firm was experienced by Aida (P10, Facility A In-charge of Exploitation Contract, CEA, Interview 1P10Int1, *2); partly due to the untimely shutdown of Facility A and the resultant time constraints during the Change of Subcontractor period. As a result, the incoming subcontractor was able to only observe or partially carry out several procedures in the presence of the exiting subcontractor. One such procedure was lowering a barrel of waste into the alveoli (Technical Observation 2TO-7). Once the Facility A cessation was over and the operations commenced, the duration of the transition process between two subcontractors had ended and thus the outgoing subcontractor was no longer present when the incoming subcontractor performed the entire procedure for the first time. On October 24, 2016, the barrel of waste was unintentionally dropped during the procedure to lower it into the alveoli. This was the first time that the incoming subcontractor carried out the procedure following the trial run. The report of significant events for this event indicated that the contents were not breached and that no nuclear

contamination was detected, categorizing the event as a “0” (deviation with no safety significance), the lowest classification on the International Nuclear and Radiological Event Scale (INES). This event occurred partly due to a lack of skills and resources and despite the full co-operation of the incoming subcontracting firm, indicative of a **performance risk** that later led to a **compliance and regulatory risk**, as the fall meant the CEA no longer conformed to regulations.

Risk 3: Non-adherence to pre-established costs

As experienced by Edgar (P07, Facility A Chief, CEA, Meeting IFM-2, *3) and discussed during his second interview (IP07Int2), there are risks in the non-adherence to the preestablished costs in the contract. The non-compliance with the financial performance factors detailed in the contract is a form of **performance risk**.

Risk 4: Non-application of rules

As experienced by Manon (P08, Facility A Occupational safety Assistant 1, Subcontractor, Interview IP08Int1, *4), Elektra (P06, Facility A Occupational safety Engineer, CEA, Interview IP06Int2), and Rigoletto (P14, Facility A Occupational safety Assistant 2, Subcontractor, Interview IP14Int1), at times the personnel do not follow the rules specified in the prevention plan despite the introductory occupational safety visit provided by Elektra (P06). It often takes 15 days from the time when the rules were last specified to the time when the rules are broken. During the months of May and July in 2016 when a total 11 and 10 discrepancies were noted respectively in three categories of risks: the risk of falling (failing to use the proper safety/attachment measures when working from a height), the failure to comply with the standard operating procedures, and working without authorization. This risk can be classified as any of the three types of risk depending on the reason why the rules were not followed and on the results of these risks. For example, if the subcontractor knowingly decides not follow the necessary safety procedures when climbing a ladder, it can be considered a **relational risk** due to poor cooperation on the part of the subcontractor. In contrast, if the subcontractor is unaware of the need to utilize safety equipment, it can be considered a **performance risk**. And finally, should either the relational or performance risk result in a hazardous situation to the employees and hence an event due to non-compliance with the standards set by governmental or regulatory authorities, then this may also lead to an additional **compliance and regulatory risk**.

Risk 5: Scheduling conflicts

As experienced by Aida (P10, Facility A In-charge of Exploitation Contract, CEA, Interview IP10Int1, *5) and discussed by Edgar (P07, Facility A Manager, CEA, Interview IP07Int3), Gotterdamm (P03, Occupational Safety Manager of the Nuclear Safety and Occupational Safety Department and later the second Facility B Manager, CEA, Interview 2P03Int1), Suor (P02, Chief of the “Change of Subcontractor Project, Interview 2P02Int1), and described in the Observation notes (Technical observation, ITO-1, *6), the challenge of co-activity is trying to co-ordinate simultaneous actions so that there is no incompatibility between the actions. As a result, one of the main risks of co-activity is an

accident from either a health and safety perspective or from a nuclear safety point of view. In the first case, an accident from a health and safety perspective may occur if two or more worker are not aware of each other (do not see each other) and this causes an accident. In the second case, an accident from a nuclear safety point of view may occur if a worker is using the safety equipment and then another person starts working in the same area and requires the same safety equipment at the same time, creating a problem.

Work executed at all nuclear facilities requires careful planning to ensure the safety of all workers. The planning becomes more intricate when several activities are required on the same day, those which may involve one or more subcontracting teams; this is the case of “Co-activity”. As indicated in the Observation notes for Facility A (*Technical observation, ITO-1, *6*), there is a weekly co-activity meeting scheduled every Friday with the intention of avoiding co-activity issues. However, manipulations that were initially intended to take place on a different day were delayed, creating an unforeseen co-activity issue. Such a potential co-activity situation that can be classified according to all three risks: In the first, the subcontractors do not apply the appropriate procedures as they are unaware of each other, yielding a ***relational risk*** that may result in a potential health and safety event. In the second, we can identify a ***performance risk*** due to a lack of resources that do not allow the attainment of predetermined results as both subcontractors require the same tool. And finally, both cases represent situations outside of the normative framework (health and safety or nuclear safety) that may lead to an event, thereby yielding a ***compliance and regulatory risk***.

A summary of the several, non-exhaustive, subcontracting-related risks are presented in the Table 11 in subsection 1.4.3 below. The table shows that in the case of four of the five risks, any given situation can be classified as more than one type of risk based on the motivations of the subcontractor and the severity of the situation. For example, Risk 2 can be classified as a performance risk that can lead to compliance and regulatory risk. Similarly, Risk 4 and Risk 5 can be classified as a *relational or performance risk*, any of which can yield a *compliance and regulatory risk*. As a result, one particular situation can yield numerous risks according to the definitions provided in the literature.

Based on the risk examples provided above, a new definition of subcontracting related risks has been developed. This definition is an appropriation of the current risk definitions from the literature detailed in Chapter 1 and that account for the particularities of the French nuclear industry. As a result, Figure 34 below details the specifics of Compliance and Regulatory Risk (RNC), Relational Risk (RR) and Performance Risk (RP) at the facilities of the CEA.

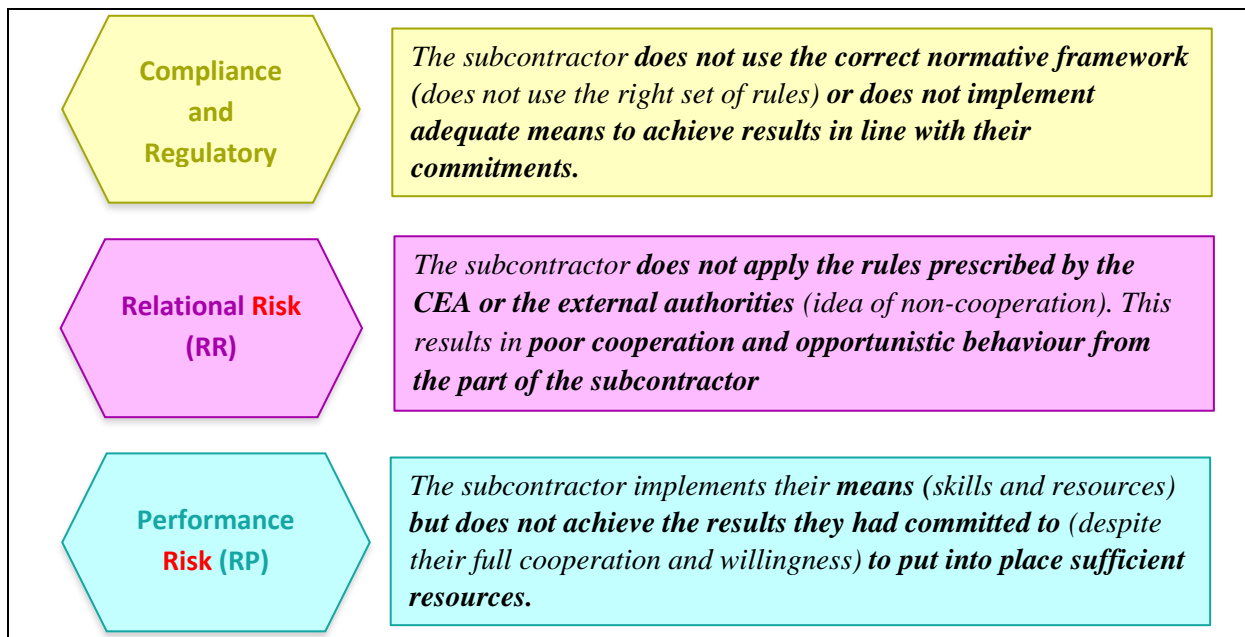


Figure 34. Definition of the three Subcontracting Related Risks in the Industrial Context

All of the aforementioned risks are present during the entire life cycle of a contractual subcontracting-CEA relationship; however certain of the risks such as the first three risks detailed above appear to be exacerbated by the organizational distance between two entities of the contractor-subcontractor relationship. This distance between the two entities peaks at two periods during the life cycle of the relationship: at the beginning during the transition process between two subcontractors when the subcontracting firm and the CEA begin a contractual partnership and at the end of the contractual relationship when the subcontractor must impart their competences and knowledge onto the incoming firm that will become their successor.

The development and implementation of control measures such as both formal and informal control mechanisms enable managers to reduce these risks while strategically obtaining operational and safety results. However, these controls mechanisms contain limits since most are based on the observation and evaluation of the elements declared by the subcontractor as the contractor is not physically present to observe and evaluate all the safety behaviors.

The following sections present the 24 MCS employed at the CEA and show how these MCS are used to avert and mitigate the subcontracting-related risks presented above.

1.2. Identification of 24 MCS common to Facility A, Facility B and Facility E

A total of 24 MCS common to each facility A, B and E were identified. Initially, only 19 MCS were identified in during phase 2-5 at Facility A, and later an additional five MCS were observed at Facility B during the immersions of phase 5-8. The 5 additional MCS were not initially observed at Facility A due to the timing of the visits that coincided with the transition process between two subcontractors; however, they were later confirmed to also be present at Facility A. There were additional MCS that were excluded from the final 24 as they were only present in Facility A, which despite its smaller size

had a greater quantity of MCS. The final 5 MCS identified in Facility B (*Mastery of Transportation; Task Preparation (Safety Minute and Pre-job Briefing); Integration of Return of Experience (REX); Verification of Procedure validation (stopping points); and Debriefing Activities*) are found underlined in the table below.

The 24 MCS were categorized into *three types of clusters* that followed the same lines indicated by the inter-organizational control literature: (1) *Social Control* that develop shared values, beliefs and goals between the subcontracting and contracting firm; (2) *Behaviour Control* that measure behaviours; and *Output Control* that measure the outcomes of the behaviours. Table 10 below provides an overview of the classification, where eight controls were categorized as **Social Controls** (*CS1, CS2, CS3, CS4, CS5, CS6, CS7, CS8*), eleven controls were identified as **Behaviour Controls** (*CC1, CC2, CC1-2bis, CC3, CC4, CC5, CC6, CC6bis, CC7, CC7bis, CC8*), and five controls were found to be **Output controls** (*CR1, CR2, CR3, CR4, CR5*).

Table 10. Categorization of the 24 MCS identified in both facilities A and B into formal and informal controls

Informal Controls	Formal Controls	
Social Controls (CS)	Behaviour (CC)	Output Controls (CR)
Health and Safety Training (<i>CS1</i>)	Authorizing Staff Access (barrier) (<i>CC1</i>)	Performance Tracking (<i>CR1</i>)
Nuclear Safety Training (<i>CS2</i>)	Authorizing Staff Access (no barrier) (<i>CC2</i>)	Radioprotection Verification (1st Level) (<i>CR2</i>)
Document Management (<i>CS3</i>)	Verification of Authorized Staff Access (Manager) (<i>CC1-2bis</i>)	Radioprotection Verification (2nd Level) (<i>CR3</i>)
Co-activity Management (<i>CS4</i>)	Health and Safety Inspection (<i>CC3</i>)	<u>Verification of Skills post-training (<i>CR4</i>)</u>
Mastery of Transportation (<i>CS5</i>)	Nuclear Safety Inspection (<i>CC4</i>)	<u>Debriefing Activities (<i>CR5</i>)</u>
Health and Safety Exercises (<i>CS6</i>)	Verification of conformity with regulations (<i>CC5</i>)	
<u>Task Preparation (Safety Minute and Pre-job Briefing) (<i>CS7</i>)</u>	Conducting Stopping points (<i>CC6</i>)	
<u>Integration of Return of Experience (REX) (<i>CS8</i>)</u>	<u>Verification of Parameters (during stopping points) (<i>CC6bis</i>)</u>	
	Performing Daily Facility Round (<i>CC7</i>)	
	Verification of the Daily Facility Round (<i>CC7bis</i>)	
	Performing Monthly Round (<i>CC8</i>)	
8 Social Controls (CS) in Total	11 Behaviour Controls (CC) in Total	5 Output Controls (CR) in Total

The specificities of each of these 24 MCS is described below. Please note that the term “Manager”, unless it is specified, may refer to both Middle Manager or CEA Manager, depending on the Facility configuration.

Health and Safety Training (CSI): Managers provide Health and Safety Training to subcontractors to transmit knowledge of the safety regulations for the facility. Such training includes information on potential risks and safety hazards, as well as the manner these risks/hazards are averted and/or mitigated.

Nuclear Safety Training (CS2): Managers dispense Nuclear Safety Training that informs subcontractors of the Nuclear Safety elements in the Facility. Such trainings occur during the safety week, and during monthly training sessions. These training sessions utilize presentations and exercises to ensure subcontractors understand that failure to follow safety rules or deviations from safety requirements may result in events.

Document Management (CS3): Managers meet with subcontractors to indicate changes to the Standard Operating Procedures of a particular task and discuss any concerns or unforeseen difficulties of such changes. This ensures that the changes are reflected in future tasks.

Co-activity Management (CS4): Managers conduct co-activity meetings that program the daily or weekly activities to ensure no conflict between the activities that will take place at the same place and the same time. This meeting ensures the compatibility of the teams working in parallel in the same area over the following day/week thus avoiding miscommunication and potential risks.

Mastery of Transportation (CS5): Preparation of the reception or the dispatch of nuclear waste barrels. This includes the reception and dispatch of waste barrels to and from the facility, as well as the transportation of waste barrels within the facility during the treatment or modification of waste where applicable.

Health and Safety Exercises (CS6): Managers conduct surprise Health and Safety exercises and simulations (occupational safety accident, fire in a building) to ensure that subcontractors respond adequately to emergencies and potential events. Subcontractor reactions are evaluated, and any inappropriate gestures are discussed and corrected.

Task Preparation (Safety Minute and Pre-job Briefing) (CS7): Managers discuss the upcoming daily tasks by detailing potential risks, safety points, and past experiences from previous times the tasks were performed. This may include the information obtained during the Integration of the REX (CS8).

Integration of Return of Experience (REX) (CS8): Manager prepares the Task Preparation (Safety Minute and Pre-job Briefing CS7), the Mastery of Transportation (CS5) or Training Sessions (CSI, CS2, CS6) by integrating the REX obtained from previous debriefs carried out at the end of the tasks.

Authorizing Staff Access (barrier) (CCI): Managers authorize staff access to certain areas of the nuclear facility with a physical barrier (bridges, ladders, roofs, examination cell for red zone). This

ensures that subcontractors do not have access to dangerous areas that can cause an Occupational Safety and a Nuclear Safety Risk. Subcontractors must obtain from a Manager the key to cross these barriers.

Authorizing Staff Access (no barrier) (CC2): Managers authorize the staff access to a zone without a physical barrier every time someone enters the facility. This MCS uses a document indicating each person must present themselves to the shift supervisor's office when arriving at the Facility. The SPR will also verify that the person is registered into the visitors' notebook.

Verification of Authorized Staff Access (Manager) (CC1-2bis): Manager verifies that the subcontractor is authorized to enter an area with a barrier in the case of CC1 providing the appropriate key for the barrier or in the case of CC2, providing authorization to the subcontractor to enter the no barrier zone. This verifies that the subcontractor can have access to this normally restricted area. This control is a verification of both CC1 or CC2.

Health and Safety Inspection (CC3): Managers perform Safety Inspections of the identified risks within the Facility. This consists of a visual inspection that when a deviation is detected, the task is halted, a measurement of the deviation is made immediately, and the gap between the expected value and the measured value is conveyed to an upper CEA Manager depending on its severity, who authorizes the continuation or not of the task. A weekly report summarizes the deviations that occurred during the week.

Nuclear Safety Inspection (CC4): Managers inspect the conformity of actions carried out by the subcontractor in line with Nuclear Safety measures and ensures they are in line with the Nuclear Safety elements within the General Operating Rules of the Facility.

Verification of conformity with regulations (CC5): Managers verify the conformity of tasks carried out by the subcontractors against the Standard Operating Procedures for those tasks.

Conducting Stopping points (CC6): Subcontractors carrying out the task, check the parameters when the stopping points appear on the Standard Operating Procedure Document. For example, this may include double checking all of the previous procedures and/or measuring a physical or objective criterium. Once the subcontractor has completed conducting this assessment, the subcontractor requests that for a Manager to carry out the CC6bis control stated below (procedure verification, validation and signature of a Manager before continuing with the rest of the procedure)

Verification of Parameters (during stopping points) (CC6bis): Managers verify the parameters during the stopping points. This includes a verification of the procedure and the validation of the task with a signature (in the form of a visa on the Standard Operating Procedure document), that allows the subcontractor to continue with the task.

Performing Daily Facility Round (CC7): Subcontractors perform the daily round by following the pre-determined circuit and note the Facility parameters on the Daily Round Document that are handed to the Manager at the end of the day.

Verification of the Daily Facility Round (CC7bis): Managers verify the Daily Round Document to confirm both the daily round was completed correctly and that the parameters registered comply with those that have been pre-defined.

Performing Monthly Round (CC8): CEA Managers perform monthly round to verify the parameters of the facility. These parameters are compared to the parameters provided by the subcontractor during the Daily Facility Rounds (CC7).

Performance Tracking (CRI): Managers verify that budget commitments are met (cost tracking, tasks performed, deadlines achieved, remaining budget) using a computer tool that analyzes and calculates real-time performance indicators. This tool tracks the subcontractors' progress to discuss inconsistencies during monthly monitoring meetings.

Radioprotection Verification (1st Level) (CR2): First level of verification to ensure the non-contamination of subcontractor and CEA staff garments (clothing) carried out by the TQRP, prior to being sent to the laundry for cleaning. Each garment is verified individually prior to being placed within a bag that will later be verified by a 2nd Level verification (CR3).

Radioprotection Verification (2nd Level) (CR3): Second level of verification using a Gamma Detector carried out by the SPR or TQRP to ensure that the bag containing the garments is not contaminated. The Gamma detector therefore detects both potential contamination of the surface and the contents of the bag.

Verification of skills post-training (CR4): Managers verify the skills and certificate acquired during the training sessions to authorize subcontractor to use the equipment (Bridge, etc.).

Debriefing Activities (CR5): Following the completion of the task, Managers conduct a debrief session with the subcontractors to discuss inconsistencies or issues identified by either the Manager or the subcontractor during the task. The information provided will be included in the Return of Experience (REX) and integrated into the next time the task is performed; referred to as the Integration of Return of Experience (CS8).

Based on the categorization of the control examples above, a new definition of the three types of MCS is proposed. This definition is an appropriation of the current MCS definitions from inter-organizational control literature accounts in the French nuclear industry. As a result, Figure 35 below details the specifics of Social Control (CS), Behaviour Control (CC) and Output Control (CR) at the CEA.

1.3. A new definition: Appropriation of the MCS in the Industrial Context

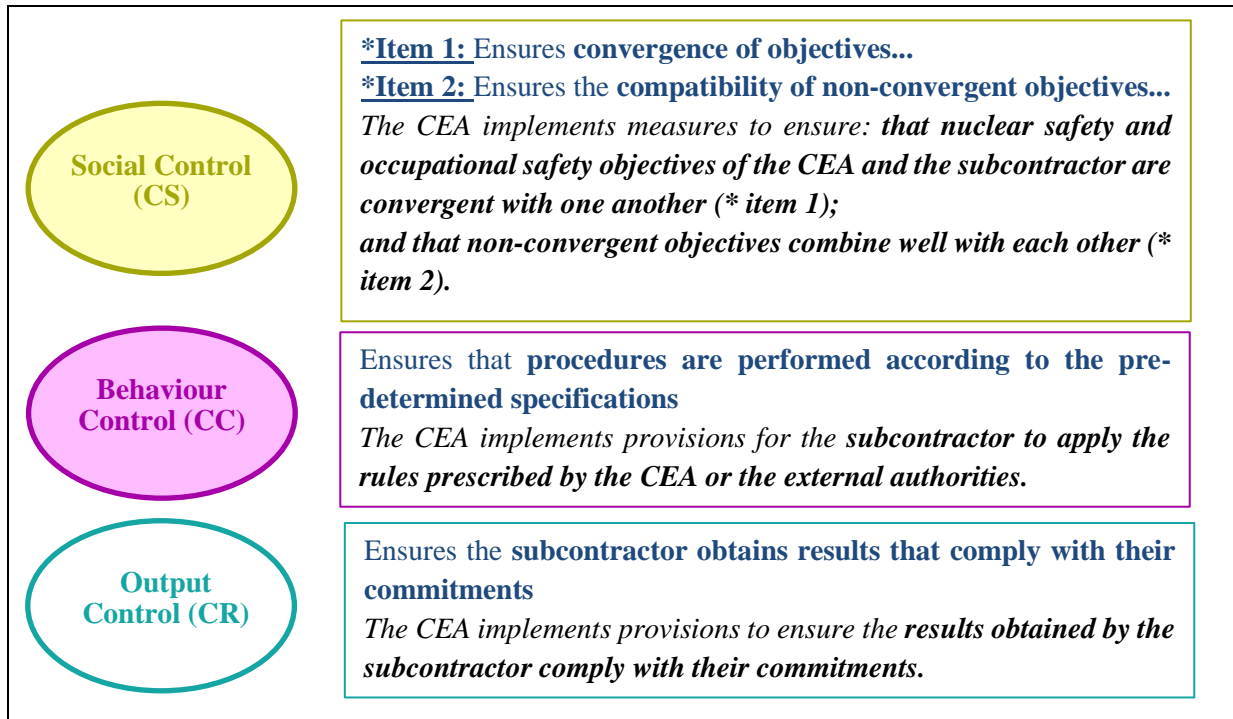


Figure 35. Definition of Social Control (CS), Behavior Control (CC) and Output Control (CR) in the French Nuclear Context.

The 24 managerial controls stipulated above are used in the CEA facilities to avert and mitigate the risks described in section 1.1, yielding a type of control-risk coupling. The following section provides clarification on the type of risks and the kinds of controls that are coupled at the CEA.

1.4. Identification of control-risk couplings at the CEA

The following section presents three main types of control – risk couplings. Social Controls on their own which appear to avert all three types of risk; Behavior Controls and social control used to avert and mitigate mainly relational risks; and Output Controls and social controls used to mitigate mainly performance risk.

1.4.1. Control- Risk Coupling 1: Social Control – Relational Risk, Performance Risk and Compliance and Regulatory Risk

Scheduling conflicts (Risk 5) - Co-activity Management (CS4)

Co-activity meetings aim to minimize temporal impediments and special constraints between subcontracting teams during daily operations. As experienced by Elektra (P06, Facility A Occupational Safety Engineer, CEA, Interview IP06Int2, *7), the co-activity meeting every Friday anticipate the following week's interventions. Should several companies intervene at the same place and time, barriers and other compensatory measures are taken including organizational procedures, controls, and physical barrier.

This type of *social control* ensures the CEA has an overview of all the activities performed during that

week, thus minimizing potential planning and scheduling conflicts that could occur if the subcontractors were left to organize the work among themselves and other external entities. In fact, **Co-activity Management (CS4)** can thus minimize all three risks, including:

- (1) Non-compliance of regulations leading to potential occupational accident or a nuclear safety event (**compliance and regulatory risk**)
- (2) The non-application of rules due to a congested working area (**relational risk**)
- (3) Any potential scheduling conflicts that may result in not obtaining results due to a lack of resources (**performance risk**)

1.4.2. Control Risk Coupling 2: Behavior Controls and Social Control used to avert and mitigate mainly relational risks

Non-application of rules (Risk 4) – Health and Safety Inspection (CC3)

Occupational safety Assistant Manon (P08) and the Occupational safety Engineer Elektra (P06) perform daily **Health and Safety Inspection (CC3)** to ensure both the CEA personnel and the subcontracting personnel are following the appropriate occupational safety and safety regulations (prevention of **RNC4, RR4, RP4**). All of these rules were initially detailed by Elektra to the subcontractors during the **Task Preparation (Safety Minute and Pre-job Briefing) (CS7)** and by the annual **Health and Safety Training (CSI)** and **Health and Safety Exercises (CS6)**.

As experienced by Manon (P08, Facility A Occupational Safety Assistant, Subcontractor, Interview IP08Int1, *8), when a rule is broken, the subcontractor is asked to stop the activity and is asked why the rule was not followed. An event report detailing the event and deviation from the appropriate practices is signed by both Edgar (P07) the Facility Chief and by Elektra (P06) the Occupational Safety Engineer.

Two types of control mechanisms were experienced by Manon (P08, Facility A Occupational Safety Assistant, Subcontractor, Interview IP08Int1):

- (1) **Social controls** in the form of training, exercises and task preparation, that aim to develop a common safety culture between the subcontracting firm and the CEA, thereby encouraging desirable behaviors (prevention of **relational risk**) and performance outcomes (prevention of **performance risk**) through the remainder of established organizational safety norms and safety values. Through extensive training and reminders of nuclear safety and occupational safety measures, subcontractors continue to comply with regulations, thereby avoiding any potential **Compliance and Regulatory Risks**.
- (2) **Behaviour Control** in the form of the daily health and safety inspection that aim to measure behavior and the process of the tasks as they are being performed, thus ensuring that the subcontractor co-operates and applies the rules prescribed by the CEA (preventing any **relational risk**).

Non-transfer of Information (Risk 1)- Ongoing behaviour and Social controls

Aida (P10) utilises real-time monitoring and obtaining ongoing feedback/information to identify and rectify any *non-cooperative relational risk* such as the reluctance to provide documents or information on the part of the subcontractor (**Risk 1**). Since **Behaviour Controls** require the actor performing the control to be physically present during the action, this ensures that each phase of an activity is performed correctly and according to predetermined procedures. This allows for deviations from the established rules to be identified through the process and rectified immediately. This requires Aida, in charge of the contract in Facility A, to be vigilant and ensure that the necessary documents and information are correctly transferred between the outgoing and incoming subcontractor, passing through the CEA. Additional **Social Controls** may also ensure a convergence of objectives or a compatibility of non-convergent objectives with the transfer of information between the CEA and the subcontractor.

1.4.3. Control- Risk Coupling 3: Output Controls and social controls used to mitigate mainly performance risk

Non-adherence to pre-established costs (Risk 3) – Performance Tracking (CR1)

Edgar (P07, Facility A Chief, CEA Meeting 1FM-2), the Facility A Chief ensures the subcontractors adhere to the pre-established costs (detection of **Risk 3**) through the use of a **Performance Tracking (CR1)** tool that monitors monthly tasks. This excel document allows Edgar to verify the monthly costs of the subcontractor and illustrates the tasks completed, the delays obtained and calculates the amount of money still available during the remaining time of the contract (5 years total). This tool is a form of **output control** as it measures the monthly cost as a form of results obtained and not the process used to obtain them, thereby helping the manager to “focus on key performance measures and react to changes”. This control mechanism minimizes the **performance risk** because it monitors the monthly costs of the service providers and ensures compliance with the financial performance factors detailed in the contract. This output control thus minimizes the non-adherence to the pre-established costs in the contract.

Non-transfer of knowledge and know-how (Risk 2) – Verification of Skills post-training (CR4)

In order to ensure that the subcontractors have the required knowledge and skills to obtain results in line with the commitments, Aida employs the use of controls such as **Verification of Skills post-training (CR4)**; in addition to the behaviour controls (*Verification of Conformity with regulations CC5* and *Verification of Parameters (during stopping points) CC6bis*). Typically, the combination of these controls ensures that the subcontractors possess the capabilities to obtain results (prevention of **Risk 2**). Nonetheless, there are times when the duration of the transition process between two subcontractors does not allow for all of the totality of the exchanges or when subcontractors experience a loss in skills of rarely executed procedures. As a result, ongoing **social controls** such as training sessions programmed throughout the entirety of the contract (and not merely at the beginning during the change of contractor

period) can help ensure that knowledge and skills are maintained. These training sessions may also provide a space where CEA can address subcontractors' questions or concerns pertaining to particular procedures. These training sessions allow the subcontractor to gain confidence in their abilities and may reduce the distance between the subcontracting and the CEA.

Table 11 below provides a summary of the five risks and the types of controls used to mitigate each of these risks.

Table 11. Summary of the Risks and the types of controls used to mitigate these risks.

Type of Risk	Compliance and Regulatory Risk (RNC)	Relational Risk (RR)	Performance Risk (RP)	MCS used to Mitigate Risks
Non-transfer of Information (Risk 1)		Reluctance to provide information	Incomplete transfer of information	(CS) (CC)
Non-transfer of Knowledge and know-how (Risk 2)	Significant event due to loss of knowledge and skills from the transition process between two subcontractors		Loss of knowledge and skills due to a bulk turnover rate	(CS) (CR)
Non-adherence to pre-established costs (Risk 3)			Non-adherence to pre-established costs	(CS) (CR)
Non-application of Rules (Risk 4)	Non-compliance with safety regulations (unwilling or unaware)	Unwillingness to follow safety procedures while working from a height.	Unawareness of a safety rule and need for safety measures while working from a height.	(CS) (CC)
Scheduling conflicts (Risk 5)	Occupational Safety or nuclear safety accident due to co-activity planning errors	Non-application of rules and potential safety issues due to co-activity planning errors	Lack of resources or tools leading to a non-abstention of results (co-activity issue)	(CS)

In general, in spite of the type of risk present in the CEA facilities, we observe that **social controls** are either: (1) *used on their own* to mitigate all three subcontracting related risks (relational risk, performance risk or compliance and regulatory risk); (2) coupled with behaviour control, in a *social and behaviour control duo* to mitigate relational risks; or (3) coupled with output control in a *social and output control duo* to mitigate performance risk.

Nonetheless, there are instances throughout the life of a nuclear facility where despite the combination and execution of controls, risks occur demonstrating and putting into question the effectiveness of the MCS at the CEA. The following section discusses several of these particular instances and compares the effectiveness of the 24 MCS in Facility A, B, and E.

1.5. Effectiveness of MCS in preventing or detecting subcontracting related risks.

As indicated previously, subcontracting related risks may arise in spite of the current MCS. Once these risks are perceived, the managers (CEA in Facility A, and **Middle Management** or CEA management in Facility B and E) take the necessary actions to ensure the current MCS are adapted to avoid the perceived risk from re-occurring. As experienced by Derk (*P26, Facility E, RCI support, CEA, Interview 3P26Int2, *9*), the modifications made to the controls differ according to the type and severity of the perceived risk. When the risk results in a near miss or nearly a significant event, then the changes to the MCS often occur immediately, however, when the risk results in a significant event, then the modifications occur following a formal inspection.

With each of the nuclear facilities at the CEA, any significant event is reported to the Internal Audit department at the Centre level known as the Cellule in a C2N control. This Cellule verifies that the facility in question establishes both preventive and corrective actions that will be implemented into the protocols for the facility following a significant event. All of the Facility Chiefs or RCIs within the Centre are then provided with information pertaining to the significant event to verify if the same risk is possible within their facility and to ensure they apply these actions in a preventive capacity.

However, a difference exists in the 3 facilities in how the corrective actions for the near misses or the nearly significant events are conducted:

In Facility A, the controls adapted following a near miss or a nearly significant event can only be conducted by the CEA given they are the sole official level of control within the facility, resulting in a one-tier verification system. The effectiveness of the control for the controllers in Facility A was experienced by Manon (*P08, Facility A Occupational safety Assistant, Subcontractor, Interview 1P08Int1, *10*). This control is based on a continuous verification of the subcontractors' behaviours and constant training exercises and reminders of appropriate protocols in the prevention plan. Specifically, subcontracting risks are categorized into 16 categories, of which Risk Category #6 "not following the rules indicated in the prevention plan" has the most events and is the most difficult risks to control. This is the case when personnel do not follow the rules specified in the prevention plan despite the introductory occupational safety visit, with the first action of breaking the rules occurring approximately 15 days after the rules was specified. Additionally, CEA policy is to point out the presence of dangerous situations even if they do not directly concern you, with aims to reduce the number of risks by increasing the effectiveness of the corrective actions through continuous C1N controls or by encouraging subcontractors to report near misses or dangerous situations. This is accomplished through the twice

daily occupational safety inspections and by way of constant CEA presence; as well as via self-monitoring and feedback of weak signals by all personnel (CEA and subcontractors).

In Facility B, the new procedures or corrective actions adapted after a near miss or a nearly significant event are validated by the CEA with the input of the **Middle Managers** and the subcontractors. As experienced by Masnadieri (*P19, Facility B Nuclear Safety Engineer, CEA, Interview 2P19Int1, *11*), the effectiveness of the current controls or of any corrective actions are largely due to the exchanges and communications between the subcontractors and the CEA. In facility B, these exchanges occur during the entire process: after the risk is detected as the subcontractors and **Middle Managers** are encouraged to propose input for the corrective actions, during the period where the corrective actions are put into place, and after the corrective actions are well in place. Close communication between the CEA and the subcontracting firm is essential once the corrective action is in place, so that any constraints with the new actions may be highlighted. Specifically, **CEA Managers** use the monitoring plan to check the effectiveness of the changes made to the controls. Prior to implementing the new procedures and corrective actions **CEA Managers** discuss with the subcontractor and **Middle Managers**, if these changes will carry constraints. Once the new procedures and corrective actions have been checked by the **Middle Managers**, the CEA is notified that the new procedures have been applied. **CEA Managers** then verify this corrective action was completed via a C1.5N control. However, in the case of corrective actions where a validation did not previously exist, the **CEA Managers** rely on the subcontracting firm to indicate if this new action yields any other constraint; nonetheless at the moment of writing this thesis new constraints in newly established corrective actions have not been identified.

As experienced by Don Carlos (*P16, Facility B QSE Support, Middle Management-Subcontractor, Interview 2P16Int1, *12*) once the newly adapted controls have been implemented into the facility protocols, the new corrective controls are determined effective once the risk is no longer present: once the actions have been cleared off the monitoring plan/ platform and once the subcontractor has settled any remaining actions). The effectiveness of these corrective action is verified once again the following year during the 2 day ‘Participative Occupational safety Visit’ during which the subcontractors inform the **Middle Managers** of any issues. This information is then transferred onto the CEA.

In Facility E, the controls adapted following a near miss or a nearly significant event are often proposed by the **Middle Managers** and then verified or re-adapted by the CEA. As experienced by Derk (*P26, Facility E RCI support, CEA, Interview 3P26Int2, *12*), during C1N controls at Facility E, the **Middle Managers** perform a control on the tasks and if they find non-conformities, they establish corrective actions. These corrective actions (established by the **Middle Managers**) are verified by **CEA Managers** during a C1.5N control to determine if they are appropriate and whether complementary actions need to be established. As experienced by Foscari (*P27, Facility E Production Manager, Middle Management-Subcontractor, Interview 3P27Int1, *13*), **CEA Managers** do not carry out day-to-day controls, but instead carry out weekly meetings that initially resulted in a delay of when the information of a near

miss or the inefficiency of the control reached the RCI because **Middle Managers** were first working to first solve the problem. This issue was subsequently corrected with the creation of an **intra-organizational** software system (created by the subcontracting firm) that allows subcontractors at any level to inform **Middle Managers** of any minor events or concerns, which are then filtered by **Middle Management** and decided (or not) passed onto the CEA. This software tool (internal electronic form) will be discussed in section 3.3 and 3.5 of this Chapter.

As a conclusion of this section, each facility has its own variant of who designs, implements and enforces corrective actions for near misses within the facility. These variants depend on the number of levels of control (one-tier verification for Facility A, and two-tier verification for Facility B and E), and the active presence and hence implication of **CEA Managers** in the facility. These variants impact how each facility views and ensures the effectiveness of these corrective controls. Part two of this chapter details additional variants of MCS in the form of 12 defining characteristics and shows how these variants interact with each other to yield two natures of control.

Summary of the Results for Section 1

The first section identifies several subcontracting-related risks and shows the control-risk couples that are implemented across the 3 facilities (A, B and E) to mitigate these risks. The following summarizes the findings from Section in five subsections.

Sub-section one identifies examples of quasi-integration risk at the CEA that can be categorized into one, two or all three types of inter-organizational risks (*relational, performance, and compliance and regulatory risk*) based on the motivation of the subcontractor and the severity of the situation. New definitions for the aforementioned risks are proposed to account for the particularities of the French Nuclear Industry:

- ***Compliance and Regulatory Risk*** occurs when the subcontractor *does not use the correct normative framework (does not use the right set of rules) or does not implement adequate means to achieve results in line with their commitments.*
- ***Relational risk*** occurs when the subcontractor *does not apply the rules prescribed by the CEA or the external authorities (idea of non-cooperation). This results in poor cooperation and opportunistic behaviour on the part of the subcontractor.*
- ***Performance Risk*** occurs when the subcontractor *implements their means (skills and resources) but does not achieve the results they had committed to (despite their full cooperation and willingness) put into place sufficient resources.*

Sub-section two identifies MCS common to 3 Nuclear Facilities and categorizes them according to the three MCS (social, behaviour, output control) proposed in the IOR literature: (1) ***Social Control*** that develops shared values, beliefs and goals between the subcontracting and contracting firm; (2) ***Behaviour Control*** that measures behaviours; and (3) ***Output Control*** that measures the outcomes of the behaviours.

Sub-section three proposes new definitions for the aforementioned controls that account for the particularities of the French Nuclear Industry:

- ***Social controls*** minimize goal discrepancies between contractor and subcontractor by the establishment of common culture and values. They can be divided into two items: The first requires managers to *implement measures to ensure that nuclear safety and occupational safety objectives of the CEA and the subcontractor are convergent with one another (* item 1)*; and the second *requires measures that ensure that non-convergent objectives combine well with each other (* item 2)*.
- ***Behaviour Control*** ensures that *procedures are performed according to the pre-determined specifications*.
- ***Output Control*** ensures the *subcontractor obtains results that comply with their commitments*.

Sub-section four identifies control-risk couplings used to mitigate the risks identified in Subsection one. There is a preference for certain types of controls to mitigate certain types of risks. These Control-risk couplings highlight the predominance of informal controls (Social controls) which have the capacity to mitigate all three categories of subcontracting-related risk (*relational risk, performance risk or compliance and regulatory risk*) ***on their own*** or can ***be coupled*** with the other two types of control (Behaviour Control or Output Control) to effectively mitigate all three types of risks. Specifically, Social control when coupled with behaviour control mitigates relational risks, while social and output control mitigates performance risk. This combination of an informal and a formal control yields a balance of preventive and detective ago-antagonistic poles (see Section 2.2 and 2.4).

Sub-section five identified how each of the three Facilities implements and enforces corrective actions in the form of adaptations to their controls following near misses or nearly significant events. Strategies to design, implement and enforce changes of the MCS, following near misses or nearly significant events, are linked to the Facility's organizational configuration. The Facilities with a ***single level of control*** emphasized inter-organizational control, while the Facilities ***with two levels of control*** emphasized both inter-organizational and intra-organizational control. In the latter case, an emphasis on one type of control (inter vs intra) is dependent on each levels' Managerial active presence and hence the implication¹⁸.

2. Characteristics of the CEA's MCS

This second section explores the characteristics of the MCS used by the CEA and their inter-connectivity in eight-sections. The first sub-section analyses the 24 MCS according to 12 defining characteristics, the second sub-section defines *preventive control* and *detective controls*, the third sub-section discusses

¹⁸ By implication, this thesis refers to the active presence of Managers (CEA Managers and Middle Managers where applicable) on the field.

the temporal aspect of averting an event, the fourth sub-section discusses ago-antagonistic systems in risk management, the fifth sub-section characterises all 24 MCS into 6 cluster groups, the sixth sub-section presents the control cycle, the seventh sub-section highlights the importance of interactive controls, auto-controls and non-interactive controls, and the eighth sub-section presents relay control couples.

2.1. Analysis of the 24 MCS according to 12 defining characteristics

The aforementioned 24 MCS were organized according to 12 defining characteristics that are presented in the form of a table. These 12 characteristics detailed in Figure 36 below, allowed for the 24 MCS to be categorized into three tables according to the type of risk these controls mitigate. The type of activity controlled was described detailing the process of the activity and how the control was carried out (*medium*). The *location* where the control took place, the *frequency* of the control, and the person(s) carrying out the control (*human resource*) were also detailed. Certain controls were carried out by multiple management levels as is the case in Facility B and E, while other controls were only carried out by a single level as was the case in both Facility A, Facility B and Facility E (see section 2.7). The *timing of the controls* with reference to the activity or the action was assessed. The nature of each control (*nature of control*) was explored, with certain controls being used to prevent a risk or an event while others were used to detect any discrepancies in operations and detect any events. The type of risk and hence what we are trying to avoid (*why the control* was carried out) was also described and categorized according to the three types of risks (RCN, RR, RP) mentioned above (1.1) All of the controls used to prevent risks (*preventive control*) were grouped and placed in the upper half of the page, while those controls used to detect risks or events (*detective control*) were grouped in the lower part of the page. A definition of both *preventive control* and *detective controls* is proposed in the next section (1.2). Each control was then rated in terms of their *effectiveness* to avert (*preventive control*) or mitigate (*detective control*) the particular risk. More precisely, in the case of a *preventive control*, “does the control limit the risk?”, and in the case if a *detective control*, “how efficient is the control in mitigating the risk?” When the control was found to contain limits and not be effective, *improvements were proposed*; specifically, what resources (human, technical and budgetary) need to be put into place in order to resolve the limits and the inefficiencies of the current control. Finally, each control was analyzed *in reference to the other risks and controls* to determine if it was effective at averting or mitigating any of the other risks and whether it was closely linked to any of the other controls.

Categorisation of the 24 MCS according to 12 characteristics

- **Medium:** *What is controlled and how? (tools, special procedures)*
- **Location:** *Where? (Office / field)*
- **Frequency:** *How often? (frequency of control)*
- **Timing:** *When are the controls performed with reference to the task?*
- **Human Resource:** *Who controls? (only one person, one team)*
- **Direction:** *Is the control descending, ascending or lateral?*
- **Technical Resource:** *What technical resources are used to control?*
- **Type or Nature of Control:** *Prevention or Detection of which task?*
- **Why the control:** *What are we trying to avoid? What risk? (RNC, RR or RP, other?)*
- **Effectiveness of the control:** *Does it limit the risk? How efficient is the control in mitigating the risk?*
- **Improvements Proposed:** *What resources (human, technical, and budgetary) are missing to resolve the limits of current control?*
- **In reference to other risks and controls:** *Is there a second or third risk that is avoided with this control? How is this control linked to the other risks? Is this control linked to the other two controls?*

Figure 36. Twelve Characteristics of the 24 MCS used at Facility A, Facility B and Facility E

The MCS were grouped into three tables according to the type of control: Social controls, Behaviour Controls, and Output Control.

Through the classification of the aforementioned MCS according to the 12 characteristics, two natures of control emerged: *control for prevention* and *controls for detection*. *Preventive controls* aim to avert risks while *detective controls* aim to identify deviations and mitigate risks. Further analysis of these two categories in Facility A, Facility B and Facility E revealed several contrasting factors between *preventive control* and *detective control*, and their links to social, behaviour and output controls. Table 12 below categorizes the 24 MCS into preventive or *detective control* and details the frequency of the controls. Controls categorized as low frequency are those used on a monthly or yearly base, while high-frequency controls are used on a daily or weekly basis.

Facility A, B, and E used the same frequency of controls (daily, weekly, monthly, yearly) for most of the 24 MCS (either low/low/low or high/high/high), with five minor exceptions (*CS3*; *CS4*, *CS6*, *CS7* and *CC8*) according to the timing in which the overall frequency of the controls remained the same (low/low/low or high/high/high) and five significant exceptions during which the controls changed in overall frequency amongst the facilities (*CS1*; *CC3*, *CC5*, *CC6* and *CC7* highlighted in Table 12). Each of the minor and major exceptions are detailed below.

More specifically, the five minor exceptions include:

Document Management (CS3) remained a low-frequency control in all facilities; however Facility A and E had yearly formal document management meetings, while Facility B employed monthly document meetings; yielding the same overall low frequency.

Co-activity Management (CS4) remained a high-frequency control in all facilities; however Facility A¹⁹ used this control weekly while Facility B and E used this control both daily and weekly; yielding the same overall high frequency.

Health and Safety Exercises (CS6) remained a low-frequency control in all facilities; however Facility A and E had yearly health and safety exercises, while Facility B employed monthly training sessions; yielding the same overall low frequency.

Task Preparation (Safety Minute and Pre-job Briefing) (CS7) remained a high-frequency control in all facilities; however, Facility A and B used this control daily, while Facility E used this control weekly; yielding the same overall high frequency.

Finally, the five major exceptions include:

Health and Safety Training (CS1) in Facility A and E were used at a low frequency (annually), while the same social control was used at a high frequency (weekly) at Facility B; yielding a significant difference in overall frequency.

Health and Safety Inspection (CC3) in Facility A was performed at high frequency (daily), while this same behaviour control was used at a low frequency (monthly) in Facility B and E; yielding a significant difference in overall frequency.

Verification of Conformity with Regulations (CC5) in Facility A and B was performed at high frequency (daily), while this same behaviour control was used at a low frequency (monthly) in Facility E; yielding a significant difference in overall frequency.

Conducting Stopping points (CC6) in Facility A and B was performed at high frequency (daily), while this same behaviour control was used at a low frequency (monthly) in Facility E; yielding a significant difference in overall frequency.

Verification of Parameters (during stopping points) (CC6bis) in Facility A and B was performed at high frequency (daily), while this same behaviour control was used at a low frequency (monthly) in Facility E; yielding a significant difference in overall frequency.

Performing Monthly Round (CC8) remained a low-frequency control in all facilities; however, Facility A and B had monthly facility rounds, while Facility E employed bi-annual facility rounds; yielding the same overall low frequency.

¹⁹ Co-Activity Management (CS4) for Facility A in 2021 is performed both weekly and daily. Nonetheless, for the purposes of this thesis where Facility A was observed, CS4 was performed weekly.

Overall, **Facility A** appears to employ **behaviour control** at a *greater frequency* compared to Facility B and E, **Facility B** employs **social controls** at a *greater frequency* than Facility A and E, while **Facility E** employs both social and Behaviour Controls at a lower frequency compared to Facility A and B. Facilities A, B and E appear to employ **output controls** at *the same frequency*.

Facility A, B, and E exhibited the same nature of controls for all of the 24 MCS. In all facilities:

Social controls were found to be entirely *preventive in nature*.

Behaviour Controls were found to be both *preventive and detective in nature*.

Output controls were found to be entirely *detective in nature*.

A more detailed definition of *preventive control* and *detective controls* is discussed in section (2.2). The definitions provided in the next section were initially created following the field immersions in Facility A and was then re-defined, attuned and validated following the field immersions in Facility B and again during the interviews with members of Facility E.

Table 12. Description of the nature (preventive or detective) and the frequency (low or high) of the 24 MCS at the CEA.

Frequency and Nature of MCS at Facility A, B and E								
Type of Control	Management Control System (MCS)	Nature of Control in Facility A, B & E		Facility A		Facility B		
		Preventive Control	Detective Control	Frequency of MCS (High/Low)		Frequency of MCS (High/Low)		
Informal Controls	Health & Safety Training	CS1	✓		Yearly	Low	Yearly	Low
		CS2	✓		Yearly	Low	Yearly	Low
		CS3	✓		Yearly	Low	Monthly	Low
		CS4	✓		Weekly	High	Daily	High
		CS5	✓		Weekly	High	Weekly	High
		CS6	✓		Yearly	Low	Monthly	Low
		CS7	✓		Weekly	High	Daily	High
		CS8	✓		Daily	High	Daily	High
	Frequency of Social Controls	8 Preventive Controls	0 Detective Controls	4 Low & 4 High (CSI : low)	3 Low & 5 High (CSI : high)	4 Low & 4 High (CSI : low)		
Formal Controls	Behavior Controls	CC1	✓		Daily	High	Daily	High
		CC1-2bis		✓	Daily	High	Daily	High
		CC2	✓		Daily	High	Daily	High
		CC3		✓	Daily	High	Monthly	Low
		CC4		✓	Monthly	Low	Monthly	Low
		CC5		✓	Daily	High	Daily	High
		CC6	✓		Daily	High	Daily	High
		CC6 bis	✓		Daily	High	Daily	High
	CC7		✓	Daily	High	Daily	High	
	CC7 bis		✓	Daily	High	Daily	High	
	CC8		✓	Monthly	Low	Monthly	Low	
		Frequency of Behavior / Process Controls	4 Preventive Controls,	6 Detective Controls	2 Low & 8 High (CC3; CC5; CC6 ; CC6bis : high)	3 Low & 7 High (CC3 : low) (CC5; CC6 ; CC6bis: high)	6 Low & 4 High (CC3; CC5; CC6 ; CC6bis : low)	
Output controls	CR1		✓	Daily	High	Daily	High	
	CR2		✓	Daily	High	Daily	High	
	CR3		✓	Daily	High	Daily	High	
	CR4		✓	Daily	High	Daily	High	
	CR5		✓	Daily	High	Daily	High	
	Frequency of Output Controls	0 Preventive Controls	5 Detective Controls	5 High (no change)	5 High (no change)	5 High (no change)		

2.2. Towards new definitions: Description of MCS as Preventive and Detective Controls

MCS are tools that avert and mitigate errors and anomalies. When used correctly, *preventive controls* are very effective as they anticipate and preclude undesirable behaviours. These behaviours can also be identified and corrected (but not averted) by *detective controls*. The sequential presence of *preventive controls* and *detective controls* is dependent on numerous parameters described in Figure 37 below.

MCS as *preventive controls* minimize goal discrepancies between the receptor (subcontractor) and the regulator (contractor) by establishing common culture and values (social controls) and check and verify the behaviour of the subcontractor (Behaviour Controls). They *aim to ensure the performance of a task carried out by the subcontractor during the operating process. This kind of MCS is performed by actors, such as the facility chief or safety officer, who are stakeholders in the task and are entrusted with responsibilities. Preventive controls take place before and during the task.*

MCS as *detective controls* enforce rules, policies, and procedures by checking and verifying the behaviour of the receptor (subcontractor) and their performance. They *aim to detect deviations. This kind of MCS is performed by actors who are not part of the task, but rather these actors take an external view of the task in order to have the most objective view possible when they check for the presence or absence of deviations. The actors carrying out this control verify both the results of the task as well as the modus operandi (method to carry out the task). Detective controls take place during and after the task.*

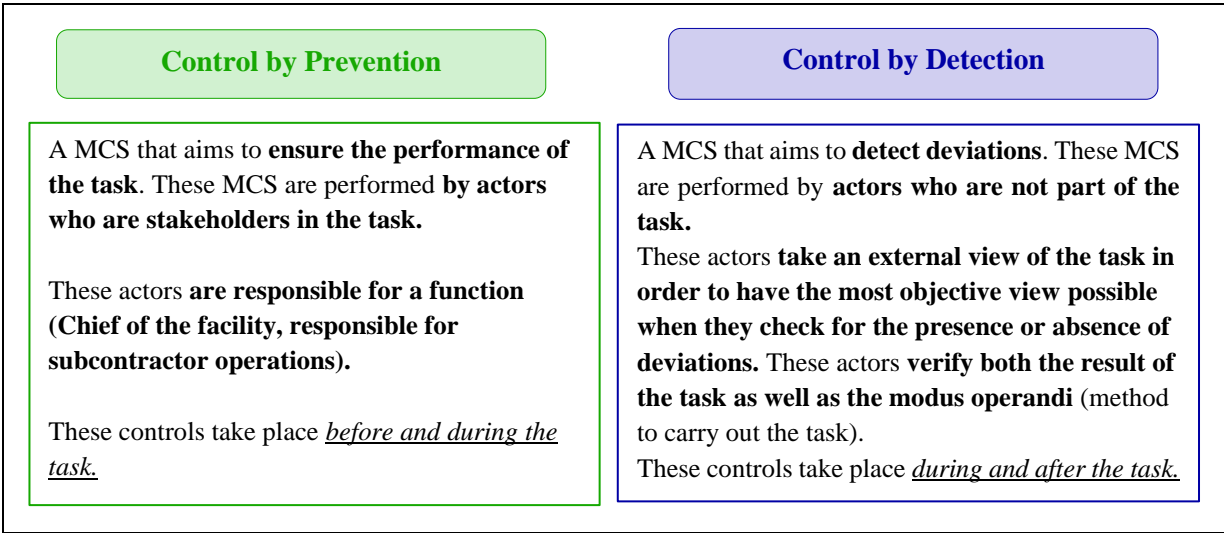


Figure 37. Proposed definition of the nature of the MCS as Preventive and Detective Controls following the analysis of 24 MCS at the CEA

When comparing the definition of *preventive controls* and *detective controls*, the contrast of several characteristics manifest. More specifically, the aim of the control, the description of the MCS, the role of the actors and finally the temporality of the control are all very different. The characteristics of *Preventive control* and *Detective control* are contrasted in Table 13 below.

Table 13. Contrasting Characteristics of MCS as preventive controls and detective controls

Characteristics	Preventive Control	Detective Control
Aim of the MCS	Ensure performance of the task	Detect deviations of the task
Role of the actor performing the MCS	Performed by stakeholders, who hold an internal view of the task. These same actors are entrusted with responsibilities within the operating process.	Performed by actors not part of the task, who hold an external view (objective) when checking for deviations as they are not part of the task.
Temporality	Takes place prior to the task and during the task	Takes place during the task and after the task

2.3. The temporal aspect of averting an event

Events frequently occur either during or after the completion of a task, as a result of the dysfunction that took place during the task. Therefore, the most effective time to control and avoid potential events is either prior to the task (*preventive control*) or during the task (*preventive control and/or detective control*). In contrast, a control that is carried out after the task such as a *detective control* serves to verify results but is futile to prevent potential events given that such controls often take place after the event, therefore are unable to detect and correct the actions that set the event in motion. Nonetheless, once the event is in motion, such *detective controls* are effective in detecting the event (see Figure 38 below).

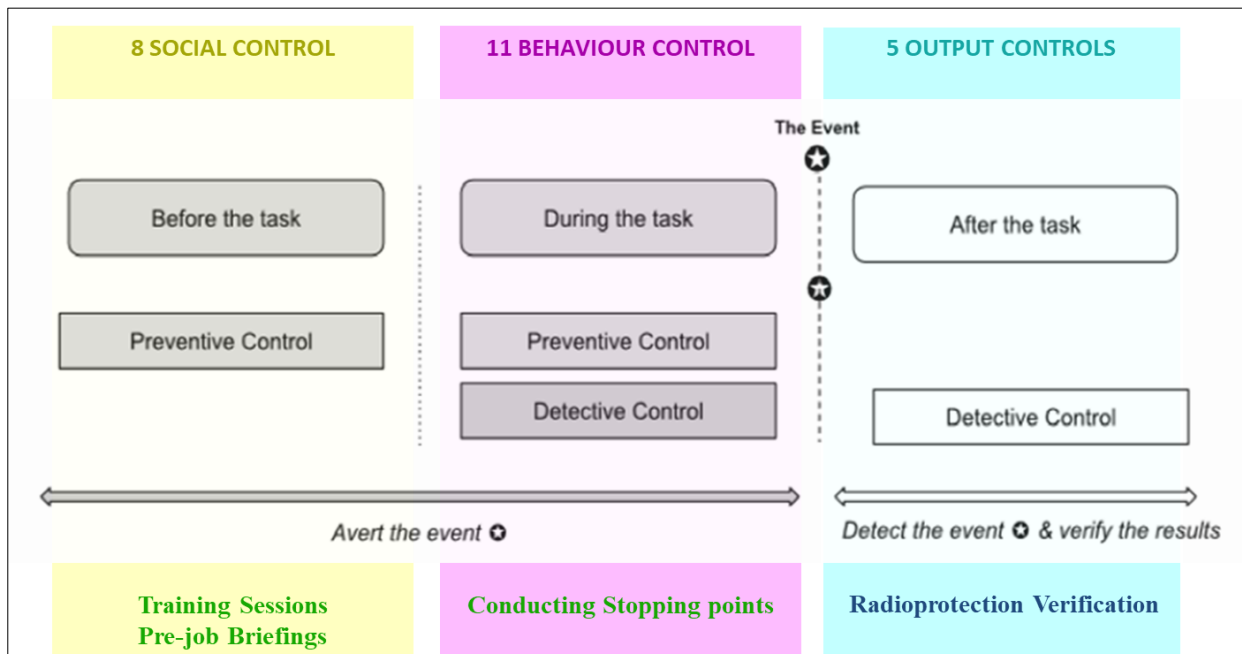


Figure 38. Temporal distribution of an event and the functionality of MCS as preventive and detective controls in averting or detecting the event.

Given the temporal aspects of events and the significance of *preventive controls* and *detective controls*, it is essential to better understand these two natures. Particularly, as the difference in the aim of the

controls (ensure performance or detect deviations) has a significant impact on the controls ability to either avert or mitigate risks and events. The following section looks at the temporal aspects of these two natures from an ago-antagonistic point of view.

2.4. Implications of Ago-antagonistic Systems (AAS) in Risk and Safety

Management

The temporal aspect of risk management and the additional parameters of *preventive controls* and *detective controls*, detailed above, are the nucleus of this Ago-antagonistic (AA) model. Specifically, *preventive controls* and *detective controls* act from an **antagonistic point of view** (*crossed actions in opposite directions*) with regards to when the controls take place (before/during after the task) and with regards to the actor’s position (internal and stakeholder in the task/ external and not part of the task). These managerial controls also act from an **agonistic point of view** (*parallel actions in the same direction*) with regards to the common regulator (contractor) and receptor of the forces (subcontractor) as well as their joint aim in safety management of decreasing risks, events (see Figure 7 in Chapter 1, subsection 1.6).

When analyzing risk management using AAS, it is possible to apply the 8 principle characteristics of AAS (described in Chapter 1) to management controls. For reference the eight principles have been provided in the first column of Table 14 below:

Table 14. Eight Characteristics of Control as an Ago-antagonistic System (AAS)

Application of Eight Characteristics of AAS to Preventive and Detective Controls

1 st	AA couple: has poles with opposing actions on one part of the receiver and actions in the same direction on another part of the receiver	Identification of <i>preventive control</i> and <i>detective control</i> as an AA couple
2 nd	AAS is a dissipative system: thermodynamically open system defined by Nobel Lauriat Prigogine, which describes equilibrium against a standard or a reproducible ready state. Mathematically AAS has two equilibrium states: a physiological equilibrium (if the standards are respected) and a pathological equilibrium (run on poor standards). The equilibrium will oscillate around the equilibrium point known as equilibrium constant.	Risk management is a dissipative system (not static) with a set of oscillating equilibrium constants (ideal balances between preventive and detection control).
3 rd	AA network: made up of a combination of AA elementary couples. Network is organized into competing pressures of hierarchy and autonomy, explaining how an action on one part of the network can rebalance the entire network.	Risk management: a network of management controls whose actions on one couple (by way of <i>preventive control</i> and <i>detective controls</i>) may rebalance the network thus preventing potential events.
4 th	Concept of constituent division: one force acts in its own interest and simultaneously for the common interest of the system.	Heterogeneity and constituent division of the preventive- <i>detective control</i> dynamics: (1) <i>Preventive controls</i> act in their own interest (as an independent barrier) to avert potential events and

		focus on an internal view of the task, while simultaneously providing a protection layer to compensate for human and organizational failures. (2) <i>Detective controls</i> offer their own independent external and objective view of the task and come into force at the failure of prevention controls, while concurrently working in unison as a protection system to maintain safe operations should an event occur.
5 th	AAS integrates dichotomies: a series of properties typically opposing compatibility with each other	Risk management dichotomies: via incompatible elements such as subcontractors who may act in their own interest (the basis of non-cooperation in relational risk); while concurrently conforming to converging safety objectives (preventive social control). Similarly, the co-operation between subcontracting firms when one firm trains another while at the same time competing for knowledge acquisition and performance.
6 th	AAS have states comparable to pathological homeostasis or autonomy: resulting in unusual strategies within these complex systems.	Pathological homeostasis or autonomic state of risk management: alternative strategies such as multi-layered safety barriers that may seem incompatible with traditional business practices that focus on benefit-cost ratios.
7 th	False AA couples: such as imbalance and balance, good and evil, which are not AA despite their semantic opposition.	The seventh emphasizes false ago-antagonistic couples, which are not prevalent in risk management.
8 th	Meta-model: required by all models irrespective of their “universality”. However, the meta-model of the AA model is yet to be created or identified.	The final characteristic describes the need to identify the meta-model of risk management. This model would offer a tool to analyze both unwanted (conceived) situations as well as unimagined events.

The first characteristic allows us to identify *preventive control* and *detective control* as an AA couple. *The second* reinforces our intuition that risk management is a dissipative system (not static) with a set of oscillating equilibrium constants (ideal balances between *preventive control* and *detective control*). *The third* can also be applied to risk management, which consists of a network of management controls whose actions on one couple (by way of *preventive control* and *detective controls*) may rebalance the network thus preventing potential events. *The fourth* highlights the heterogeneity and constituent division of the *preventive-detective control* dynamics. On one hand, *preventive controls* act in their own interest (as an independent barrier) to avert potential events and focus on an internal view of the task, while simultaneously providing a protection layer to compensate for human and organizational failures. On the other hand, *detective controls* offer their own independent external and objective view of the task and come into force at the failure of prevention controls, while concurrently working in unison as a protection system to maintain safe operations should an event occur. *The fifth* integrates dichotomies present in risk management via incompatible elements such as subcontractors who may act in their own

interest (the basis of non-cooperation in relational risk); while concurrently conforming to converging safety objectives (preventive social control). Similarly, the *co-operation* between subcontracting firms when one firm trains another while at the same time *competing* for knowledge acquisition and performance. *The sixth* highlights the pathological homeostasis or autonomic state of risk management, which yields alternative strategies such as multi-layered safety barriers that, may seem incompatible with traditional business practices that focus on benefit-cost ratios. *The seventh* emphasizes false ago-antagonists couples, which are not prevalent in risk management. *The final characteristic* describes the need to identify the meta-model of risk management. This model would offer a tool to analyze both unwanted (conceived) situations as well as unimagined events. Therefore, after careful study of the eight characteristics of AAS, risk management through *preventive and detective controls* is a type of AAS.

Finally, this section on Ago-antagonistic Systems is further divided into the two subsections below: the *first* contrasts the preference of poles in the three facilities and the *second* provides examples of rebalancing of Facility B's ago-antagonistic poles.

2.4.1. Contrasting Preference of Ago-antagonistic Poles at Facility A, Facility B, and Facility E.

From section 2.1 we observed that managers at the three Facilities all employ different types of controls at a greater frequency. Depending on the nature of these controls, Managers often favour one of the two ago-antagonistic poles or balance both poles simultaneously. Based on the data from Table 12:

Facility A employs **behaviour** (during the task) at a greater frequency compared to Facility B, augmenting the frequency of Health and Safety Inspections (*CC3 a detective control*) to detect the event and verify results. As a result of comparison between the three Facilities, the *detective ago-antagonistic pole* used by **CEA Managers** of Facility A is more important than *detective ago-antagonistic poles* of the other two Facilities.

Facility B employs **social controls** (before the task) at a greater frequency than Facility A and Facility E, thereby focusing on Health and Safety Training (*CSI a preventive control*) to avert the event. Both **CEA Managers** and **Middle Managers** at Facility B also employ a large quantity of Behaviour Controls (*CC5, CC6bis* all *detective control*) similarly to Facility A (later discussed in section 2.6) enforcing a strong "on-site presence". As a result of comparison between the three Facilities, the *preventive ago-antagonistic pole* used by both **CEA Managers** and **Middle Managers** of Facility B is more important than the *preventive ago-antagonistic pole* of the other two Facilities. Additionally, when comparing between the three Facilities, the balance between the *preventive* and the *detective ago-antagonistic poles* used by both **CEA Managers** and **Middle Managers** are more important in Facility B than the balance between the *preventive* and the *detective ago-antagonistic poles* of the other two Facilities.

Facility E employs both social (*CSI*) and behaviour (*CC3, CC5, CC6, CC6bis*) controls in line with Health and Safety and safe operations at a lower frequency compared to Facility A and B. **CEA Managers** (C1.5N) in Facility E rely on **Middle Managers** (C1N) to perform in-house controls (**social**

and behaviour), meanwhile using mainly **output controls** themselves after the task has occurred to ensure results are obtained. As a result of comparison between the three Facilities, Facility E like Facility B also balances the *preventive* and the *detective ago-antagonistic poles*, however the *preventive ago-antagonistic poles* are mainly employed by **Middle Managers** while the *detective ago-antagonistic poles* are employed by both **Middle Managers** and **CEA Managers**. As a result, the **Middle Managers** that perform in-house **Social Controls** and **Behaviour Controls** consider the collective impact of adjusting both the *preventive* and the *detective ago-antagonistic poles*.

In conclusion for this section, Facility B's contrasting use of *preventive ago-antagonistic poles* compared to Facility A and E's predominance of *detective ago-antagonistic poles* seems to originate from several changes that were put into place at Facility B following several events and near misses. Prior to these changes, Facility B also had a stronger emphasis on controls in the *detective ago-antagonistic pole*. These changes to the procedures at Facility B, encourage a transition in the ratio of controls used moving towards a balance to increase controls in the *preventive ago-antagonistic pole*. Additionally, the three changes detailed below, encouraged the **Middle Managers** from Facility B to lead such *preventive controls*, thereby empowering both the subcontractors and **Middle Managers**.

2.4.2. Examples of Re-balancing of Facility B's Ago-antagonistic Poles

For any single task, multiple types of control can be used depending on the type of risk one aims to avert and mitigate. Certain tasks such as those surrounding Safety and Occupational Safety require both actions of prevention and detection. The following provides three examples of procedural changes at Facility B that led to a transition in the ratio of controls used, thereby moving towards a new balance of risk prevention by augmenting *preventive controls*:

Example 1: In order to ensure a new standard of Health and Occupational Safety (H and OS) objectives are being met, Facility B carries out three controls: A Task Preparation safety brief called “**Safety Minute**” (CS7) led by a **Middle Manager** to prevent potential **relational risk and compliance and regulation risks** that is used before the task (*preventive control*); A safety inspection (CC3, CC4) (*detective controls*) to verify the application of H and OS procedures during the task; and once again re-applies a *preventive control* in the form of a “Safety Minute” (CS7), until the next task; thereby, reinforcing **Middle Manager** led controls in the *preventive ago-antagonistic pole* at the beginning and at the end of each task.

Example 2: Often results were controlled via “**Verification of skills post-training** (CR4 a *detective control*)” after the task using controls in the *detective ago-antagonistic pole* to “ensure the subcontractor obtains results that comply with their commitments, thereby mitigating **performance risk and compliance and regulatory risks**. However, changes to Facility B were implemented to mitigate such risks by also employing controls (CS7 TaskPreparation a *preventive control*) in the *preventive ago-antagonistic pole* encouraged by **Middle Managers** before the task.

Example 3: The **co-activity meeting (CS4)** at Facility B is now a daily (previously weekly) *preventive control* that takes *place before any task*, to discuss the day's tasks, elements of concern, previous experiences and points to consider while performing these tasks. Additionally, prior to each (high-risk) task, **operational preparation** occurs in the form of a detailed **pre-job briefing** meeting (Task Preparation *CS7* a *preventive control*), an additional *preventive control* that details the order of procedures to be performed and the presence of “**stop points**” (*Conducting Stopping points CC6* a *preventive control*). A stop point (*CC6* a *preventive control*) is a clearly designated “pause moment” during which the activity is halted, and **CEA Managers** are called upon to verify the activity and to sign a document validating the task during the “Verification of Parameters (during stopping points) (*CC6bis* a *detective control*); once authorized the subcontractor can continue with the task. During the stop points, the contractor is not part of the initial operating process and therefore has an external objective view while inspecting the activity for the presence or absence of deviations. Stop points are further detailed in section 2.8. Relay Controls; which consist of a *preventive* and *detective control* that are grouped (for example *CC6* and *CC6bis*) and hence automatically balance the preventive and detective ago-antagonistic poles.

At the end of the task, a debrief activity of the subcontractors known as a “**return on experience**” (*CR5* a *detective control*) is conducted to: *determine if the results were obtained; discuss issues or concerns during the manoeuvre (completion of the task, procedures and documents, equipment or tools, planning of the task); determine points that were missed during the pre-job briefing; discuss future predicaments to avoid; and propose suggestions for this task in the future.* This debriefs serves as a control in the *detective ago-antagonistic pole* from which the results will be taken into account the next time this activity is programmed. The information obtained from the return on experience will also be discussed during future *preventive controls* such as future **pre-job briefings (CS8** a *preventive control*) and other operational preparations prior to the task. Specifically, this pre-job briefing discusses *the intended results of the activity; the potential risks; the situations prone to errors; the alternative scenarios; and permits the appropriation of the previous returns on experience.*

These aforementioned examples indicate a transition in the ratio of controls used by **Middle Managers** at Facility B often in the presence of **CEA Managers**, moving towards a new balance of risk prevention by augmenting the controls in the *preventive ago-antagonistic pole*. Given the ago-antagonistic nature of *preventive* and *detective controls* and their temporal aspects, it is essential to better understand the 24 MCS in terms of these two ago-antagonistic natures. These strategies used to balance *preventive* and *detective controls* are presented in the next section.

2.5. Categorization of the 24 MCS into the 6 cluster groups: Preventive CS, Detective CS, Preventive CC, Detective CC, Preventive CR, Detective CR

The 24 MCS previously categorized into 3 cluster groups (CS, CC, CR) in section 1.3, were further broken down into two subgroups to account for *preventive* and *detective controls*. As a result, all of the MCS may be theoretically re-categorized into a cluster of 6 groups: *Preventive Social Controls; Detective Social Controls; Preventive Behaviour Control, Detective Behaviour Control, Preventive Output Control, and Detective Output Control*. Table 15 below details the *preventive controls* in green and the *detective controls* in grey, within each of the three categories of MCS. Social controls (CS) were found to be entirely preventive in nature (8 *preventive controls*), Behaviour Controls (CC) were found to include both *preventive* and *detective controls* (4 *preventive controls* and 7 *detective controls*), while output controls (CR) were entirely detective in nature (5 *detective controls*). However, only four of the six cluster groups contain MCS as social controls only appear to be preventive in nature and as output controls only appear to be detective in nature.

Table 15. Distribution of the 24 MCS according to either their preventive or detective nature.

	Informal Controls	Formal Controls	
	Social Controls (CS)	Behaviour Controls (CC)	Output Controls (CR)
Preventive controls	Health and Safety Training (CS1) Nuclear Safety Training (CS2) Document Management (CS3) Co-activity Management (CS4) Mastery of Transportation (CS5) Health and Safety Exercises (CS6) Task Preparation (Safety Minute and Pre-job Briefing) (CS7) Integration of Return of Experience (REX) (CS8)	Authorizing Staff Access (barrier) (CC1) Authorizing Staff Access (no barrier) (CC2) Conducting Stopping points (CC6) Performing Daily Facility Round (CC7)	
	8 Preventives Social Controls	4 Preventive Behaviour Controls	0 Preventive Output Controls
Detective controls		Verification of Authorized Staff Access (Manager) (CC1-2bis) Health and Safety Inspection (CC3) Nuclear Safety Inspection (CC4) Verification of conformity with regulations (CC5) Verification of Parameters (during stopping points) (CC6bis) Verification of the Daily Facility Round (CC7bis) Performing Monthly Round (CC8)	Performance Tracking (CR1) Radioprotection Verification (1st Level) (CR2) Radioprotection Verification (2nd Level) (CR3) Verification of Skills post-training (CR4) Debriefing Activities (CR5)
	0 Detective Social Controls	7 Detective Behaviour Controls	5 Detective Output Controls

The distribution of the 24 MCS according to the type of control and the temporal aspect of the task is detailed in Figure 39 below. Controls that have a preventive nature are presented in green and on the upper left-hand corner of the figure, while controls with a detective nature are identified in blue on the bottom right-hand side of the image. This figure provides the repartition of the nature of control (preventive or detective) according to the type of control (social, behaviour or output). From the figure below, we can identify that behaviour control appears to be the only of the three types to have both controls of preventive and detective nature. The section below further details the difference between these controls.

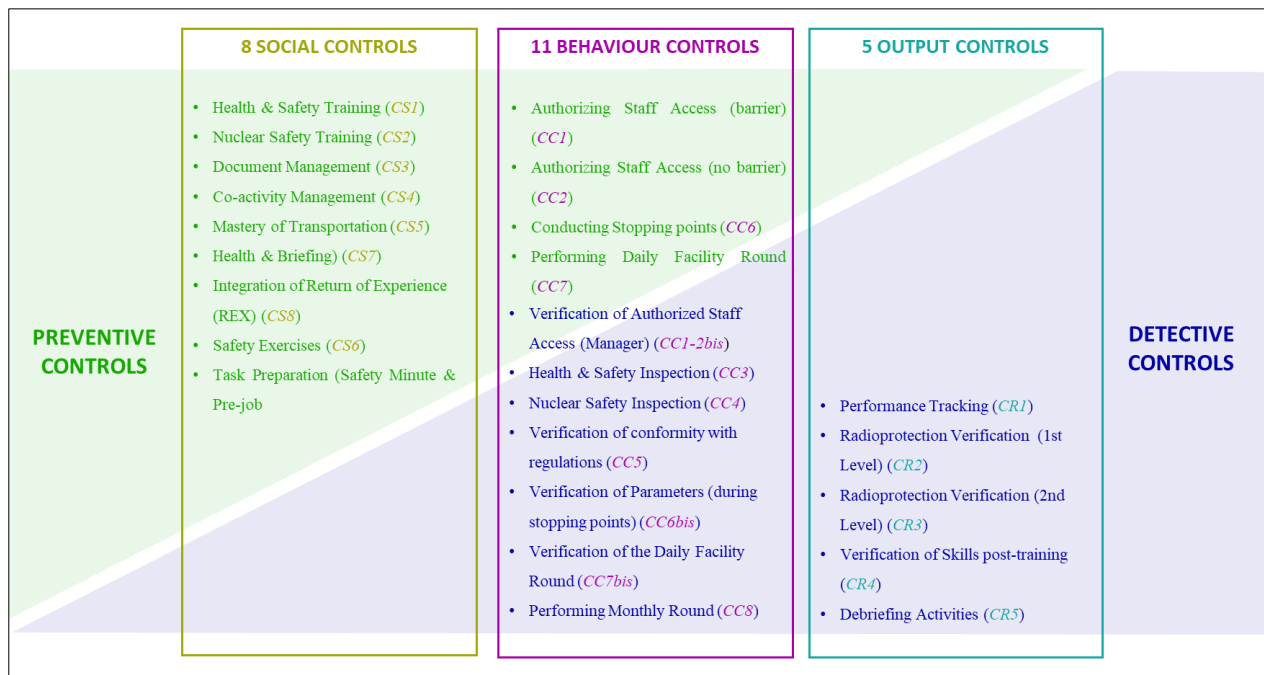


Figure 39. Distribution of MCS according to the type of control and the temporal aspect of the task

As discussed previously, the timing of the execution of the controls (before the task, during the task and after the task) indicates the type of control (social, behaviour, output); while the position (internal/external) of the actor carrying out the activity denotes the nature of the control (preventive/detective). The first and last control (Social Control and Output Control) are entirely dependent on the timing of the operation while the second control (Behaviour Control) makes a differentiation on the position of the actor performing the task. More precisely concerning Behaviour Control, if the actor is internal to the task then the action is of preventive nature, while if the actor is external to the task the action is of detective nature. The following section provides a clearer description of each of these 4 clusters of control: preventive social control; preventive behavioural control; detective behavioural control; and detective output control.

2.6. The Control Cycle: Towards an integrated Cycle of four clusters of controls

Following this new categorization of the 24 MCS into the four functional cluster groups above, several factors emerged: nature of controls; types of interactions; the number of actors; the timing of the control

with respect to the action. The differentiation of these three factors further refined the description of the three controls. Figure 40 below details the cycle. Specifically:

Social Controls are solely of *preventive nature*. These “*Preventive Social Controls*” are MCS that involve *two actors (subcontractors and managers)* and that *take place before the task*. **These controls are interactive** and allow a strong exchange between the two actors to address any questions, queries or concerns. The actor performing the task is a subcontractor, who is or will be part of the operating process, while the actor who facilitates the activity has managerial status and may not be part of the operating process. In the case of Facility A, the managers only includes **CEA Managers**, while in Facility B, the managers may be either **CEA Managers** or **Middle Management** from the subcontracting firm. These MCS include Training and Exercises (**CS1/CS6** Health and Safety, **CS2** Nuclear Safety), Discussions including the Integration of Return of Experience (**CS8**), Document Management (**CS3**), Task Preparations (**CS7** Safety and Pre-job Minute briefings), Mastery of Transport (**CS5**) and Co-activity Meetings (**CS4**). As a result, the CEA implements social controls to ensure that nuclear safety and occupational safety objectives of the CEA and the subcontractor are convergent with one another (* item 1); and that non-convergent objectives combine well. These controls often integrate Return of Experience (REX) or other points discussed during previous detective output controls.

Behaviour Controls can be both *preventive and detective in nature*. These controls ensure that the procedures are performed according to the pre-determined specifications. During certain MCS, the *preventive control* is relayed by (followed by) a *detective control* within the same task that will be discussed as a Relay control in sub-section 2.8.

- “*Preventive Behaviour Controls*” involve a *single actor (the subcontractor)* and *take place during the task*. During this control, the subcontractor is internal to the process and uses his skills and knowledge gained during social controls to assess the operation. These MCS include ongoing *auto-controls* during tasks such as Daily Facility Rounds (**CC7**), authorized access to zones with (**CC1**) or without a barrier (**CC2**), and procedural validation during the formalized stopping points (**CC6**).
- “*Detective Behaviour Controls*” involve *two actors (subcontractors and managers)* and also *take place during the task*. As a result, **these controls are interactive**, requiring the presence and exchange between the two actors. During this control, the subcontractor continues to carry out the operation, while the manager who is external to the process observes and objectively evaluates the modus operandi of the subcontractor. As a result, the manager can objectively ascertain the presence or the absence of deviations within the operating process. From these observations, the CEA can immediately notify the subcontractor of any anomalies or potential risks and implement provisions to ensure the subcontractor applies the rules prescribed by the CEA or the external authorities. These controls include all inspections (Health and Safety **CC3**, Nuclear Safety **CC4**, Verification of Conformity with Regulations **CC5**) and rounds (Verification of the Daily Facility

Round **CC7bis**, Performing Monthly Round **CC8**). As mentioned above the authorized access with a barrier control can act as either a preventive or as a *detective control* depending on the absence or presence of a Manager; therefore, the detective authorized access with a barrier control- Manager detailed here is one containing a managerial presence (see section #2.7 for further information).

Output controls are solely of a *detective nature*. These “*Detective Output Controls*” are MCS that involve at least *one managerial actor*, and they take place after the task. In the case of certain interactive output controls, a subcontractor may also be present. The manager assesses the results of the operating process, from an external viewpoint, to determine if there are any discrepancies or deviations from the expected results. It should be noted that immediately following the last part of the task, the subcontractor carrying out the task may perform a final control. However, since this control is performed by the person who carried out the task, it is considered part of the preventive behaviour control and not an output control as this control is still part of the task. As a result, an output control cannot be performed by the subcontractor or team doing the task as this control would be considered as “still part of the action”; and instead must be completed by someone (generally management) exterior to that task. As previously mentioned, detective output controls may be interactive (requiring the presence of subcontractor in addition to the mandatory presence of managers) such as is the case with debriefing activities that include a return on experience. Queries or observations made by the subcontractors at any stage of the process can be discussed during these debriefing activities. Other tasks do not require the presence of a subcontractor and may take place with a single managerial presence, such as Performance Tracking (**CR1**), Radioprotection Verification 1st Level (**CR2**), and Radioprotection Verification 2nd Level (**CR3**).

Finally, any observations made throughout the four clusters of controls, whether they are interactive or not, are re-integrated into the next social control (training, Task Preparation and implementation of the REX). Figure 40 below illustrates the actors at each step of the cyclic action of the four clusters of control.

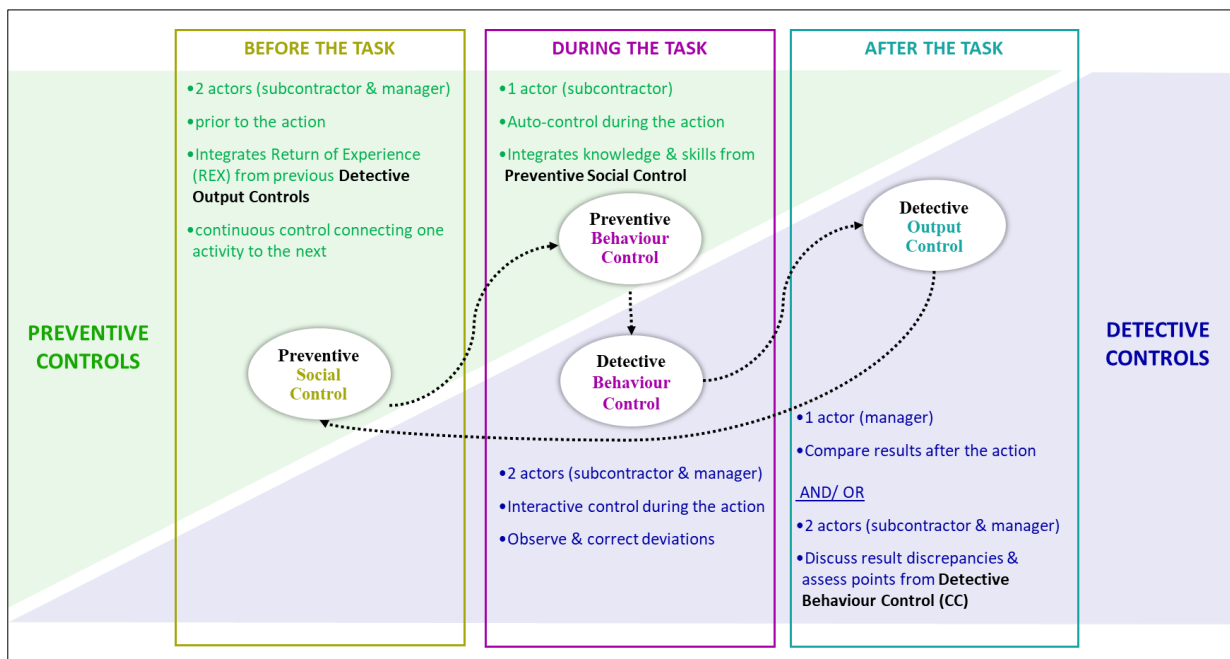


Figure 40. The cycle of control

Overall as a conclusion of this subsection, all three controls (social, behaviour, and detective) include interactive controls. Some controls such as social controls are solely interactive while behaviour controls and output controls can also be non-interactive (as auto controls during behaviour controls and as a single actor control during output controls), as described in the next section.

2.7. Synchronous Interactive MCS, Synchronous Auto controls, and Asynchronous MCS in the CEA

Upon examining the number of system levels involved in each of the MCS and the types of interactions or lack of interactions that occur during the MCS used at the CEA, three types of interactions within the MCS emerged. Table 16 provides an overview of these types of controls and their interactions:

- **Synchronous Interactive MCS** provide a platform of communication between the actors at the CEA, involving an exchange between 2 or more system levels such as managers (**Middle Managers** or **CEA Managers**) and the subcontractor.
- **Synchronous non-interactive Auto controls:** MCS which are carried out by a person that controls their own task, allowing the actor carrying out the task a moment to verify their actions and the results of the task. As a result, auto controls involve a single system level that takes place during the action.
- **Asynchronous non-interactive MCS**, as is the case when the regulator verifies the results. This verification of someone else's work does not need to be done in the presence of another actor and therefore is not interactive nor an auto control. This third type of control generally takes place after the task has occurred and involves a single system level.

Table 16 provides details for each of the 24 MCS of the regulator and the receiver of the control²⁰, the type of control (synchronous and asynchronous) and the number of system levels involved within the control. A summary of these interactions is provided in Table 17. This table provides an overview of the types of interactions (asynchronous non-interactive; synchronous auto control, **intra-organizational** synchronous interactive, **inter-organisational** synchronous interactive) during the controls used at each of the three facilities of the CEA. The percentage of controls is given as a percentage of the total quantity of controls conducted by each facility.

Social controls provide *informal synchronous interactive (preventive)* exchanges between the subcontractors and the management. Specifically, social controls serve to (1) facilitate exchanges through training sessions (*Health and Safety Training CS1, Nuclear Safety Training CS2, Health and Safety Exercises CS6*), (2) encouraging subcontractors to voice suggestions in case of unexpected operational changes (*Document Management CS3, Co-activity Management CS4, Mastery of Transportation CS5*) and (3) encouraging new safety initiatives (*Task Preparation CS7, Integration of Return of Experience CS8*). The frequency which these controls take place and the quantity of personnel implicated in these interactive exchanges can also have an impact on the solidity of the inter-organizational relationship; thus re-enforcing an environment to report near misses or minor events (as indicated in section 3 of this Chapter). A difference in the frequency and the quantity of staff included in three particular Social controls were observed in Facility A, Facility B and Facility E. It is important to note that during the training related social controls, the subcontractor tests and verifies their knowledge and skills, but since no action is taking place these are not considered auto controls.

In the case of Facility A, these synchronous controls occur between the CEA Managers and the subcontractors, as the **1st official level of control (C1N)**. These synchronous interactive social controls occur between **2 system levels**: *Field Worker and Team Management (subcontractor)*; *Facility Senior Management (CEA)*. As a result, social controls in Facility A consist of 100% **inter-organisational** interactions between the CEA Managers and the subcontractors.

In the case of Facility B and E, these synchronous controls occur between (1) the **Middle Manager** (subcontractors) and the subcontractors of the same firm, as the **1st official level of control (C1N)**; and (2) the CEA and the subcontractors as a **2 official levels of control (C1.5N)**. These synchronous interactive social controls occur amongst a maximum of **3 system levels**: *Field Worker and Team Management (subcontractor)*; *Middle Management (subcontractor)*; *Facility Senior Management (CEA)*. Overall, social controls in facility B and E both consist of 57% **intra-organizational** synchronous interactions and 43% of **inter-organisational** synchronous interactions; despite Facility E's lack of training session controls (*Health and Safety Training CS1, Nuclear Safety Training CS2, Health and Safety Exercises CS6*) as these controls are only carried out by the Internal Audit

²⁰ The term of regulator used makes reference to the term regulator employed in the Ago-antagonistic theory.

Department at the Centre level in what is referred to as a C2N control. Nonetheless, for the purpose of this dissertation, we are only interested in the controls that occur within the facility.

Behaviour control can be either *synchronous auto controls (preventive)* or *synchronous interactive controls (detective)*. Specifically, behaviour controls serve to: (1) provide an auto control, that is an official moment where the actor carrying out the task can verify his actions (*Authorizing Staff Access (barrier) CC1, Authorizing Staff Access (no barrier) CC1, Procedure validation (stopping points) CC6, Daily Facility Round CC7*); (2) as an *synchronous interactive control* where the regulator (**Middle Manager** or **CEA Manager**) detect any deviations via an inspection and can communicate them to the subcontractor (*Verification of Authorized Staff Access (Manager) CC1-2bis, Health and Safety Inspection CC3, Nuclear Safety Inspection CC4, Verification of Conformity with regulations CC5, Verification of Parameters (during stopping points) CC6bis, Verification of the Daily Facility Round CC7bis, Performing Monthly Round CC8*). It is important to note that the three “bis” controls above (*CC1bis, CC6bis, CC7bis*) are MCS where the regulator performs a follow-up control to the respective auto-control (*CC1, CC6, CC7*) which jointly are referred to as “relay control couples” (*CC1/CC1bis, CC6/CC6bis and CC7/CC7bis*) as detailed in section 2.8.

In all three Facilities the 3 *synchronous auto controls* are regulated by the subcontractor (CON) on themselves involving 1 system level: *Field Worker* and *Team Management (subcontractor)*.

In Facility A, the 7 *synchronous interactive controls* are regulated by C1N (CEA) on the receiver, the Subcontractor. These interactive behaviour controls are carried out by the **1st official level of control (C1N)** and occur amongst the *same 2 system levels* cited above in the Facility A social controls. As a result, behaviour controls in facility A consist of 36% synchronous non-interactive auto controls and 64% **inter-organisational** synchronous interactive controls between the CEA and the subcontractors.

In the case of Facility B and E, the 7 synchronous interactive controls are regulated by: (1) the **Middle Manager** on the receiver (the subcontractors of the same firm) (**C1N intra-organizational** control), and (2) the CEA on the subcontractors (**C1.5N inter-organisational** control). These interactive behaviour controls are carried out by the **2 official levels of control (C1N and C1.5N)** and occur amongst the *same 3 system levels* cited above in the Facility B and E social controls. Overall, behaviour controls in Facility B consist of 24% synchronous non-interactive auto controls, 35% **intra-organizational** synchronous interactive controls, and 41% **inter-organisational** synchronous interactive controls. In contrast, behaviour controls in Facility E consist of 31% synchronous non-interactive auto controls, 46% **intra-organizational** synchronous interactive controls, and 23% **inter-organisational** synchronous interactive controls.

Output controls tend to be either *synchronous interactive controls* or an *asynchronous non-interactive control* the latter which is neither interactive nor an auto control. Both of these type of output controls are *detective controls*. Specifically, output controls serve to (1) control the results and detect

any discrepancies between the expected and the current results after the task (*Performance Tracking CR1, Radioprotection Verification (1st Level) CR2, Radioprotection Verification (2nd Level) CR3*); and (2) as a *synchronous interactive control* at the end of the task to provide a Return of Experience (REX) and discuss any difficulties or near misses (*Verification of Skills post-training CR4, Debriefing Activities CR5*).

In all three Facility, one of the 3 asynchronous non- interactive output controls (*Radioprotection Verification 1st Level CR2*) is regulated by C1N level on the results, and therefore is neither an auto control nor an interactive control. This control involves 1 system level.

In the case of Facility A, there are 2 additional non-interactive controls (*Performance Tracking CR1, Radioprotection Verification 2nd Level CR3*) regulated by C1N (CEA) on the results of the operation carried out by the Subcontractor. These 2 non-interactive controls are carried out by the **1 official level of control (C1N)** and occur amongst the ***1 system level: Facility Senior Management (CEA C1N)***. The remaining 2 interactive controls (*Verification of Skills post-training CR4, Debriefing Activities CR5*) are regulated by C1N (CEA) on the subcontractor occurring amongst the ***same 2 system levels*** cited above in the Facility A social and behaviour controls. As a result, output controls in facility A consist of 60% asynchronous non-interactive controls and 40% **inter-organisational** synchronous interactions between the CEA and the subcontractors.

In the case of Facility B and E, there are 2 additional non-interactive controls (*Performance Tracking CR1, Radioprotection Verification 2nd Level CR3*) regulated by (1) the **Middle Management (C1N subcontractors)** and (2) then again by the CEA (**C1.5N**) on the results of the operation carried out by the Subcontractor. These 2 non-interactive controls are carried out by the **2 official levels of control (C1N and C1.5N) independent of each other: Middle Management (subcontractor-C1N) and Facility Senior Management (CEA- C1N)**. The remaining 2 interactive controls (*Verification of Skills post-training CR4, Debriefing Activities CR5*) are also regulated by the **2 official levels of control (C1N and C1.5N)** (1) the **Middle Management (C1N subcontractors)** on the subcontractors and (2) the CEA (**C1.5N**) on the subcontractor and occur amongst the ***same 3 system levels*** cited above in the Facility B and E social and behaviour controls. Overall, output controls in facility B consist of 56% asynchronous non-interactive controls, 22% **intra-organizational** synchronous controls, and 22% **inter-organisational** synchronous interactions. In contrast, output controls in Facility E consist of 57% asynchronous non-interactive controls, 29% **intra-organizational** synchronous controls, and 14% **inter-organisational** synchronous controls.

As a conclusion for this sub-section, when considering the three types of controls (Social Control CS, Behaviour Control CC, and Output Control CR), Facility A used 29% non-interactive MCS (synchronous non-interactive auto controls and asynchronous non-interactive controls) and 71% **inter-organisational** synchronous interactive MCS. As a result, it was the facility amongst the 3 that used the highest quantity of **inter-organisational** synchronous interactions during its controls. Facility B used

22.5% non-interactive MCS (synchronous non-interactive auto controls and asynchronous non-interactive controls), 40% **intra-organizational** synchronous interactive MCS, and 37.5% **inter-organisational** synchronous interactive MCS. As a result, it was the facility amongst the three to best balance **intra-organizational** and **inter-organisational** interactions. Facility E used 30% non-interactive MCS (synchronous non-interactive auto controls and asynchronous non-interactive controls), 44% **intra-organizational** synchronous interactive MCS, and 26% **inter-organisational** synchronous interactive MCS. As a result, it was the facility amongst the 3 to almost have a 2:1 ratio of **intra-organizational** to **inter-organisational** interactions.

Table 16. Level of Control, Type of Interaction and System levels involved in the MCS at the CEA.

Type of Control	Facility A				Facility B				Facility E			
	Regulators of Control on the Subcontractor	Type of Control	System Levels Involved	Regulators of Control on the Subcontractor	Type of Control	System Levels Involved	Regulators of Control on the Subcontractor	Type of Control	System Levels Involved	Regulators of Control on the Subcontractor	Type of Control	System Levels Involved
Management Control System (MCS)	CS1	Health and Safety Training	2	CIN ; CL5N	Synchronous interactive; Intra / Inter	3	C2N (N/A)	Synchronous interactive (CEA and Middle Managers present)	4	C2N (N/A)	Synchronous interactive (CEA and Middle Managers present)	4
	CS2	Nuclear Safety Training	2	CIN ; CL5N	Synchronous interactive; Intra / Inter	3	C2N (N/A)	Synchronous interactive (CEA and Middle Managers present)	4	C2N (N/A)	Synchronous interactive (CEA and Middle Managers present)	4
	CS3	Document Management	2	CIN ; CL5N	Synchronous interactive; Inter	3	CL5N	Synchronous interactive; Inter	2	CL5N	Synchronous interactive; Inter	2
	CS4	Co-activity Management	2	CIN ; CL5N	Synchronous interactive; Inter	3	CIN ; CL5N	Synchronous interactive; Intra / Inter	3	CIN ; CL5N	Synchronous interactive; Intra / Inter	3
	CS5	Mastery of Transportation	2	CIN	Synchronous interactive; Intra	2	CIN	Synchronous interactive; Intra	2	CIN	Synchronous interactive; Intra	2
	CS6	Health and Safety Exercises	2	CIN ; CL5N	Synchronous interactive; Inter	3	C2N (N/A)	Synchronous interactive (CEA and Middle Managers present)	4	C2N (N/A)	Synchronous interactive (CEA and Middle Managers present)	4
	CS7	Task Preparation Safety Minute and Pre-job Briefing	2	CIN	Synchronous interactive; Inter	2	CIN	Synchronous interactive; Intra	2	CIN	Synchronous interactive; Intra	2
	CS8	Integration of Return of Experience (REX)	2	CIN ; CL5N	Synchronous interactive; Inter	3	CIN ; CL5N	Synchronous interactive; Intra / Inter	3	CIN ; CL5N	Synchronous interactive; Intra / Inter	3
Informal Controls	<p>All 8 Synchronous interactive intra-organisational controls (CIN by Middle Managers mostly in presence of CEA); 6 Synchronous interactive inter-organisational controls (CL5N by CEA in the presence of Middle Managers); 2 or 3 system levels present and 2 official levels of Control (CIN; Middle Management and CL5N; CEA)</p>											
	<p>8 Synchronous interactive inter-organisational controls (all carried out by the CEA); 2 system levels and 1 official level of Control (CIN; CEA)</p>											
	CC1	Authorizing Staff Access (barrier)	1	CIN	Synchronous non-interactive auto	1	CIN	Synchronous non-interactive auto	1	CIN	Synchronous non-interactive auto	1
	CC2	Authorizing Staff Access (no barrier)	1	CIN	Synchronous non-interactive auto	1	CIN	Synchronous non-interactive auto	1	CIN	Synchronous non-interactive auto	1
	CC1-2bis	Verification of Authorized Staff Access (Manager)	2	CIN ; CL5N	Synchronous interactive; Intra / Inter	3	CIN	Synchronous interactive; Intra	3	CIN	Synchronous interactive; Intra	3
	CC3	Health and Safety Inspection	2	CIN ; CL5N	Synchronous interactive; Inter	3	CIN	Synchronous interactive; Intra	2	CIN	Synchronous interactive; Intra	2
	CC4	Nuclear Safety Inspection	2	CIN ; CL5N	Synchronous interactive; Inter	3	CIN	Synchronous interactive; Intra	2	CIN	Synchronous interactive; Intra	2
	CC5	Verification of Conformity with Regulations	2	CIN ; CL5N	Synchronous interactive; Intra / Inter	3	CIN ; CL5N	Synchronous interactive; Intra / Inter	3	CIN ; CL5N	Synchronous interactive; Intra / Inter	3
Behaviour Controls	CC6	Conducting Strapping points	1	CIN	Synchronous non-interactive auto	1	CIN	Synchronous non-interactive auto	1	CIN	Synchronous non-interactive auto	1
	CC6 bis	Verification of Parameters (during stopping points)	2	CIN ; CL5N	Synchronous interactive; Inter	3	CIN ; CL5N	Synchronous interactive; Intra / Inter	3	CIN ; CL5N	Synchronous interactive; Intra / Inter	3
	CC7	Performing Daily Facility Round	1	CIN	Synchronous non-interactive auto	1	CIN	Synchronous non-interactive auto	1	CIN	Synchronous non-interactive auto	1
	CC7 bis	Verification of the Daily Facility Round	2	CIN ; CL5N	Synchronous interactive; Inter	2;2	CIN	Synchronous interactive; Intra	2	CIN	Synchronous interactive; Intra	2
	CC8	Performing Monthly Round	2	CL5N	Synchronous interactive; Inter	2	CL5N	Synchronous interactive; Inter	2	CL5N	Synchronous interactive; Inter	2
	<p>7 Synchronous interactive inter-organisational controls by the CEA Manager; 4 Synchronous non-interactive autocontrols regulated by subcontractors on themselves; 1 or 2 system levels present and 1 official level of Control (CIN; CEA Manager)</p>											
	<p>Type of MCS interactions in Behaviour Controls</p>											
	Output controls	CR1	Performance Tracking	2	CIN ; CL5N	Asynchronous non-interactive	2;2	CIN ; CL5N	Asynchronous non-interactive	2;2	CIN ; CL5N	Asynchronous non-interactive
CR2		Radioprotection Verification (1st Level)	2	CIN	Asynchronous non-interactive	2	CIN	Asynchronous non-interactive	2	CIN	Asynchronous non-interactive	2
CR3		Radioprotection Verification (2nd Level)	2	CIN ; CL5N	Asynchronous non-interactive	2;2	CIN	Asynchronous non-interactive	2	CIN	Asynchronous non-interactive	2
CR4		Verification of Skills post-training	2	CIN ; CL5N	Synchronous interactive; Inter	3	CIN ; CL5N	Synchronous interactive; Intra / Inter	2;2	CIN ; CL5N	Synchronous interactive; Intra / Inter	2;2
CR5		Debriefing Activities	2	CIN ; CL5N	Synchronous interactive; Inter	3	CIN	Synchronous interactive; Intra	2	CIN	Synchronous interactive; Intra	2
<p>2 Synchronous interactive inter-organisational controls by the CEA Manager; 3 Asynchronous non-interactive inter-organisational controls by the CEA Manager; 1 official level of Control (CIN; CEA Manager)</p>												
<p>Type of MCS interactions in Output Controls</p>												
<p>2 Synchronous interactive inter-organisational controls (CIN by Middle Managers in presence of CEA Manager); 3 Asynchronous non-interactive inter-organisational controls (CL5N by CEA Manager in presence of Middle Managers); 3 Asynchronous non-interactive controls regulated by the Middle Manager (CIN); 2 system levels present and 1 official level of Control (CIN; CEA Manager)</p>												
<p>6 Synchronous interactive inter-organisational controls (CIN by Middle Manager mostly in presence of CEA Manager); 7 Synchronous interactive inter-organisational controls (CL5N by CEA Manager mostly in presence of Middle Managers); 4 Synchronous non-interactive autocontrols regulated by subcontractors on themselves; 1, 2 or 3 system levels present and 2 official levels of Control (CIN; Middle Manager and CL5N; CEA Manager)</p>												
<p>2 Synchronous interactive inter-organisational controls (CIN by Middle Manager independently of CEA Manager); 3 Asynchronous non-interactive inter-organisational controls (CL5N by CEA Manager in presence of Middle Managers); 3 Asynchronous non-interactive controls regulated by the Middle Manager (CIN); 2 system levels present at a time and 2 official levels of Control (CIN; Middle Manager and CL5N; CEA Manager)</p>												

Legend:
 C2N (N/A) = The CS1, CS2 and CS6 training MCS for Facility E are carried out by the C2N (Internal Audit Department at the Centre level), and since we are only interested in MCS conducted within the facility these controls are non-applicable;
 Inter = inter-organisational controls regulated by the CEA Manager (CIN for Facility A and CL5N for Facility B and Facility D) on the subcontractor also known as the receiver;
 Intra = intra-organisational controls regulated by Middle Manager (CIN for Facility B and Facility D) on the subcontractor also known as the receiver;
 Intra-Inter = inter-organisational controls involving an exchange between 2 or more system levels such as managers (Middle Manager or CEA Manager) and the subcontractor;
 Non-interactive controls involve the exchange between at least 1 system level (1 in the case of autocontrols and 2 in the case of CIN and CL5N controls that are carried out on the result of the tasks carried out by the subcontractor);
 Synchronous non-interactive autocontrols are regulated by the same person receiving the control, such as subcontractors that perform an autocontrol on themselves;
 Facility AS System Levels include: Field Worker and Team Management (subcontractors); Facility Senior Management (CEA Manager);
 Facility BR Facility ES System Levels include: Field Worker and Team Management (subcontractors); Project Manager (Middle Manager); Facility Senior Management (CEA Manager)

Table 17. Overview of the types of interactions (non-interactive; intra-organizational interactive, inter-organizational interactive) during the controls used at the CEA

Overview of the types of MCS (Synchronous and Asynchronous non-interactive; Intra-organizational Interactive ; Inter-organizational interactive) used in Facility A, B and E															
Type of Control	Facility A					Facility B					Facility E				
	Non-interactive MCS		Interactive MCS		Total MCS	Non-interactive MCS		Interactive MCS		Total MCS	Non-interactive MCS		Interactive MCS		Total MCS
	Synchronous non-interactive auto control (CON)	Asynchronous non-interactive	Intra-organizational Synchronous Interactive (NA)	Inter-organizational Synchronous Interactive (CIN)		Synchronous non-interactive auto control (CON)	Asynchronous non-interactive	Intra-organizational Synchronous Interactive (CIN)	Inter-organizational Synchronous Interactive (CL5N)		Synchronous non-interactive auto control (CON)	Asynchronous non-interactive	Intra-organizational Synchronous Interactive (CIN)	Inter-organizational Synchronous Interactive (CL5N)	
Social Control (CS)	0	0	0	8	8	0	0	8	6	14	0	0	4	3(+3)	7
	0%	0%	0%	100%	100%	0%	0%	57%	43%	100%	0%	0%	57%	43%	100%
Behaviour Control (CC)	4	0	0	7	11	4	0	6	7	17	4	0	6	3	13
	36%	0%	0%	64%	100%	24%	0%	35%	41%	100%	31%	0%	46%	23%	100%
Output Control (CR)	0	3	0	2	5	0	5	2	2	9	0	4	2	1	7
	0%	60%	0%	40%	0%	0%	56%	22%	22%	100%	0%	57%	29%	14%	100%
TOTAL	7	0	17	24		9		16	15	40	8		12	7	27(+3)
	29%	0%	71%	100%		22.5%		40.0%	37.5%	100%	30%		44%	26%	100%

Figure 41 below provides a summary of the total number of Social Controls (CS), Behavioural Controls (CC) and Output Controls (CR) at Facility A, B and E. Each Facility employs a different number of controls, with varying distribution of synchronous non-interactive controls, asynchronous non-interactive controls, Intra-organizational synchronous interactive controls and Inter-organizational synchronous interactive controls. However, the proportion of controls in each of the Facilities appears to remain the same.

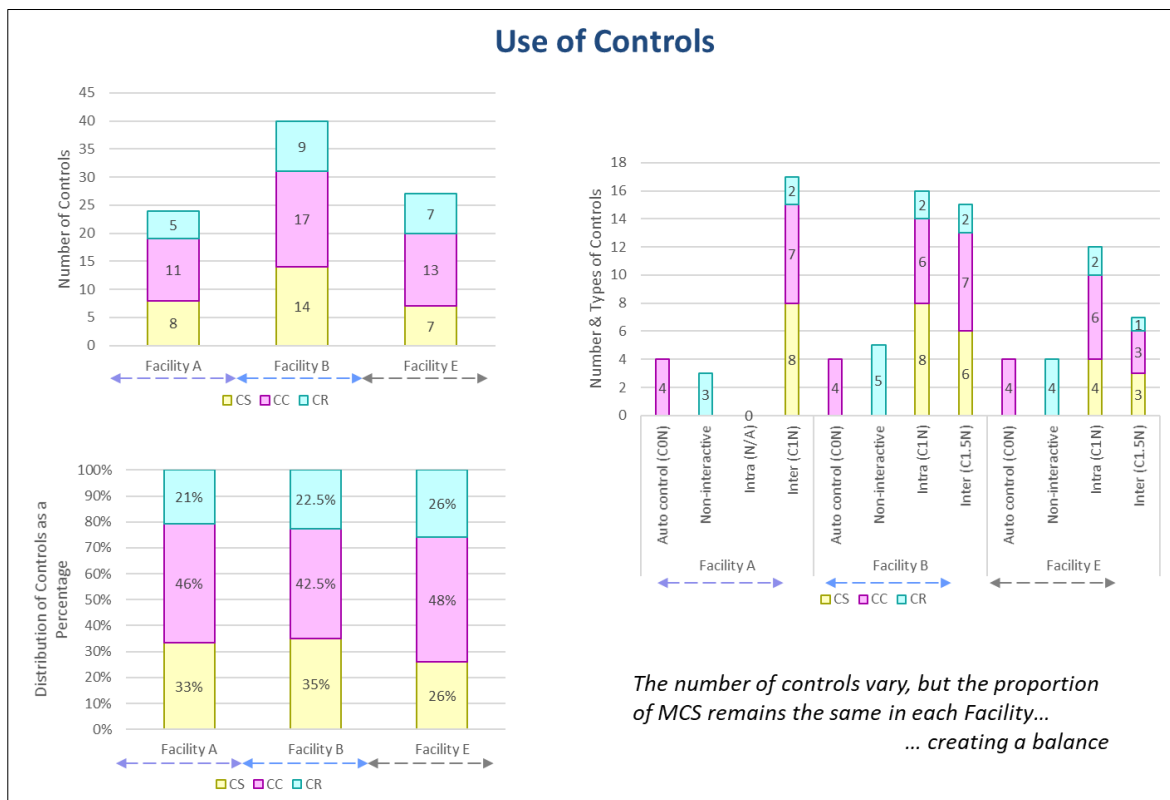


Figure 41. Number of Controls used at each Facility

Information exchanged during the Detective Output controls (*synchronous interactive controls*) will be fed into the next round of social controls (*synchronous interactive controls*) such as the *Task Preparation CS7* and the *Integration of Return of Experience CS8*. As a result, *synchronous interactive Social controls and synchronous interactive Output controls* serve as the beginning of the control cycle and at the end of the control cycle creating a continuous circle; thereby resulting in Social controls that become the Alpha and the Omega of an operation.

In Facility A, all synchronous interactive controls (behaviour, output and social) take place between **CEA Managers (C1N)** and the subcontractors, thereby strengthening the *inter-organisational relationship*.

In Facility B and E, all the synchronous interactive controls (behaviour, output and, social) occur at two instances: initially between the **Middle Management (C1N)** and the subcontractors of the same firm, and a second time between the **CEA Managers** and the subcontractors (**C1.5N**); thereby strengthening the *intra-organizational relationship* and the *inter-organisational relationship* respectively.

More precisely, the interaction loop allows Managers (CEA in the case of Facility A, and both **Middle Managers** and CEA in the case of Facility B and E) a time period to (1) evoke safety requirements and encourage compliance with safety procedures in an informal manner during the *synchronous interactive social controls* prior to the action, (2) detect and halt risky behaviours during the *synchronous interactive behaviour controls* throughout the action, (3) discuss any concerns and establish a dialogue between managers and subcontractors during the *synchronous interactive output control* immediately after the action, and then, the next time the procedure is programmed, (4) implement any changes or return of experience (REX) that arose during the preceding *synchronous interactive output control*; thereby enhancing safety participation and fostering safe work behaviours. Such safety participations are confirmed during the detective interactive behaviour controls that detect deviations and provide a follow-up or relay control to the subcontractor's synchronous non-interactive auto-control. The nature of these relay controls is discussed in Section 2.8. below.

2.8. Relay Control Couples (bis controls): An immediate or nearly immediate sequence of Preventive and Detective Behaviour Controls

Relay controls are regulated by a manager (**Middle Manager** or **CEA Manager**) during the task and provide a verification to the subcontractor's auto-control. More precisely, the CEA employs four preventive behaviour auto controls (**CC1**, **CC2**, **CC6** and **CC7**) that have a subsequent secondary detective interactive behaviour control (**CC1-2bis**, **CC6bis** and **CC7bis**) that is carried out either immediately following the first set of behaviour controls or within a subsequent time period (nearly immediately) following the initial auto control. As noted, the **CC1-2bis** serves as secondary behaviour control for both **CC1** and **CC2**.

For example, *Authorizing Staff Access (barrier) CC1* can be considered a *preventive control* (as the subcontractor is confronted with a barrier and performs an auto control). *CC1-2bis* which is a *detective control* serves as a relay to the first control *CC1*, as the subcontractor must ask a Manager for a key to access a particular area. Similarly, *Authorizing Staff Access (no barrier) CC2* is another *preventive control* where the subcontractor must again perform an auto control this time without the presence of a reminder/barrier. Once again, *CC1-2bis (detective control)* serves as a relay to the first control *CC2*, as the subcontractor requests the permission of a Manager to access this area.

For example, a *Procedure Validation (stopping point) CC6*, a *preventive control*, will be immediately followed by a Verification of Parameters (during stopping points) *CC6bis (detective control)* before any further action can be taken. It is only following this second *detective interactive control (CC6bis)* that the operating process may continue. As a result, this verification has the ability to halt the operating process effectively ensuring that all controls have been validated prior to continuing with the next task. The first control (*CC6*) is a control carried out by one or more subcontractors involved within the operation process indicative of a *preventive control*, while the second control (*CC6bis*) is carried out by an actor that is external to the operation process. This provides an objective view to identify deviations resulting from the operation process as is the case in *detective controls*. This relay type of preventive–*detective controls* provide a strong control structure ensuring that any errors or deviations during the operation are identified and corrected prior to the continuation of the activity. These secondary *detective controls* take place prior to actions that may trigger an event. Finally, the actors carrying out this second *detective control* (*CEA Managers* in the case of Facility A or a *Middle Managers/ CEA Managers* in the case of Facility B and Facility E) may or may not have been present during the procedure. They are called to verify all of the steps have been taken correctly and then sign and stamp the procedure form authorizing the continuation of the activity. This type of control cannot be classified as an output control (*CR*) as the action has not been carried out to completion.

In contrast to the all previous examples (*CC1/CC1-2bis, CC2/CC1-2bis, CC6/CC6bis*), the Daily Facility Round *CC7* and its subsequent relay control Verification of the Daily Facility Round *CC7bis* does not require daily operations to halt. Instead, the first *preventive control (CC6)* is carried out at the end of the day by a single subcontractor who is internal to the task and entrusted with the responsibility of carrying out the control, indicative of a *preventive control*. The second relay or “bis” control is carried out by the *CEA Manager* on call who receives the first control in the form of a document and must then verify that all of the information is completed. This *CEA Manager* then becomes the person responsible for the Facility overnight. This secondary control aims to detect any deviations denoted in the first control and is carried out by a person external to the initial control, indicative of a *detective control*. Given that the Daily Facility Round *CC6* occurs at the end of the day, timing between the first (*CC7*) and second control (*CC7bis*) are not of utmost urgency since the facility does not operate at night, but must be carried out within a short period of time before the first actor leaves the facilities.

In conclusion to this section, relay controls provide an automatic balance of both AA Poles, as the initial auto-control carried out by the subcontractor addresses the *preventive ago-antagonistic pole*, followed closely by the second verification carried out by the **Middle Manager**/ CEA Agent thereby balancing the *detective ago-antagonistic pole*. Additionally, it appears that these relay controls that are not only composed of two synchronous behaviour controls: an synchronous non-interactive preventive auto controls plus a synchronous interactive detective control, but are also essential controls in establishing positive leadership qualities that reduce the distance between the subcontractor and contractor relationship. Part 3 of this chapter further describes this process.

Summary of the Results for Section 2

The second section analyses the MCS across the 3 facilities (A, B and E), proposing definitions of the nature of these controls, the timing in averting events, their ago-antagonistic nature, and their contribution to the cycle of control. The following summarizes the findings from Section 2 in eight sub-sections.

Sub-section one analyses the MCS used in Risk Management at all CEA Facilities and characterizes them according to 12 defining characteristics. From this classification several elements emerged:

- The timing of the control (before, during and after the stain) indicates the type of control (social, behavioural or outcome).
- The position (internal/external) of the actor performing the task indicates the nature of the control (Control by Prevention / Control by Detection)²¹. ***Controls for prevention*** avert risks and ***Controls for detection*** identify deviations and mitigate risks.
- The number of system levels that participate in the control (subcontractor, **Middle Manager**, **CEA Manager**, Internal Audit Department) indicates the type of interaction of the control (synchronous non-interactive auto-control, synchronous interactive control, asynchronous non-interactive control).

Social controls, which take place prior to the action, are ***solely preventive in nature***. Behaviour controls, which occur during the action, can be both preventive and detective in nature depending on the position of the actor performing the task (***preventive when the actor is internal*** to the task and ***detective when the actor is external to the task***). Output controls, which take place after the task, are ***solely detective in nature***.

Sub-section two proposes a new definition for ***Preventive*** and ***Detective controls***:

- ***Preventive controls*** minimize goal discrepancies between the receptor (subcontractor) and the regulator (contractor) by establishing common culture and values. They can be defined as ***a task that aims to ensure the performance of the operating process. This task may not result in action directly influencing the process and is performed by actors who are part of the operating process.***

²¹ See section 2.2 of Chapter 3 for the definition of Preventive and Detective Control.

These actors, such as the facility chief or safety officer, are stakeholders in the operating process and are entrusted with responsibilities. *Preventive controls* take place before and during the task. A directory of verbs used to describe *preventive controls* includes: to ensure, to follow, to organize, to dispense, to review, to program, and to authorize.

- *Detective controls* enforce rules, policies, and procedures by monitoring the behaviour of the receptor (subcontractor) and by rewarding performance. They can be defined as *a task that aims to detect deviations. This task is performed by actors who are not part of the operating process at this point in time, but rather these actors take an external view of the exploitation process in order to have the most objective view possible when they check for the presence or absence of deviations. The actors carrying out this control verify both the results of the task as well as the modus operandi (method the task was carried out)*. *Detective controls* take place during and after the task. A directory of verbs used to describe *detective controls* includes: to verify, to check, to execute, to effectuate, and to perform.

Sub-section three identifies the timing of controls as an important factor in Risk Management. Potential events can best be averted prior to the task (*preventive control*) or during the task (*preventive control and/or detective control*). However, the use of controls after the task (*detective controls*) are effective in detecting the event, but are futile to prevent potential events or correct the actions that set the event into motion (since they generally take place after the event).

Sub-section four analyses *preventive and detective controls*, as two ago-antagonistic poles of controls. They are *antagonistic* (*crossed actions in opposite directions*) in the timing of the controls (before/after the activity) and in the position of the actor (internal and part of the operating process/ external and not part of the operating process). They are *agonistic* (*parallel actions in the same direction*) with the joint efforts of the *regulator* (contractor) and the *receptor* (subcontractor) to strengthen safety practices and to decrease risks and events. A balance of both ago-antagonistic poles is essential in Risk Management practices as the movement towards a balance of *ago-antagonistic poles* was observed following several events and near misses.

Sub-section five illustrates the timing of the controls (before the action, during the action and after) and the position (internal/external) of the actor carrying out the activity proposing an order of controls: Social Control, Behaviour Control and then Output Control.

Sub-section six, seven and eight presents the cycle of control, identifies for each control the number of actors, the types of interactions, and elucidates how controls follow a temporal cyclical pattern where one control merges into the next:

- First *Preventive Social Controls* (*training, Activity preparation including Safety Minute and pre-job briefings, Integration of Return of Experience -REX*) evoke safety requirements and encourage compliance with safety procedures in an informal *synchronous interactive* manner before the task.

- Next, **Preventive Behaviour Controls** (*Procedure Verification including stop-points, daily rounds, monthly rounds*) are **auto-controls**, where the subcontractor (internal to the process) uses the skills and knowledge obtained during the **social controls** to evaluate the operation during the task. **Detective Behaviour Controls** (*inspections, audits or the verification of the stop points*) detect and halt risky behaviours through the **synchronous interactive** exchange between the receptor (internal to the process) and the regulator (external to the task). This allows the regulator to inform the receptor *in-vivo* of any potential risks or deviations during the task.
- Relay²² (*bis*) controls, the amalgamation of **Preventive** (*stop points*) and **Detective Behaviour Controls** (*verification of the stop points*) into a joint control, yield an automatic balance of both *ago-antagonistic poles*. These relay controls are thus composed of a synchronous non-interactive preventive auto controls plus a synchronous interactive detective control
- Then, **Detective Output Controls** identify discrepancies between the results obtained and the expected results. These controls can involve solely the presence of a regulator or Manager (**asynchronous non-interactive**) or also incorporate the receptor or subcontractor (**synchronous interactive**). The former (*Performance Tracking CRI*) allows Managers to independently verify the results. The latter (*Debriefing activities CR5 that includes Return of Experience [REX] feedback*) provides a moment to establish a dialogue immediately after the task between Managers and subcontractors to discuss any concerns observed during the task (inspection or other Detective Behaviour Control).
- Finally, REX feed-back is implemented during the next **Preventive Social Control** completing the cycle of control and enhancing safety participation and fostering safe work behaviours.

Sub-section eight further analyses how Relay controls, a combination of two formal controls, can balance both ago-antagonistic poles. The initial auto-control carried out by the subcontractor (Preventive Behaviour Control) addresses the *preventive ago-antagonistic pole*. The second verification carried out by a Manager (Detective Behaviour Control) confirms the subcontractor's auto-control thereby balancing the *detective ago-antagonistic pole*. Finally, synchronous controls, including relay controls (composed of a synchronous non-interactive preventive auto controls plus a synchronous interactive detective control) – are important controls to establish positive leadership qualities thereby reducing the distance between the subcontractor and contractor relationship.

3. Impact of Contingent Variants on the use of MCS and leadership style in Facility A, Facility B and Facility E.

The third section contrasts six contingent variables across the 3 facilities (A, B and E) and shows how these variants indicate the type of MCS employed in each facility and explain the apparent differences

²² See Section 2.8 of Chapter 3 for more information on Relay Controls.

in leadership styles amongst the three facilities. The six contingent variables amongst the facilities include: The external environment including the quantity of information symmetry between the CEA and the subcontractors; the technology and thus the facility's work processes and unit interdependencies; the organizational structure and managerial configuration that yields a centralized single level of control or a decentralized double level of control with a contrast of system level interactions; the size of the facilities including the ratio of management (**Middle Managers** and **CEA Managers**) to subcontractors; the strategies and methods used to achieve results and safety objectives; and the implication of managers (**Middle Managers** and **CEA Managers**) in promoting safety culture. These contrasting contingent variables highlight the diverse use of MCS in each facility and the connection to the type of leadership styles extrapolated in Facility A, Facility B and Facility E.

3.1 External Environment and Information Asymmetry

Information asymmetry is one of the major subcontracting related risks (Risk#1 and #2) discussed in section 1.1 due to environmental uncertainty that enunciates itself by a **gap between the information required and the information made available to make decisions**. This particular information asymmetry is heightened during transition process between two subcontractors, but may also present at a lower degree throughout the entire contractual period. This results in an increased need for MCS to mitigate information asymmetry to ensure an appropriate transfer of information between the subcontracting firm(s) and the CEA. Due to the nature of this changeover period, and the distance in the contractor-subcontractor business entity, information asymmetry is prevalent.

The visiting period of Facility A, (t=0 years) coincided with the entire change of subcontracting period during which the *highest information asymmetry* was observed as Elektra(P06) and Aida (P10) indicate, resulting in a successful combination of informal and formal controls. The first combination is Aida's real-time monitoring via behaviour controls (*Health and Safety Inspections CC3*) and the use of social controls (*Health and Safety Training CS1, Health and Safety Exercises CS6, Task Preparation (Safety Minute and Pre-job Briefing) (CS7) and Implementation of Return of Experience CS8*) to increase the overseeing of subcontractors when behaviour controls were ineffective (see section 1.4.2). The second combination employs output controls (*Verification of Skills post-training CR4, Debriefing Activities CR5*) performed by Aida (P10) to verify the subcontractor's skills post-training and discuss any issues. Thereafter, any difficulties or information gaps can be bridged prior to the next training sessions, through the use of social controls. Overall, Facility A had extensive formal controls as Aida supervised and assisted every operation (behaviour controls), ensuring the intended results were obtained (output controls) during the 5 weeks of the transition process between two subcontractors; employing a greater frequency of Behaviour Controls (see section 2.1). Aida and the **CEA Managers'** continuous on-site presence in Facility A in addition to the use of informal (social controls) via training session indicated the CEA's implication during the process, thereby stabilizing the external environment and reducing the distance between all 3 system levels of the contractor and subcontractor entity. This is

a critical period in the relationship that is at the same time the start for the new incoming subcontractor and the end of the exiting subcontractor (and hence a preview of the incoming subcontractor's future if they do not win the future call for tender) **inter-organisational** relationship.

The visiting period of Facility B, (t=3 years) occurred three years after the transition process between two subcontractors, during a period of **lower information asymmetry**. This was in part due to the active presence of the **Middle Management** level. The CEA's continuous on-site active presence during the morning social controls (*Co-activity Management CS4, Task Preparation (Safety Minute and Pre-job Briefing CS7, and Implementation of Return of Experience CS8)*) functions as a communication platform (amongst all system levels present in the facility) where subcontractors could voice concerns thereby decreasing the information asymmetry. The accessibility of the RCI and the **CEA Managers** on a daily level allows not only a fast transmission of information, near misses or concerns in real-time, but additionally allows the RCI to respond to questions and the **Middle Management** team to orient the operations and assist if required. This accessibility also reduced the distance between the contractor-subcontractor business entities. Facility B used a greater frequency of Social controls (see section 2.1) and the second highest frequency of Behaviour controls.

The visiting period to Facility E, (t=1.5 years) took place one and half years following the transition process between two subcontractors. As experienced by Foscari (*P27, Facility E Production Manager, Middle Management- Subcontractor, Interview 3P27Int, *14*), difficulties with information asymmetry took place both during the transition process between two subcontractors in 2017 (non-cohesive environment) as well as during the operation of the facility 1.5 years after the transition process between two subcontractors. The **CEA Managers'** role and implication during the change of the subcontractor period helped in minimizing information asymmetry between the exiting and incoming subcontractor team; this implication has since changed at the time of the interview (1.5 years after the transition process between two subcontractors). Specifically, when the current subcontracting firm (incoming subcontracting firm) took over the Facility (at the beginning of the project) there was a more symbiotic contractor-subcontractor business entity as the CEA provided global training and cohesive session with the outgoing subcontractor firm and the incoming subcontracting firm. Nonetheless, the outgoing subcontractor was neither content to vacate the premises nor to train the incoming subcontractor, leaving the incoming subcontractor with information asymmetry and a need to be resourceful in obtaining the know-how. During the first 2-3 months of the transition process between two subcontractors, the CEA were present every evening for the 4pm daily activity meeting, a combined output and social control (*Debriefing Activities CR5 and Co-activity Management CS4*), to discuss the day's events and the activities that would be carried out the following day. Upon expressing the issues of information asymmetry between the Historic Operator and the incoming subcontractor, the CEA implemented controls to resolve the issue. The incoming subcontractors were provided with the authorization by the CEA to operate the facility and could call the Historic Operator for a period of 6 months in case of a

problem. A few calls were made during this time period, partly because the incoming subcontractor did not want to contact them too often as this may indicate a lack of know-how.

Then, 1.5 years after taking over the facility, as experienced by Foscari (*P27, Facility E Production Manager, Middle Management- Subcontractor, Interview 3P27Int, *15*), the production at Facility E was halted for several months as the alveoli were full, having an impact on the **CEA Managers'** presence. Previously, when the facility was in production (when the alveoli were not full) the **CEA Managers** conducted a round of the facility when they were in the facility (following a scheduled meeting). Nonetheless, the majority of inspections and participative occupational safety visits were conducted as internal C1N controls. This reduced the **CEA Management** presence led to information asymmetry and a distant contractor-subcontractor relationship (reduced symbiosis), that embodies a customer-subcontractor relationship.

In conclusion to this subsection, facilities with information asymmetry had an increased use of formal controls: behaviour controls when CEA on-site active presence was high (Facility A) and output controls for low on-site CEA active presence (Facility E). Facilities with less information asymmetry used less formal controls and more informal controls (Facility B). The active presence of a **Middle Management** level (Facility B and E) provided a manner of decreasing the information asymmetry, but only when the distance between the contractor- subcontractor business entity was reduced; as was the case with Facility B where the CEA had a stronger on-site presence. It is also important to highlight, as indicated in Chapter 2, that the timing of the visits to Facility A, Facility B and Facility E differs not only in duration but also in the points in the life cycle of the subcontracting contract. As a result, the difference in timing may not only provides us with data for a longitudinal study to gain a better understanding of the controls and risks used during and after the transition process between two subcontractors; but they may also provide an indication in the evolution of these controls during different times in the life cycle of a contractual subcontracting-CEA relationship.

3.2. Technology: Work Processes and Interdependencies within and between System levels

Technology relates to two aspects that are (1) the characteristics of the facilities' work processes and (2) the level of interdependencies amongst and between the units of the facility. The *first* of these relates to the facilities' *aspect of work processes* and whether outputs are measurable in goal-consistent terms. Each Facility (A, B and E) has very specific goals in terms of safety and results that are measured through interactive or non-interactive formal output controls as detailed in section 2.6. Facilities with a preference of interactive output controls (Facility A and Facility B) can discuss and measure those goals with the subcontractors, creating a space where workers can talk honestly as to why certain goals were not obtained. The *second* of these relates to the *level of interdependencies among and between units* of the facility as detailed in Figure 42 below. Specifically: (a) amongst the **CEA Manager** system level, (b) amongst **Middle Manager** system level, and (c) between Managers (CEA and/or **Middle Managers**) and

subcontractors. Figure 42 shows the number and the percentage of non-interactive controls (Output controls) in grey, the interactive **intra-organizational** controls (in green) and inter-organizational controls (in red) at Facility A, Facility B and Facility E.

Specifically: (a) amongst the **CEA Manager** system level, (b) amongst **Middle Manager** system level, and (c) between Managers (CEA and/or **Middle Managers**) and subcontractors. Figure 42 shows the number and the percentage of non-interactive controls (in grey), and the number of the **intra-organizational** controls (in green) and inter-organizational controls (in red) at Facility A, Facility B and Facility E.

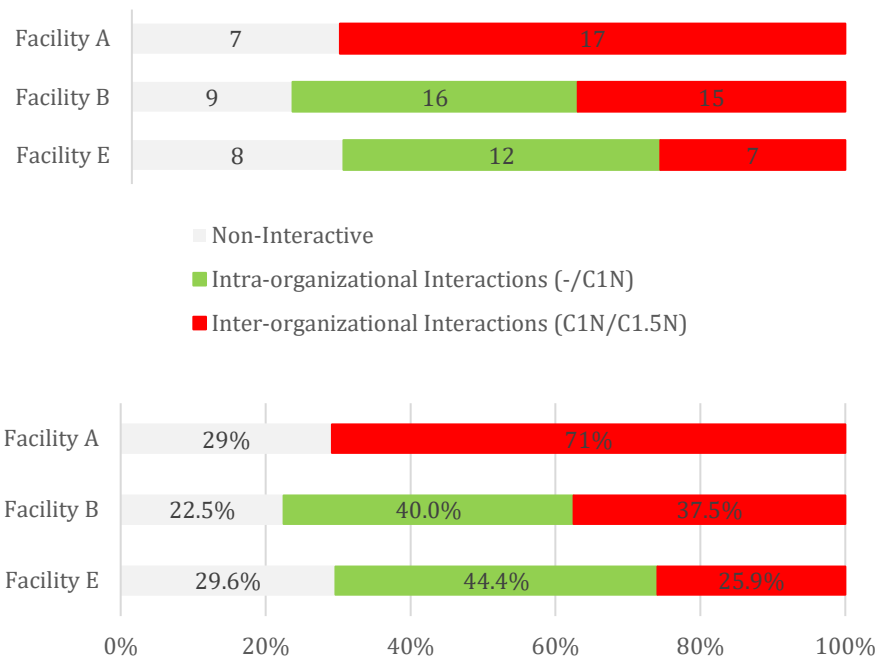


Figure 42. Number and percentage of non-interactive controls, inter-organizational controls, and intra-organizational controls at Facility A, Facility B and Facility E

Facility A exhibits both low and high interdependency with (a) low interdependencies amongst the few **CEA Managers** who control their particular expertise, but (c) a strong **inter-organisational** interdependency between **CEA Managers** and subcontractors. Facility A employs a significant quantity of formal controls performing individual **inter-organizational** C1N inspections to detect if a subcontractor breaks a rule and if any anomalies occur to ensure that rules and results are followed to precision; as indicated by Manon (*P08, Facility A Occupational Safety Assistant, Interview 1P08Int1*) in section 1.1.

Facility B, exhibits high interdependency in all three categories with:

- (a) high interdependency amongst the **CEA Managers**
- (b) high inter-dependencies within the **Middle Management** units, control systems that allow for flexibility, open communication and combine several MCS in a package in a daily morning Co-activity – Occupational Safety Minute. As experienced by Douphol (*P24, Facility B Quality and Environment*

Manager QHSE Middle Management, Interview 2P24Int1) the interdependencies amongst the **Middle Management** level to bring a “fresh set of eyes” to the C1N level controls to highlight anomalies that could have otherwise gone unnoticed by the “overly trained eye” that repetitively carries out these controls. Here **Middle Managers** are encouraged to work together as a joint “business unit”, make any observations on how the C1N controls occur, identify areas of concern, and propose improvements. The cross-control of their colleagues’ inspections (at the same system level) and the understanding that they too are being controlled – takes the emphasis further away from the scrutiny of mistakes and towards “lending an eye”. By putting themselves in the place of their colleague during a cross control (at the same system level), **Middle Managers** may diffuse this “lending an eye mentality” towards their control of subcontractors (across multiple system levels); leading to more “empathic behaviour controls” where the controller looks at the situation from the subcontractor’s point of view. This lending an eye mentality, in conjunction with the interactive work environment between the CEA and the **Middle Managers** that establishes a communication platform during the Morning Social Package Controls (see section 3.6), can develop a durable safety culture and a more united contractor- subcontractor business entity. Additionally, the repetition of these daily rituals can also have a profound effect on the facility’s cohesion that in combination with empathic actions and thoughts may have a profound effect on safety.

(c) high **intra-organizational** and **inter-organizational** interdependencies between subcontractors, **Middle Managers** and **CEA Managers**.

Facility E, exhibits mostly low interdependency in all three categories:

(a) medium to low interdependency amongst the two **CEA Managers**

(b) low interdependencies within the **Middle Management** layer, as each unit works individually to perform C1N controls for their particular expertise.

(c) low **intra-organizational** and **inter-organizational** interdependencies between Subcontractors, **Middle Managers** and **CEA Managers** of different teams but higher **intra-organizational** interdependencies between Subcontractors and **Middle Managers** of the same team. Similar to Facility A, Facility E employs a significant quantity of formal controls however these controls are carried out by **Middle Managers** focusing on interactive **intra-organizational** C1N behaviour and output controls to also identify incorrect procedures and report abnormalities. In contrast, Facility E **CEA Managers** focus on non-interactive **inter-organizational** C1.5N output controls to verify the results initially presented by C1N **Middle Management** controls.

3.3. Organisational Structure/ Managerial Configuration and System level

Interactions

Organizational structure refers to the actors and their decisional position and leadership style. As a result, organisational structure is strongly related to the particular managerial configuration at each facility, but also the active presence and hence the implication of the CEA yield a difference in interactions and

leadership styles amongst these facilities. In the following sections, the notion of *proactive* and *reactive/adaptive* are associated with the preventive and detective controls respectively.

Facilities that have *Centralized control such as Facility A*, with a single level of Control by the CEA (C1N), make all of their decisions at the top. *Facility A* organises their centralized control via the planning and execution of tasks, and the strong use of performance measurement systems. As a result, this centralized control encourages formal controls with the highest frequency of Behaviour Controls in the form of continuous inspections (Table 12 in Section 2.1). These detective behaviour controls are *reactive/adaptive* to the behaviour and actions of the subcontractors, identifying anomalies and correcting or warning the subcontractors when rules have been broken. Facility A also has the highest number of *inter-organisational* interactive controls amongst all the facilities in each category of control (social, behaviour and output) due to this sole level of control (Table 16 in Section 2.7). These interactions encourage strong leader and subordinate relationships, as the CEA seeks to enforce strong contractor-subcontractor relationships during the transition process between two subcontractors and throughout the entire contractual period. These characteristics are typical of a leadership style known as transactional leadership.

Facilities that have *Decentralized Control such as Facility B and Facility E*, with a double official level of control of the *Middle Manager* (C1N) and the CEA (C1.5N) generally make their decisions at two separate instances. Nonetheless, there are striking differences between Facility B and E in terms of the frequency of *intra-organizational* and *inter-organisational* interactions (Table 16 in Section 2.7) and their control preferences (Table 12 in Section 2.1) yielding different leadership styles. Figure 43 below depicts the centralized or decentralized control of the three Facilities.

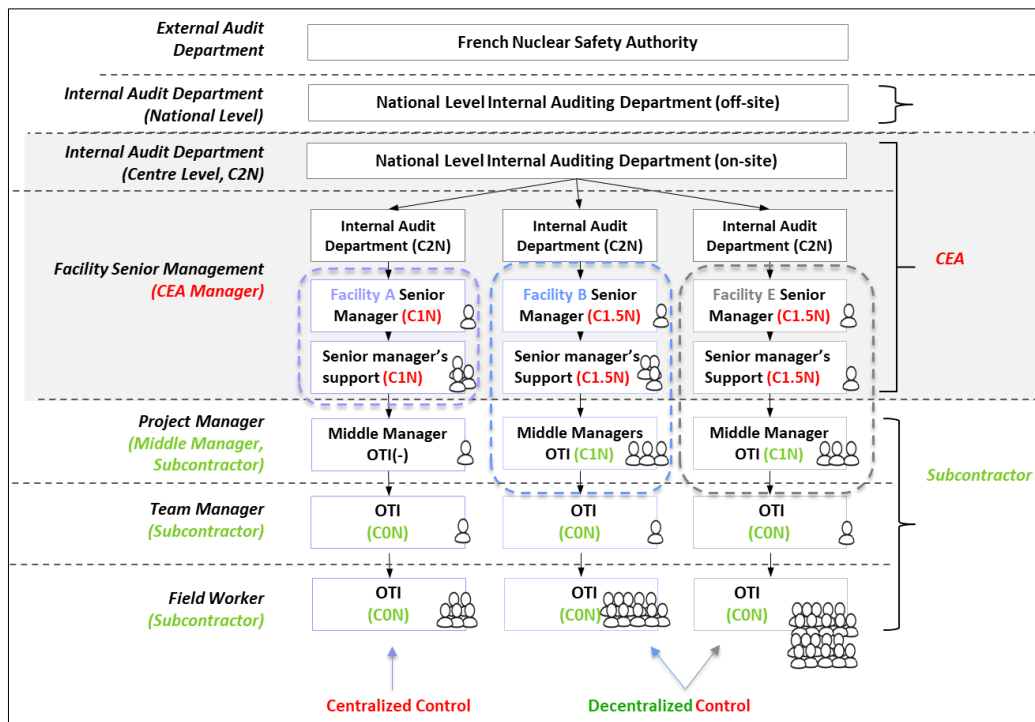


Figure 43. Organizational Structure and decentralized or centralized control of Facilities A, B and E

Facility B's *integrated and symbiotic nature of joint and high interdependencies* (see section 3.2) yields a Facility where **Middle Managers** and subcontractors are encouraged to make suggestions, where decisions are discussed between the **Middle Managers** (C1N) and the **CEA Managers** (C1.5N) and then implemented by the **Middle Managers** (C1N) with the validation, support and often the active presence of the **CEA Managers** (C1.5N). As a result, decisions are decentralized but remain at the managerial level and thus in a central manner. Furthermore, the communication and co-ordination between the CEA the **Middle Managers** and the subcontractors is constant in order to mitigate agency problems and to ensure open communication channels. *During Social Controls*, both Facility B and Facility E prioritize **intra-organizational** and **inter-organisational** interactive controls, with Facility B focusing on morning or weekly health and safety training, and performing Nuclear Safety Training and health and safety exercises (three controls that in Facility E are only carried out by the Internal Audit department at the Centre -C2N, rather than by C1N or the C1.5N control levels). *During behavioural controls*, Facility B prioritises **inter-organisational** interactive controls between the CEA, the **Middle Manager** and the subcontractors; while *during output controls*, *Facility B balanced their priorities between **intra-organizational** and **inter-organisational** interactive controls*. Like with Facility A, performance measurements (detective behaviour controls and interactive output controls) are used to mitigate any agency problems, which are then re-addressed during the morning social control meetings; thereby completing a full interactive control cycle with all system levels (see Figure 40 in section 2.6 for the full cycle of control). As a result, Facility B focuses on balancing the quantity of interactive informal controls (prior to the task) to balance their interactive formal controls (during and after the task) to include all 3 system levels (Field worker/Team Manager, **Middle Managers**, and **CEA Managers**). As a result, this Facility addresses both the informal and formal ago-antagonistic poles of control. This ensures open lines of communication for employees to take on the responsibility of signaling near misses, promoting improvements and being informed thereby providing all system levels with the necessary knowledge to become empowered decision makers throughout the day. These characteristics are typical of a leadership style known as a transformational leadership.

Facility E's *less integrated, less symbiotic nature with low interdependencies in the **intra-organizational** and **inter-organisational** relationships* (see section 3.2) yields a decentralized control where the majority of the initial temporary decisions are taken by the **Middle Managers** (C1N) and subcontractors, and then they are either approved or adapted by the **CEA Managers** (C1.5N); implying that CEA controls are final. However, unlike with Facility B, these controls are carried out in two separate instances with little consultation of one party to the other. This organizational structure due to the limited **inter-organisational** interaction has an impact on the leadership styles of both the **CEA Managers** and the **Middle Managers** towards their team members. As mentioned above in Facility B's social control description, Facility E has limited number of social controls with the Co-activity Management meeting (**CS4**) and the Integration of Return of Experience (**CS8**) being the two sole social controls whereby all 3 system levels are present (See Figure 40 in section 2.6). *During both behaviour*

controls and output controls, *Facility E prioritized the intra-organizational interactions* once again due to the lower active presence of **CEA Managers**. These predominately **intra-organizational** controls in Facility E follow a particular Control Cycle of their own. As experienced by Foscari (*P27, Facility E Production Manager, Middle Management- Subcontractor, Interview 3P27Int1, *16*), when Facility E is in production, the [control] cycles are always the same. The pre-job briefing and the occupational safety minute during the Co-Activity meeting take place every morning between the CEA and the **Middle Management**, indicating the tasks of the day, and a short return of experience of what occurred the evening before. Following this meeting with the CEA, the **Middle Management** transmit to the subcontractors the instructions on the different points of the daily activities. There after, additional extensive controls throughout the day are carried out by **Middle Managers** and depend on the type of activity. For example, when the nuclear waste barrels are placed in the alveoli (repetitive and computerized actions), the subcontractors complete the quality records/files for each barrel in each cell. After the barrels have all been moved into the alveoli, the Quality **Middle Manager** cross-checks the records/files to control that nothing has been forgotten and that the operation results are as expected. This verification may take place at a later time as no fixed time-period is attributed to this verification (for example the following day).

As experience by Foscari (*P27, Facility E Production Manager, Middle Management- Subcontractor, Interview 3P27Int1, *17*) the low interdependency within and between system levels results in a lower degree of interaction amongst all members of the Facility and hence prolongs the duration between when things go wrong and when CEA is informed of any irregularities. During one event, the subcontracting firm was trying to solve the problem and since the **CEA Managers** were not on-sight at the time, the subcontracting firm did not inform the CEA of the event until the end of the day. Following this event, the CEA indicated that they want to be notified immediately of any important issues. As a result, Facility E **Middle Managers** have created an **intra-organizational** software system with an electronic form that allows subcontractors at any level to inform **Middle Managers** of any minor events or concerns, which are then filtered by **Middle Management** and decidedly (or not) passed onto the CEA. This tool has helped to integrate suggestions or concerns from subcontractors; however, it is not accessible to all system levels. Nonetheless it helps to ensure interactions between all system levels in an effort to reduce the communication distance between the CEA and the subcontracting firm. Specifically, the subcontracting firm has created an internal electronic form (software tool) that allows subcontractors to provide information at any time concerning any abnormal findings. This form is then transmitted to the Health and Safety **Middle Manager**, then onto the Nuclear Safety **Middle Manager** and then to the Production **Middle Manager**. Each leader provides their opinion if the RCI should be informed of the concern, allowing to prioritize the level of gravity and react accordingly. As soon as this form is created it is immediately dispatched to the **Middle Managers** and mechanisms are activated to trace/correct the anomaly and to inform the CEA.

As a result, Facility E has the most decentralized set of control mechanisms, often leaving the **Middle Managers** to resolve the situation prior to informing the CEA. The **Middle Management** level's communication initiative shows a preventive focus to mitigate potential deviations. Facility E's strong intra-communication exchanges encourage a communication platform albeit non-interactive, possibly due to their low interdependent actor configurations. These characteristics (low CEA presence and **Middle Managers** innovative and adaptive systems) are typical of a leadership style known as a Delegative/ Laissez-faire leadership.

3.4. Size and Ratio of **Middle Managers** and **CEA Managers** to **Subcontractors**

Facility A, Facility B and Facility C all differ not only in the size of the facility, the number of personnel at each level, but also in the levels of control that are officially recognized by the CEA. Facility Size and particularly (1) the ratio **CEA Managers** to subcontractors, (2) the ratio of **Middle Managers** to subcontractors, and (3) the ratio of **CEA Managers** to **Middle Managers**, are important contingent variables that indicate the scope of the communication and coordination challenges faced by the Facility, thereby impacting the level of interaction between all actors' at all system levels. Table 18 below details the size and number of personnel at each level, while Figure 44 shows the ratio of personnel at the subcontractor level (in grey), the **Middle Manager** level (in green) and at the CEA Manager level (in red).

Facility A is the *smallest* in size with 23 staff. The subcontracting firm consists of 12 subcontractors and 1 **Middle Manager** that is not present on-site in a permanent capacity²³, while the CEA consists of 1 Facility Chief and 9 supporting staff or **CEA Managers**. In Facility A:

(1) The ratio of **CEA Managers** to subcontractors (C1N) is 3:4 that is nearly 1 CEA manager per 1 subcontractor, yielding the *highest inter-organisational ratio*.

(2) The ratio of **Middle Managers** to subcontractors is negligible given that no official *intra-organizational* control exists at this level; nonetheless there is approximately 1 **Middle Manager** to 12 subcontractors. The lack of **Middle Managers** may lead to a higher information asymmetry, but due to the quantity of formal controls (interactive detective behaviour controls and interactive output controls) and social controls (when required see section 1.4), in addition to the **CEA Manager's** implication, Facility A is able to overcome and mitigate potential information asymmetry (see section 3.1).

(3) The ratio of **CEA Managers** to **Middle Managers** is 9:1 making this the largest difference in **Middle Manager** to **CEA Managers** out of all of the 3 facilities. This autonomy of control, provides the CEA with an even stronger level of authority over the subcontractors which they exercise through formal

²³ In 2021, Facility A has a "Team Manager" role within the subcontracting firm. This team manager appears to function as an intermediate role similar to the "Middle Managers" described throughout this thesis.

controls that sanction subcontractors should rules not be followed, without the use of complex controls such as those of facility B's morning package routine.

As a result, Facility A's main communication and co-ordination occurs between the **CEA Managers** and the subcontractors directly, yielding *the strongest of the inter-organisational exchanges* and the *weakest intra-organizational exchanges* amongst the 3 facilities (see section 2.7).

Facility B is twice the size of Facility A with a total of 40 staff members. The subcontracting firm consists of 24 subcontractors and 7 **Middle Managers**, while the CEA consists of 1 RCI and 8 supporting staff (**CEA Managers**). Facility B has a strong **Middle Management** presence out of all of the three facilities, which mirrors the quantity of CEA supporting staff. In Facility B:

(1) The ratio of **CEA Managers** to subcontractors (C1.5N) is 1:3, the second ratio amongst all three facilities indicating a *strong inter-organisational exchange* in part due to this ratio but even more so due to the frequency and quantity of exchanges between all 3 system levels.

(2) The ratio of **Middle Managers** to subcontractors (C1N) is 7: 24, that is nearly 1 **Middle Manager** for every 3 subcontractors, yielding a similar *intra-organizational exchange* to that of the *inter-organisational exchange* stated above. This **Middle Management** layer decreases information asymmetry and Facility B's leadership style allows for more sophisticated daily control systems that incorporate all system levels thereby enforcing strong communication and co-ordination; tackling any potential information asymmetry due to its larger size and ratio of **Middle Managers** to subcontractors.

(3) The ratio of **CEA Managers** to **Middle Managers** is 8:7, that is nearly 1 CEA for 1 **Middle Manager**. Facility B balances these two *intra-organizational* and *inter-organisational* exchanges partly due to the similar ratio of **CEA Managers** and **Middle Managers**, as well as the joint morning social controls put in place by the CEA and that are led by the **Middle Managers**. In this way, the CEA empowers **Middle Managers** by promoting the C1N controls and showing their implication through continuous active presence and accessibility to subcontractors. This joint managerial effort allows for more complex controls such as the informal daily morning package of social controls (*Co-activity Management CS4, Task Preparation (Safety Minute and Pre-job Briefing) CS7, and Implementation of Return of Experience CS8*) and the formalized document meetings in Facility B (see section 3.6 for more details). Like with Facility A, the **CEA Managers** establish rules and procedures for the subcontractors, but Facility B's management style encourages subcontractors to daily voice their concerns on rules and procedures.

As a result, Facility B's main communication and co-ordination occurs jointly amongst both the **CEA Managers** and the subcontractors and the **Middle Managers** and the subcontractors, resulting in *the most balanced of inter-organisational and intra-organizational exchanges* amongst the 3 facilities (see section 2.7). This results in a

Facility E is the *largest* of the facilities, with a total of 53 staff members. The subcontracting firm consists of 42 subcontractors and 8 *Middle Managers*, while the CEA consists of 1 RCI and 2 supporting staff. Facility E has the smallest quantity and percentage of RCI support staff. In Facility E:

(1) The ratio of **CEA Managers** to subcontractors (C1.5N) is 1:24 yielding the *lowest inter-organisational exchange* amongst the three facilities; mirrored by the least interactive controls amongst all 3 facilities due to the reduced number of joint controls or weekly meetings that include all 3 system levels.

(2) The ratio of *Middle Managers* to subcontractors (C1N) is 1:5 that is nearly 1 *Middle Manager* for every 5 subcontractors, the second ratio amongst all three facilities indicating a *strong intra-organizational exchange* within the subcontracting firm.

(3) The ratio of **CEA Managers** to *Middle Managers* is 1:4, highlighting that the *Middle Manager* active presence outweighs the **CEA Managers** not only by the ratio but also by the frequency and active presence of **CEA Managers** in the facility, explaining the *Middle Managers* decisive power and influence over the subcontracting firm. Indirectly, the CEA’s communication and coordination style empowers the *Middle Managers* as they are the main control and point of reference for the subcontractors. Like with Facility A and B, the **CEA Managers** establish general rules and procedures in the contract for the subcontractors but due to the stronger *Middle Manager* active presence on-site these rules are initially and mainly controlled by *Middle Managers*.

As a result, Facility E’s main communication and co-ordination occurs between the *Middle Managers* and the subcontractors directly, yielding *the strongest of the intra-organizational exchanges* and the *weakest inter-organisational exchanges* amongst the 3 facilities (see section 2.7).

Table 18. Size of Staff at each level in Facility A, B and E

Facility A (Smallest)	Subcontracting Firm		CEA C1N		TOTAL staff
	Subcontractors C0N	Middle Management (-)	Facility Chief	Support Staff	
	12	1	1	9	

Facility B	Subcontracting Firm		CEA C1.5N		TOTAL staff
	Subcontractors C0N	Middle Management C1N	Facility RCI	Support Staff	
	24	7	1	8	

Facility E (Largest)	Subcontracting Firm		CEA C1.5N		TOTAL staff
	Subcontractors C0N	Middle Management C1N	Facility RCI	Support Staff	
	42	8	1	2	

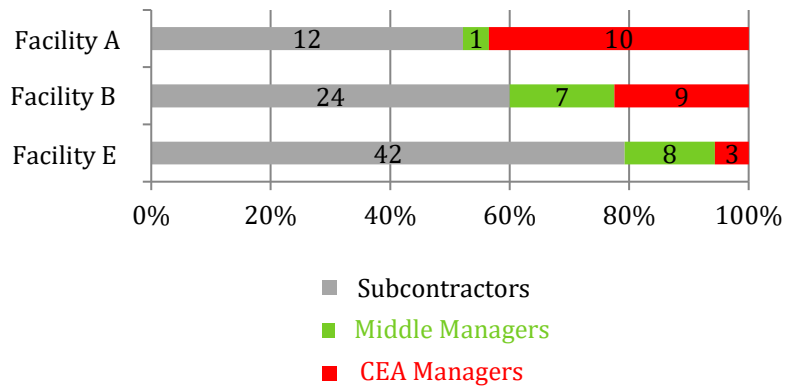


Figure 44. Ratio of Personnel at the Subcontractor, Middle Management and CEA Management Level in the three Facilities

3.5. Strategies and Methods to Achieve Results and Safety Objectives

The facilities' strategies and methods used to achieve results and safety objectives are aligned or "fit" to the use of MCS and their incidental leadership style. Figure 48 below details a segment of 8 controls used daily or nearly daily in all facilities in the control cycle (section 2.6) that commences with social controls, moves onto behaviour controls and output controls and then circles back to social controls; thereby re-initiating the cycle. This figure helps to explain how the predominant type of MCS used by **CEA Managers** in each facility "fits" with the facility's distinct leadership style and subsequently empowerment style. Specifically, this figure indicates: (1) the temporal aspect of the controls (before the task, during the task, after the task); (2) the nature of control (preventive, detective); (3) the type of interaction possible (interactive; non-interactive, auto-control); (4) the control (Social **CS**, Behavioural **CC**, Output **CR**); (5) the aim of the control; (6) the 5 **Empowerment Leadership Factors** (Arnold et al., 2000) associated with each of the 9 controls (*leading by example, coaching, informing, participative decision making, showing concern and interacting*); and (7) The CEA's primary focus of controls denoted by a thick line along the control sequence to obtain results and safety objectives (Facility A in purple, Facility B in blue and Facility E in grey).

In terms of result objectives, all of the three facilities use daily output controls to ensure that the expected results are obtained and to detect any deviations from those results. All facilities use non-interactive and interactive output controls to discuss how operations occurred with each facility employing different strategies: Facility A's single authoritarian control was performed by **CEA Managers** (C1N); Facility B's symbiotic controls involved both Middle (C1N) and **CEA Managers** (C1.5N) simultaneously; and Facility E's independent controls involved Middle and at times **CEA Managers** in two separate controls. Additionally, as indicated by Foscarini, P27, in section 3.3, some of Facility E's non-interactive output controls by the Quality **Middle Manager** take place when time permits rather than on a daily basis.

In terms of safety objectives:

Facility A's transactional leadership style by **CEA Managers** encourages the planning and execution of a perfect safety record through twice-daily occupational safety inspections; given the **CEA Managers** are the only official control. By considering the frequency and the number of the controls, Facility A appears to be mainly **reactive**/adaptive to the subcontractor's behaviour, **prioritizing formal detective behaviour and both interactive and non-interactive output controls**; and implementing proactive social controls only following the detection of broken rules during behaviour controls (as most of the exchanges following broken rules occurs during the interactive Debriefing Activities **CR5** at the end of the day). Overall, Facility A employs *preventive informal social controls on occasion* (such as the annual Health and Safety week) and **independently** of the *systematic and daily formal interactive detective behaviour and interactive detective output controls* (in the thick purple line in Figure 48) that have formal feed-back loops in the form of formalized meetings and weekly written minutes. In fact Facility A uses these daily systematic behaviour controls (*health and safety inspections **CC3**, Verification of Procedure Validation **CC6bis***) to provide **CEA Managers** with an opportunity to develop Arnold et al.'s (2000) **Empowerment Leadership Factors** to *lead by example, inform* subcontractors of any discrepancies and *show concern and interact* with the subcontractors; while the daily interactive output control (*Debriefing Activities **CR5***) add to the **CEA Manager's** ability to *coach* the subcontractors on points they identified during the inspections, and provide an atmosphere for *participative decision making* in terms of future suggestions, as indicated in Figure 48. As a result, **CEA Managers** in Facility A do not balance informal controls with formal controls (as is the case in Facility B) and instead rely on daily interactive output controls. As a result, **CEA Managers** from Facility A focus on the *detective ago-antagonistic pole* through their implication in the daily interactive output controls.

Facility B's transformational leadership style encourages innovation and communication amongst all system levels in order to increase safety leadership. Since the first sets of formal controls are delegated to **Middle Management**, this not only empowers **Middle Managers** to show **Empowerment Leadership Factors**, but it also encourages a *united contractor-subcontractor business entity*. Facility B **CEA Managers** have made several changes to the frequency and the implementation of several social controls, in which precise motivations were identified as the source of these changes related to the *leadership factors*. These changes are summarized in Figure 45 below and include:

- (1) **Co-activity Management(**CS4**)** entails the programming of operational activities to diminish possible planning and scheduling conflict (incompatibilities where teams may operate in parallel on the same zone or require the same equipment). Co-activity meetings take place at the end of the week with **CEA Managers** and **Middle Management** to ensure minimal impediments or temporal constraints on the following week's operations. Facility B implemented a daily co-activity meeting each morning with all staff members across three system levels, in order to include subcontractors and supervisors (not previously included in the weekly co-activity meeting). (*Motivation at the source of the change: interaction with employees, participative decision-making*).

(2) **Health and Safety Training (CS1)** is typically scheduled several times during a safety week, followed by health and safety exercises (S6) carried out without warning by the senior CEA management within the facility. Facility B has formalized this training, led by **Middle Management**, in its daily morning routine as a final “safety minute” segment of the co-activity meeting. (*Motivation at the source of the change: coaching, leads by example*).

(3) **Document Management (CS3)** procedures consist of notifying the subcontracting firm (**Middle Management**, supervisors, subcontractors) of new documents or updated versions via email and the document platform. Facility B implemented a sequence of meetings between (1) **CEA Managers** and **Middle Management** and (2) **Middle Management** and their subordinates (subcontractor and supervisor level) to formalize the dissemination of new documents to all members of the organization. (*Motivation at the source of the change: informing*).

Empowerment Leadership Model (ELM):	 Leading by example "shows the leader's commitment to their work & the work of the team" *	 Coaching "educates team members and help them to become self-reliant" *	 Informing "disseminates important company information" *	 Participative decision making "uses a team members' information and input in making decisions" *	 Showing Concern / Interacting with employees "demonstrate a general regard for team members when interacting with the team" *
CO- ACTIVITY MANAGEMENT				✓ Encouraging safety suggestions	✓ Re-enforcing reporting
HEALTH & SAFETY TRAINING	✓ Encouraging safety commitment	✓ Empowering via knowledge			
DOCUMENTATION MANAGEMENT			✓ Encouraging new ideas	✓ Encouraging new ideas	
INTERNAL ELECTRONIC FORM TO REPORT SAFETY ISSUES			✓ Enhancing safety participation & safety practices	✓ Enhancing safety participation & safety practices	

Figure 45. Leadership Factors associated with the changes that altered the balance of Prevention & Detection

By considering the frequency and the number of the controls, Facility B appears to be **proactive** rather than reactive/ adaptive (as is the case in Facility A and E) to the subcontractor’s behaviour and actions, *prioritizing formal preventive social controls before the task jointly with interactive output controls after the task*; recognizing the importance of communicating before and after the process to ensure adequate safety awareness, openness and leadership practices during the process through auto-controls. Overall, Facility B employs *preventive informal social controls on a daily basis* in a **package of morning controls accompanied** with *daily interactive detective output controls* (in the thick blue line in Figure 48) that provide informal and formal discussions to identify where procedures could have gone better and to voice any concerns or frustrations. In fact, this unique combination of balance between the informal and formal discussions begins with (1) the daily package of informal morning controls that’s binds 4 social controls (Co-activity meeting, Safety Minute, Pre-job briefing, and implementation of the REX) together into a morning ritual allowing the ability to identify how procedures should take place (proactively). It is essential to note that this is the only Facility to carry out these controls in this sequence on a daily basis led by **Middle**

Managers, in the presence of all 3 system levels including the RCI providing direct access to all **CEA Managers**. These informal discussions are then followed by (2) the daily interactive debriefing activities to discuss how procedures actually took place, any problems encountered, the solutions proposed and how subcontractors adapted to these unforeseen constraints. By accompanying these informal morning discussions with the daily formal afternoon discussions, all system levels can gain better insights into the daily operations at the facility, contrast how things should be done with how they are actually done, and provide subcontractors with a space to voice any suggestions. As a result, **CEA Managers** in Facility B balance informal controls with formal controls through this unique combination of daily morning informal and evening formal controls (as indicated in Figure 48). This balance of both *ago-antagonistic poles* further reinforces **all 5 Empowerment Leadership Factors** by allowing **Middle Managers** and **CEA Managers** to: (1) *lead by example* and demonstrate their commitment to safety; (2) provide a communication platform for safety concerns and reminders, and to identify areas that require **Coaching**; (3) allocate a time period to *inform* or disseminate crucial safety references, allowing subcontractors to voice concerns regarding procedures; (4) increase *participative decision making* by facilitating discussions of contingencies in case of unexpected Operational Changes; (5) to *interacting with and showing concern for subcontractors*, encouraging subcontractors to voice suggestions for daily operations.

Facility E's Delegative/Laissez-faire leadership style by **CEA Managers** encourages adaptability, autonomy and accountability within the **Middle Managers** to ensure safety leadership within the subcontracting firm; as **CEA Managers** rely on **Middle Managers** due to the large differentiation in ratio between the two (1:4) and the reduced CEA –subcontractor interactions. Like with Facility B, Facility E has also made changes to how they implement several controls; however, in this case these controls have been designed and implemented by **Middle Managers** on an internal level, independently of **CEA Managers**. Specifically, **Middle Managers** have adapted how they rapidly filter, track and move information up the hierarchy to **CEA Managers** by implementing a new control in the form of an internal electronic form (software tool) that empowers subcontractors at all levels to do their part and immediately report any safety concerns. (For additional information on this adaptation, see Forscari's (P27), description in section 3.3). By considering the frequency and the number of the controls, Facility E's **CEA Managers** appear predominantly *reactive*/adaptive to the subcontractor's behaviour, *prioritizing daily non- interactive controls* (in the thick grey line in Figure 47); thereby inadvertently encouraging **Middle Managers** to take on a more *proactive* stance to safety leadership in addition to their own reactive/adaptive posture. Overall, Facility E's **CEA Managers** employ a limited and lower amount of *preventive informal social controls* and do so *independently* of the *daily formal non- interactive detective output controls* (in the thick grey line in Figure 48). It is important to note the frequency and the number of system levels involved in these preventive informal social controls by **CEA Managers**, specifically according to Derk, P26, Facility E CEA manager, interview 3P26Int 2):

- Safety trainings (*Health and Safety Training CS1, Nuclear Safety Training CS2 and Health and Safety Exercises CS6*) are carried out by the C2N Internal Audit Department (“la cellule”) at the Centre level on a yearly basis and with all 4 system levels.
- *Document Management meetings (CS3)* occur yearly with only 3 system levels.
- *Co-activity Management Meetings (CS4)* during the Change of Subcontractor Process took place with all 3 system units and with both the exiting and the incoming subcontractor; but currently 1.5 years later only between **Middle Management** and **CEA Managers**; therefore, subcontractors do not interact directly with **CEA Managers** on a daily basis.
- *Integration of Return of Experience (CS8)* is carried out on a daily basis between **Middle Managers** and subcontractors (C1N) but on a weekly basis between **CEA Managers** and subcontractors (with all 3 system levels).
- The other two Social controls (*Mastery of Transportation CS5 and Task Preparation CS7*) are only carried out by **Middle Managers** (C1N)

As a result, **CEA Managers** in Facility E do not balance informal controls with formal controls (as is the case in Facility B), instead focusing on the *detective ago-antagonistic pole*. This focus on a single polarity used by **CEA Managers** encourages **Middle Managers** to compensate by implementing occasional safety training sessions in an unofficial capacity independent of **CEA Managers**. As a result, and according to Foscari, P27, he as **Middle Manager** employs a leadership style towards the subcontractors that combines qualities of the Transformative and Delegative/Laissez-faire leadership; thereby mirroring the **CEA Managers** leadership style while simultaneously encouraging safety leadership through daily preventive social controls (*Co-activity Management Meeting CS4 and Integration of Return of Experience CS8*) and like Facility A through daily interactive behaviour and output controls. **CEA Managers** also develop the 5 **Empowerment Leadership Factors**, on a more reduced capacity, during the weekly meetings such as the *Implementation of REX CS8*, allowing them to: *show concern and interact* with the subcontractors, *lead by example*, *inform* and *coach* subcontractors of any REX from other Facilities, and provide an atmosphere for *participative decision making* in terms of how to integrate REX into future operations, as indicated in Figure 48.

Figure 45 below summarizes the predominant type of control and Leadership style used in each of the Facilities to achieve results and safety objectives.



Figure 46. Predominant type of control and leadership style of Facility A, Facility B and Facility E.

Each Facility has their own particular combination of control and leadership, and each of the 24 MCS has a link with the 5 aforementioned **Empowerment Leadership Factors**. (1) Social controls (*CS*), which are interactive *preventive controls*; and (2) Interactive output results (*CR*) which are *detective controls* allow for all five leadership factors. (3) Behaviour controls (*CC*) allow for certain leadership factors while (4) non-interactive output controls (*CR*) do not a lot any of the five **Empowerment Leadership Factors**. Figure 47 below details the interactions between the types of control and the five **Empowerment Leadership Factors**.

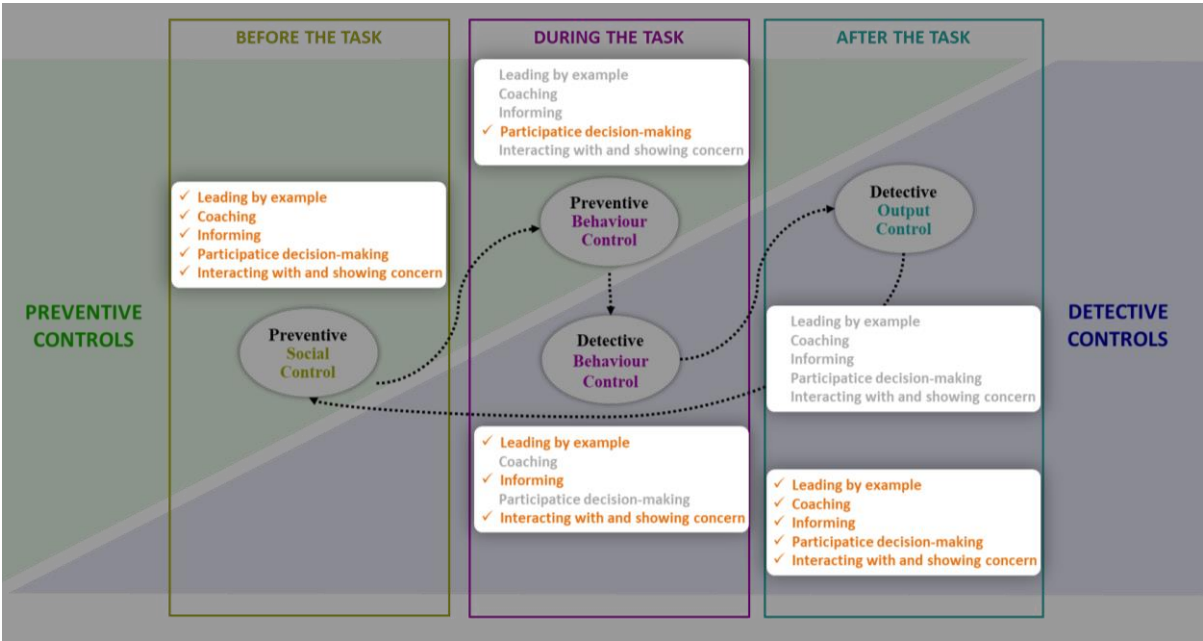


Figure 47. Types of Controls and their interaction with the five Empowerment Leadership Factors.

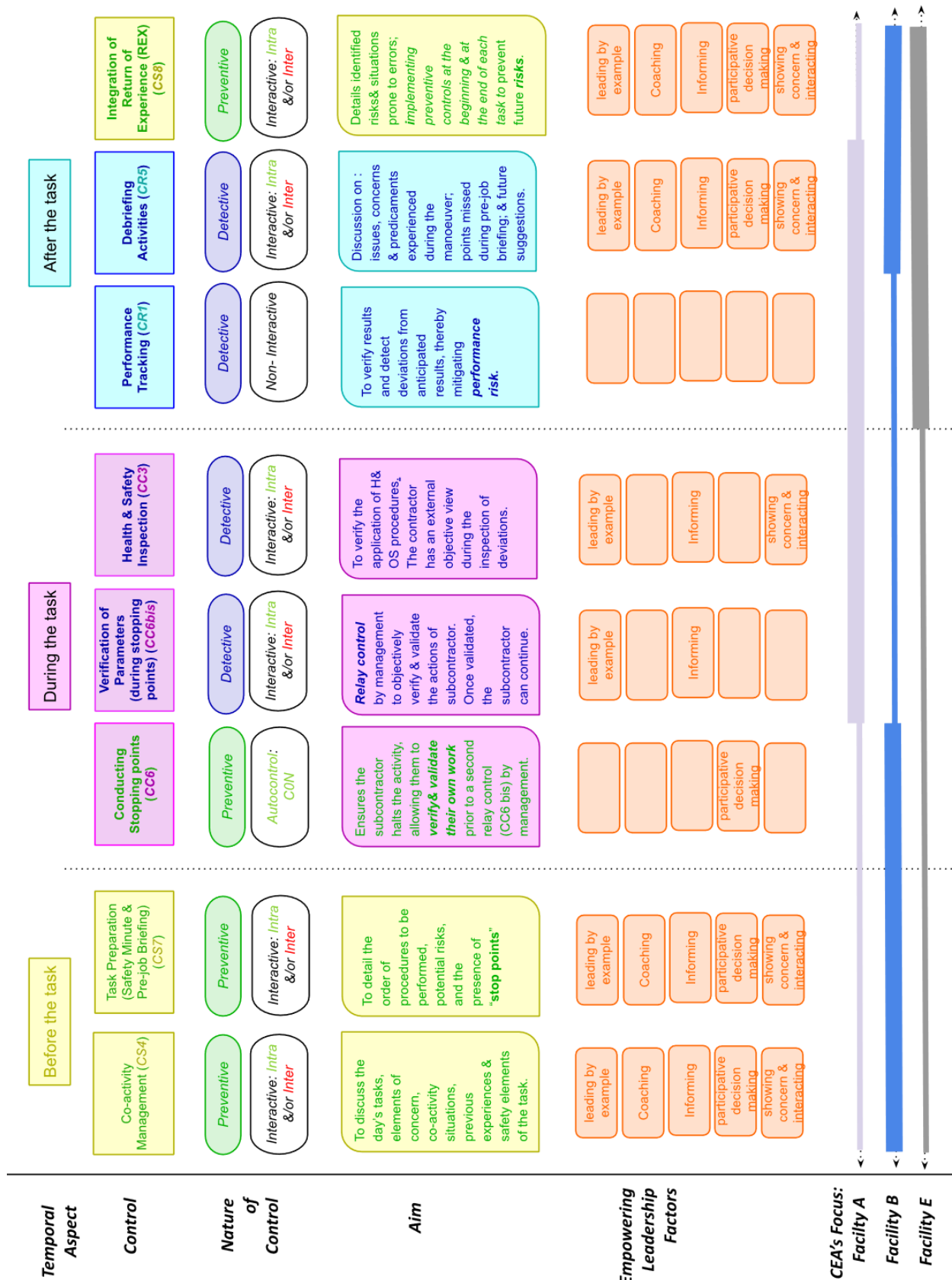


Figure 48. Comparison of the predominant choice of controls amongst the daily sequence of controls of the control cycle and the fit of these MCS with the distinct leadership styles of Facility A, Facility B, and Facility E

3.6. Implication of CEA Managers in Promoting Safety Culture

Organizational Culture and Safety Culture, particularly in the case of the CEA, plays a key role in the development of safety leadership, ensuring the convergence of safety objectives or the compatibility of non-convergent objectives. The use of MCS, with a particular focus on the use of preventive social controls to mitigate all three types of subcontracting related risks (Section 1.4) and to develop **Empowerment Leadership Factors** appears to play a key role in aligning the diverse safety cultures amongst the CEA and the subcontracting firm into an equivalent Safety Culture shared by a united contractor-subcontractor business entity. All three facilities use MCS to mitigate safety-related subcontracting risks, but their use of leadership practices varies. This difference Manager’s leadership style appears to vary according to: (1) *the choice of MCS and CEA managers’ implication (active presence)*, a factor that appears to be linked to the type of managerial configuration (3.3), size of facility (3.4) and work process (interdependencies amongst actors) (3.2), and (2) *the manner in which CEA Managers promote safety culture*, a factor that appears to be linked to the external environment due to the timing of when the immersions took place in relation to the transition process between two subcontractors (3.1) and the strategies and methods used to achieve results and safety objectives (3.5). Figure 49 below provides an overview of the five aforementioned contingency factors and how they are related to Culture; as *culture* influences both *the implication and the manner that Managers promote safety culture*. Finally, leadership style is another way to express the set of Empowerment Leadership Factors.

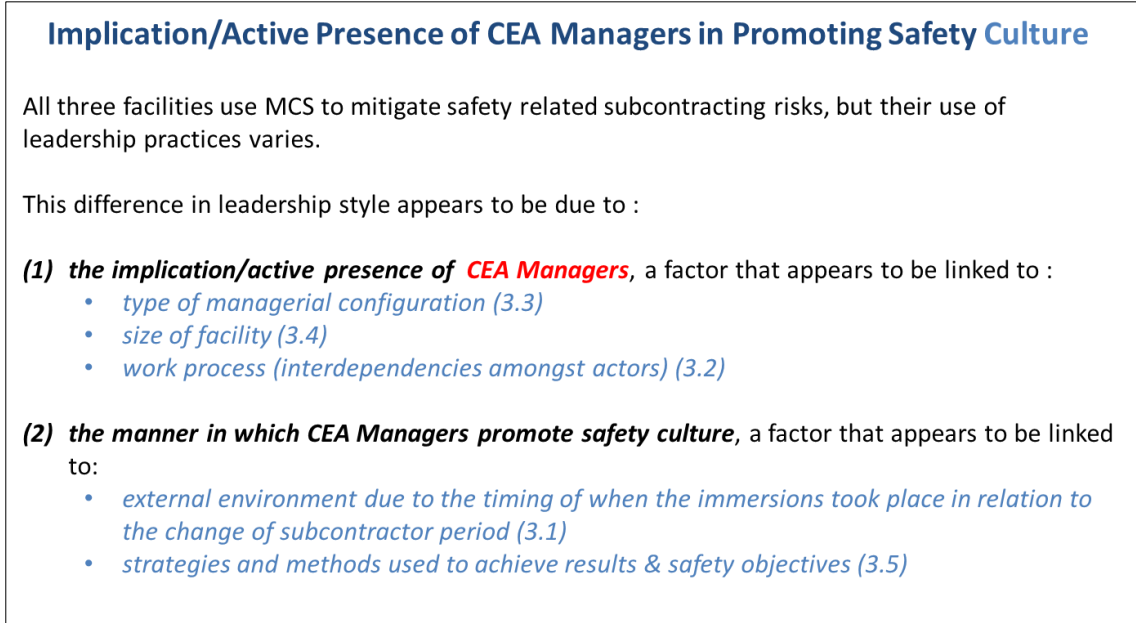


Figure 49. Relationship between all of the Contingent Variables and their effects on leadership style

The 24 MCS common to all 3 facilities were mapped out across the 4 system levels, providing insight into the distance between the elements and their connection to the five **Empowerment Leadership Factors**. Figure 53, Figure 54, and Figure 55 depict Facility A, Facility B and Facility E’s respective distribution of the 24 MCS used to prevent and mitigate safety-related subcontracting risks according to

the system level of control that carries out the control (subcontractor, supervisor, **Middle Management**, senior CEA management within the facility, internal audit department, external regulating body). Of the 24 MCS identified in the 3 facilities, 19 (over 79% of the total controls) in Facility A, 17 (42.5% of the total controls) in Facility B, and 8 (26.6% of the total controls) in Facility E occurred in the **CEA Management Level**. In contrast, Facility B's **Middle Management level**, carried out 18 (45% of total controls) of the MCS, while Facility E's **Middle Management** level carried out 14 (46.6% of the total controls) of the MCS with the C2N Internal Audit department carrying out 3 (10% of the total controls) of the controls to support the reduced quantity of **CEA Managers** in Facility E. Finally, nearly all of the MCS carried out at the **CEA Management** and **Middle Management** Level, with the exception of non-interactive output controls, showed a link to at least one leadership factors; with Interactive Social Controls and Interactive Output Controls demonstrating a link to all five **Empowerment Leadership Factors**.

In terms of the implication of managers in promoting safety culture :

Facility A's CEA Managers, as a centralized managerial configuration and sole level of control, are highly implicated in promoting Safety Culture. The small size of the facility and the even CEA to subcontractor ratio (nearly 1:1) fortified by the high **inter-organizational** interdependency between **CEA Managers** and subcontractors, allows for the **CEA Managers** to implement formal controls in a top-down direction. The timing of the immersion (t=0 years) coincided with the beginning of the second transition process between two subcontractors²⁴, during which the **CEA Managers** strove to ensure a strong relationship with both the exiting and the incoming subcontracting firm. A strong united subcontractor-contractor relationship, allows the CEA to rapidly establish an effective safety culture that would later be re-enforced through the facility's strategy to achieve results and safety objectives. More specifically these strategies consist of a continuous in-facility active presence (high implication) and daily reactive/adaptive or detective behaviour and output controls such as onsite health and safety inspections and debriefing activities. (To date, knowledge of changes to MCS and specifically Social controls is non-existent but this does not indicate that improvements to the MCS initially put into place at the timing of the immersion have not occurred). This combination of contingent variables shows a **strong implication on the part of CEA Managers to utilize tight formal controls to establish and enforce a common safety culture using a transactional leadership style**. Figure 50 below provides an overview of the implication of CEA managers in promoting Safety Culture and the type of leadership style of Facility A managers.

²⁴ This was the second change of the subcontractor period for Facility A, as the outgoing subcontractor firm at t=0 years had already undergone the first transition process between two subcontractors 5 years earlier when the firm took over from the previous operator. As a result, this is the second transition process between two subcontractors for Facility A.

Implication/ Active Presence of CEA Managers in Promoting Safety Culture

Facility A:

(3.3) centralized managerial configuration, 1 level of control highly implicated in promoting safety.

(3.4) small size facility ; CEA to subcontractor ratio (nearly 1:1)

(3.2) high inter-organisational interdependency between CEA Managers and OTI

→ Implication allows CEA Managers to implement formal controls in a top down direction.

(3.1) timing of immersion (t=0 years) → beginning of 2nd change of subcontractor period;

CEA Managers : strong relationship with exiting and incoming OTI → strong united subcontractor-contractor relationships

(3.5) strategies: continuous in-facility presence (high implication) and daily reactive/ detective behaviour controls and output controls (onsite health and safety inspections/ debriefing activities).

→ allows CEA to establish an effective safety culture

This combination of contextual variables demonstrates a **strong implication/active presence on the part of CEA Managers to utilise tight formal controls to establish and enforce a common safety culture using a transactional leadership style.**

Figure 50. Relationship between all of the Contingent Variables in Facility A and their effects on Facility A's leadership style

Facility B's CEA Managers and Middle Management, as a decentralized double level of control are both jointly and highly implicated in promoting safety culture. The large size of the facility yields an uneven CEA to subcontractor ratio (nearly 1:3). However, when the inter-organisational and intra-organizational Managerial presence combine (CEA Managers and Middle Managers) the ratio of joint Managers to subcontractors becomes more even (nearly 1:1). The high interdependency between CEA Managers, Middle Managers and subcontractors, allows for the CEA Managers to implement flexible informal controls in a bottom-up direction, encouraging adaptability and openness to change through facilitated participative decision-making. The timing of the immersion (t=3 years) coincides with the middle of the contractual period of the facility's first transition process between two subcontractors²⁵, where the CEA- subcontractor relationship is well established compared with the other facilities. Additionally, the CEA Managers' continual re-enforcement of a symbiotic Middle Manager and CEA Manager partnership during the numerous joint preventive social controls and interactive output controls (debriefing activities), augments CEA Managers' accessibility to subcontractors; thereby further diminishing the distance within the contractor –subcontractor business unity. The balance between Facility B's loose (informal) and tight (formal) controls strategy to achieve results and safety objectives, in addition to the three changes in social controls motivated by safety leadership (detailed in Section 3.5), ensures (1) continuity of the Safety Culture transposed from the historical operator to the current

²⁵ This was the first change of the subcontractor period for Facility B, as 3 years earlier the facility had been exploited by the historical operator and hence the current subcontractor during the immersions (t=3 years) was the first incoming subcontractor since the transition process between two subcontractors was established at the CEA. As a result, this is the first transition process between two subcontractors for Facility B, from a historical operator with an industrial giant in terms of Safety Culture and experience.

subcontractor during the transition process between two subcontractors, and (2) empowerment of **Middle Managers** to inspire safety leadership and help innovate risk prevention strategies to manage safety of human and organizational factors within the facility. For example, in addition to the Document Management meetings (CS3) for new documents, CEA documents (*18) indicate that each month the RCI and the **CEA Managers** establish a theme within the General Control Plan to evaluate. In the event of dissatisfaction with the results of the monthly C1.5N control, the person in charge of the topic from the CEA informs the RCI of any degradation to this level of satisfaction during the periodic team meetings. Next, the RCI then informs the **Middle Managers** at the follow-up meetings and together they identify the improvement actions to be undertaken. Then finally, the subcontracting firms' operational documents in accordance with the theme in question are verified and validated by the RCI and the **CEA Managers**.

The actions of ensuring the CEA and the subcontractors together considering the issues, and establishing a joint plan via a symbiotic exchange of culture, guarantee the subcontracting firm is implicated in the improvement of safety indicators and embodies the proposed changes. This combination of contingent variables in addition to the **Middle Managers' and the CEA Managers' ago-antagonistic balanced use of loose informal controls and tight formal controls empowers Middle Managers to innovate, construct and promote a united Safety Culture using a transformational leadership style**. Figure 51 below provides an overview of the implication of CEA managers in promoting Safety culture and the type of leadership style of Facility B managers.

Implication/ Active Presence of CEA Managers in Promoting Safety Culture

Facility B:

(3.3) **CEA Managers** and **Middle Management** decentralized 2 level of control jointly and highly implicated in promoting safety.

(3.4) large size facility; uneven **CEA** to **OTI** ratio (nearly 1:3), but even joint managerial presence (**CEA +Middle**) to OTI ratio (nearly 1:1).

(3.2) high interdependency between **CEA Managers**, **Middle Managers** and OTI
 → Implication/active presence allows **CEA Managers** to implement flexible informal controls in a bottom up direction, encouraging adaptability and openness to change through **facilitated participative decision-making**.

(3.1) timing of immersion (t=3 years) → middle of the contractual period of 1st first change of subcontractor period, meaning that **CEA- OTI** relationship: well established cf. Facility A and Facility E.
CEA Managers: continual re-enforcement of symbiotic **Middle Manager** and **CEA Manager** partnership during joint **preventive social controls** and interactive **output controls** → augments **CEA Managers' accessibility to OTI** → further diminishing distance within the **CEA- OTI** unit.

(3.5) Strategies: balance of loose (informal) and tight (formal) controls and 3 changes to **social controls** motivated by **safety leadership**
 → Symbiotic exchange of Culture: ensures continuity of Safety Culture and empowers **Middle Managers** to inspire safety leadership, innovate risk prevention strategies and embodies the proposed changes.

This combination of contextual variables in addition to the **Middle Managers' and the CEA Managers' balanced use of loose informal controls and tight formal controls empowers Middle Managers to innovate, construct and promote a united Safety Culture using a transformational leadership style**.

Figure 51. Relationship between all of the Contingent Variables in Facility B and their effects on Facility B's leadership style

Facility E's CEA Managers and **Middle Management**, also have a decentralized double level of control, however Facility E's Managerial presence functions independently, mirrored by a low interdependency. **CEA Managers** show a lower implication in promoting safety culture, when compared with the **Middle Managers** implication, possibly due to the size of the facility (the largest) and the most uneven CEA to subcontractor ratio out of all of the facilities (1:21). However, the **Middle Manager** to subcontractor ratio is less uneven (1:5) allowing for a better implication at the **Middle Management** level, while compensating for the lower CEA implication. Since the managerial presence works independently, **CEA Managers** employ a top-down strategy while **Middle Managers** mirror this top-down strategy, simultaneously promoting a bottom-up direction encouraging employees to communicate any concerns, and forming them to make strategic decisions and react quickly in passing information up the hierarchy to **CEA Managers**. The timing of the immersion (t=1.5 years) coincided with the recent transition process between two subcontractors from the historical operator to the first subcontracting firm²⁶. According to Forscari, P27, the exchange between the CEA and the subcontracting firm following the change of the subcontracting period resembles a customer –supplier relationship, similar to the previous relationship between the CEA and the historical operator. The lack of joint interactive controls between the few **CEA Managers** and the subcontracting firm subsequently inspires **Middle Managers** to fortify their own internal Safety Culture (see section 3.3 and 3.5 for a description of changes made by **Middle Management** to fortify safety). The subcontracting firm's safety initiatives are then assessed and confirmed to align to the CEA Safety Culture during the yearly C2N Safety Culture Initiatives organised by the Internal Audit Department, and in which the **CEA Managers** partake in. The Facility E strategies to ensure safety and result objectives rely heavily on tight non-interactive formal output controls, thereby yielding a larger distance between the CEA and the subcontractors. As a result, **CEA Managers** inspect the subcontractor's culture, and with the assistance of the C2N Internal Audit Department ensure that this Safety Culture aligns with the social controls. As experienced by Derk (*P26, Facility E, RCI support, CEA, Interview 3P26Int2, *19*), the managerial configuration of Facility E (RCI mode with a decentralized organisational structure) warrants two official control levels in terms of nuclear safety and occupational safety compared to the centralized managerial configuration with a single control (of Facility A). This configuration adds a supplementary monitoring loop (C1N, C1.5N) possibly increasing the reliability of the controls: a first control of the nuclear safety, occupational safety and environment monitored by the **Middle Management** C1N level who are always on-site and after that a second control by the **CEA Managers** of their own nuclear safety, occupational safety and environment controls at the C1.5N level.

²⁶ This was the first transition process between two subcontractors for Facility E, 1.5 years after the change of the historical operator of the facility.

This combination of contingent variables shows a **low implication on the part of CEA Managers in their use of tight non-interactive formal controls to verify safety objectives and results via a Delegative/Laissez-faire leadership style**. As a result, **Middle Managers internally promote safety leadership through a combination of Transformational and Delegative/ Laissez-faire leadership style**, thereby establishing a Safety Culture that aligns with the CEA Culture as verified by the yearly C2N Social controls performed by the Internal Audit department. Figure 52 below provides an overview of the implication of CEA managers in promoting Safety culture and the type of leadership style of Facility E managers.

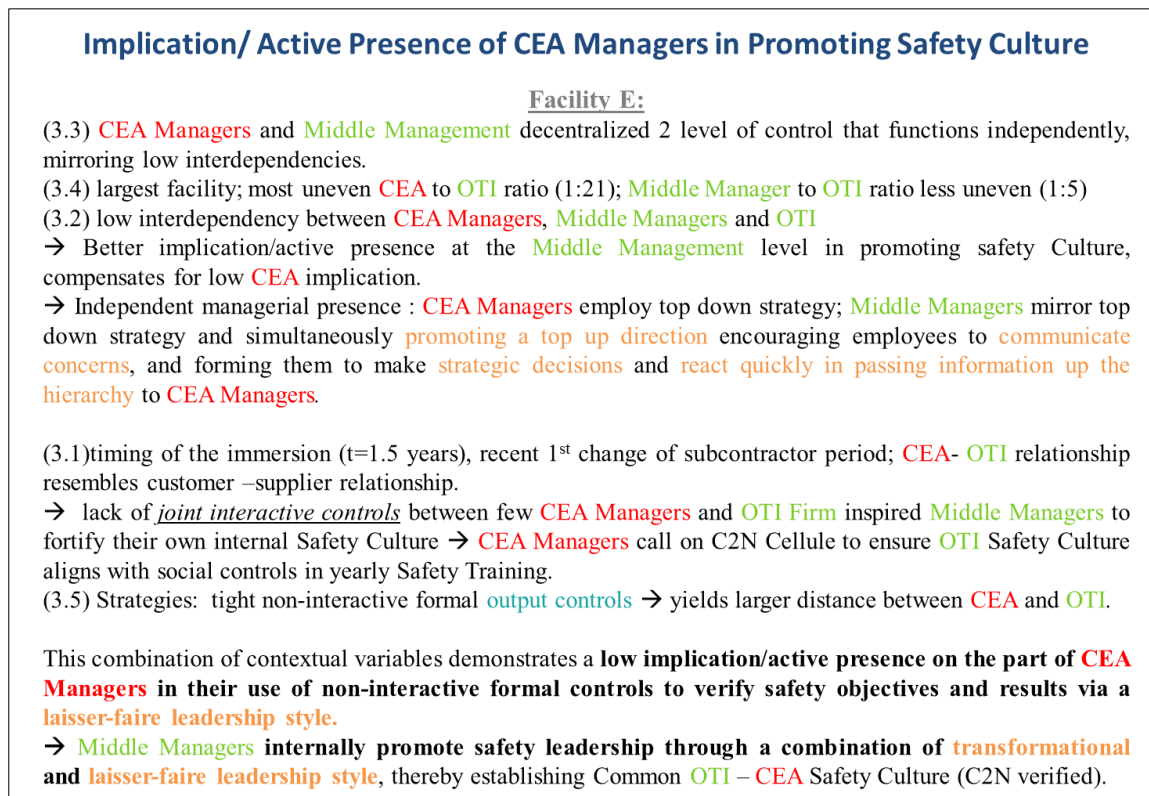


Figure 52. Relationship between all of the Contingent Variables in Facility E and their effects on Facility E's leadership style

External Audit Department	Regulate French Nuclear Facilities		
Internal Audit Department (National Level)	Regulate CEA Nuclear Facilities		
Internal Audit Department (Centre Level, C2N)	Regulate Nuclear Safety	Regulate Environmental safety	Regulate Health & Safety
Facility Senior Management (CEA Manager, C1N)	Promoting shared values (Social Control) Health & Safety Training (CS1) Nuclear Safety Training (CS2) Document Management (CS3) Co-activity Management (CS4) Mastery of Transportation (CS5) Health & Safety Exercises (CS6) Task Preparation (Safety Minute & Pre-job Briefing) (CS7) Integration of Return of Experience (REX) (CS8)	Establishing objectives (Behaviour Control) Verification of Authorized Staff Access (Manager) (CC1-2bis) Health & Safety Inspection (CC3) Nuclear Safety Inspection (CC4) Verification of conformity with regulations (CC5) Verification of Parameters (during stopping points) (CC6bis) Verification of the Daily Facility Round (CC7bis) Performing Monthly Round (CC8)	Monitoring results (Output Control) Performance Tracking (CR1) Radioprotection Verification (2nd Level) (CR3) Verification of Skills post-training (CR4) Debriefing Activities (CR5)
Project Manager (Middle Manager Subcontractor, CON)	Identify scheduling issues		Formalized document meeting
Team Manager (Subcontractor, CON)	Promotes safety initiatives	Monitors safety while performing contractual obligations Monitors behavior Authorizing Staff Access (barrier) (CC1) Authorizing Staff Access (no barrier) (CC2) Conducting Stopping points (CC6)	Obtains results in accordance with safety objectives in accordance with the normative framework Radioprotection Verification (1st Level) (CR2)
Field Worker (Subcontractor, CON)	Compliance with safety objectives Voices safety concerns	Use of normative framework Application of prescribed rules	

Figure 53. Distribution of 24 MCS in Facility A according to the system level that conducts the control



Figure 54. Distribution of 24 MCS in Facility B according to the system level that conducts the control and the Empowerment Leadership Factors as the motivation for changes made to 3 Social Controls

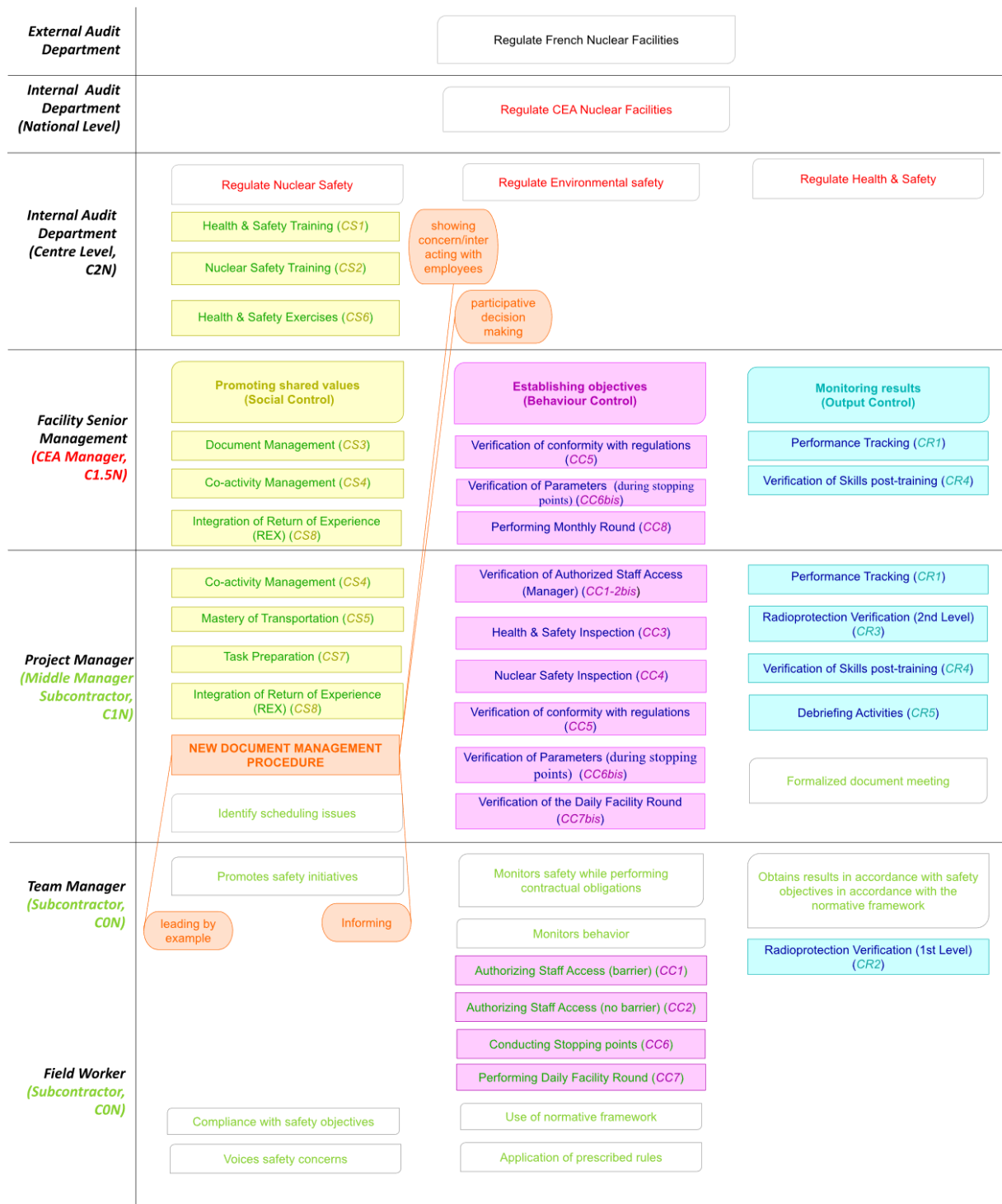


Figure 55. Distribution of 24 MCS in Facility E according to the system level that conducts the control and the Empowerment Leadership Factors as the motivation of a new social control created to re-enforce communication between the CEA and the subcontractors

Summary of the Results for Section 3

The third section contrasts six contingent variables across the 3 facilities (A, B and E) and shows how these variants affirm the type of MCS employed in each facility and explain the apparent differences in leadership styles amongst the three facilities. The following summarizes the findings from Section 3 in six sub-sections. All of these results are summarized in Table 19 below.

Sub-section one illustrates how the type of control varies according to the External Environment and Information Asymmetry of the Facility, which is due to a gap between the information required and the information made available to make decisions. Specifically:

- Facilities with ***high information asymmetry*** or ***environmental uncertainty*** implement more formal controls. Specifically, increased behaviour controls when Managerial presence was high and an increase in output controls when Managerial presence was low.
- Facilities with ***less information asymmetry*** or ***environmental uncertainty*** implement more informal controls in addition to formal controls. Managerial presence in the subcontracting firm (**Middle Managers**) decreased information asymmetry, but only when the distance between the contractor-subcontractor business entity was reduced.

Sub-section two addresses the link between the Technology (*characteristics of the facilities' work processes and level of interdependencies amongst and between the units*) and the type of MCS used by each facility. Facilities with ***high work processes*** (ability to measure safety outputs in goal-consistent terms) all employ, at a minimum, formal output controls. Additional controls (of varying degrees of interaction and nature) are added with the growing level of interdependency between and amongst units. Facilities where units have ***low interdependencies*** retain the predominant use of formal non-interactive controls. However:

- As the ***interdependency increases***, within **OR** between the units, the ***level of interaction of the controls increases***, with an emphasis on formal interactive controls.
- As the ***interdependency increases***, within **AND** between the units, the level of interaction is the highest with an emphasis on both interactive social controls (as a package) and the use of interactive formal controls.

Interactive controls have the highest connection to the five ***Empowerment Leadership Factors***.

Sub-section three identified the differences in Organizational Structure, Managerial Configuration and System level Interactions in each Facility and their link with their type of control and leadership style.

- The Facility with ***centralized control (contractor is the only level of control)*** employs formal controls designed and enforced by **CEA Managers** in the form of inspections. These detective behaviour controls are reactive/adaptive to the behaviour and actions of the subcontractors, identifying anomalies and correcting or warning the subcontractors when rules have been broken. Their ***strong inter-organizational interactions*** in each category of control (social, behaviour and output) encourage strong leader and subordinate relationships. These characteristics are typical of a leadership style known as ***transactional leadership***.

- Facilities with *decentralized control (two levels of control)* employ controls that are designed and enforced by both **CEA Managers** and **Middle Managers**. The type of control and the manner in which these controls are designed and enforced varies according to the type of inter-organizational relationship (between the units). Specifically,
 - (i) The decentralized Facility with *high inter-organizational interactions* employs a balance of interactive formal and informal controls that are designed and enforced jointly by **CEA Managers** and **Middle Managers**. This results in open lines of communication for subcontractors to signal near misses, promote improvements and become informed, thereby providing all system levels with the necessary knowledge to become empowered decision-makers. These characteristics are typical of a leadership style known as *transformational leadership*.
 - (ii) The decentralized Facility with *low inter-organizational interactions* uses mainly formal controls with occasional informal controls that are initially designed and implemented by **Middle Managers** and then are approved or adapted as the final non-interactive formal control by **CEA Managers**. In response to the low intra-organizational interactions, alternative communication initiatives (software systems) are implemented by **Middle Managers** (initial control) to ensure that important information via Non-interactive Behaviour Controls (Autocontrols) is rapidly communicated to **CEA Managers** (final control). These characteristics are typical of a leadership style known as *Delegative/Laissez-faire leadership*.

Sub-section four discusses the link between the size of the facility and the complexity of the communication and coordination process of controls.

- The Facility with a *small size* employs a more direct and less complex communication and coordination process of MCS between **CEA Managers** and the Subcontractors. The low complexity of the communication and co-ordination of MCS also appear to be influenced by this small Facility's centralized control and emphasis on formal controls.
- Facilities with *a larger size* employ a more complex communication and coordination process of MCS. The complexity of the managerial controls appears to be influenced by the larger Facilities' decentralized control. The type of communication and coordination of the managerial control system varies according to the inter-organizational interactions between the firms. Specifically,
 - (i) The large facility with a *high inter-organizational interaction* uses sophisticated daily interactive controls that incorporate all system levels to jointly enforce strong communication and co-ordination (through increased use of informal controls as a package).
 - (ii) The large facility with a *low inter-organizational interaction* (limited **CEA Managers'** presence) employs sophisticated non-interactive communication and coordination style with limited system levels that occur at two stages (initial by the empowered **Middle Managers** and the second by **CEA Managers**).

Sub-section five highlights how the strategies and methods used to *achieve results objectives* and *safety objectives* are aligned or “fit” to the Facility’s MCS and leadership style.

- All of the Facilities employ daily formal control as ***strategies to achieve and control result objectives***: interactive output controls (debriefing activities) and non-interactive output controls (performance tracking **CR1**).
- Strategies to ***achieve safety objectives*** vary according to the Facility’s leadership style (choice of proactive or reactive/adaptive controls) and the emphasis of ago-antagonistic poles. Specifically,
 - (i) The Facility with ***Transactional leadership style*** on the part of **CEA Managers** encourages the planning and execution of exemplary safety records through twice a day safety inspection (formal controls). These interactive behaviour controls are ***reactive/adaptive*** and provide a formal feed-back loop (cybernetic) through formalized output controls (debriefing activities). The independent and occasional use of informal social controls (Health and safety trainings) ***proactively*** encourages the development of ***Empowerment Leadership Factors***. Nonetheless, the frequency of the informal ***preventive controls*** is not enough to balance the *dominant detective ago-antagonistic poles*.
 - (ii) The Facility with a ***Transformational leadership style*** encourages innovation and communication amongst all system levels which increase safety leadership through participative changes on how the facility implements operations and controls. The daily morning informal controls ***accompanied by*** daily interactive behaviour and detective output controls ensure the emphasis of both proactive and reactive/adaptive controls as well as the balance of both *preventive and detective ago-antagonistic poles*. The daily informal controls further reinforce ***Empowerment Leadership Factors*** on a daily basis, while encouraging a united contractor-subcontractor business entity.
 - (iii) The Facility with a ***Delegative/Laissez-faire leadership style*** on the part of **CEA Managers** encourages adaptability, autonomy and accountability of **Middle Managers** who ensure safety leadership within the subcontracting firm. **CEA Managers** emphasize ***reactive/adaptive controls*** (daily non-interactive controls) and ***proactive controls*** in a more reduced capacity during weekly meetings. This encourages **Middle Managers** to employ a ***proactive*** stance to safety (through frequent interactive social controls) that complement both their own reactive/adaptive interactive controls as well as **CEA Managers’** ***reactive/adaptive*** posture. **CEA Managers’** emphasis on the *detective ago-antagonistic pole*, is balanced by the **Middle Managers’** independent implementation of informal controls and ***transformational leadership*** style that both mobilizes the ***Empowerment Leadership Factors*** and emphasizes the *preventive ago-antagonistic pole*.

Sub-section six presents how the *types of MCS implemented* and the *manner in which Managers promote Safety Culture* (Safety ***Leadership Style***) is impacted by the combination of the Facility’s contingent variables (*environment, technology, organizational structure, strategy and safety culture*).

On one hand, *Managers' choice of MCS and implication* appear to be linked to the Facility's managerial configuration (3), size of facility (4) work process and interdependency of the units (2). On the other hand, the *manner in which Managers promote safety culture (Managers' Leadership style)* appear to be linked to the Facility's external environment (1) (due to the timing within the lifecycle of the Facility) and the strategies and methods Managers use to achieve results and safety objectives (5). The combination of contingent variable factors also affect the *ago-antagonistic pole(s) (preventive, detective or both)* emphasized by Managers, how managers react to imbalances, and their use of Empowerment Leadership Factors (*leading by example, coaching, informing, participative decision making, showing concern and interacting*) to facilitate the balance of *ago-antagonistic poles*. Empowerment of **Middle Managers** as ambassadors, by: (1) encouraging Safety Leadership; (2) reducing the distance between **CEA Managers** and subcontractors; (3) and either affirming or complementing the **CEA Managers'** control and leadership style. Specifically:

- The Facility with a new contractor-subcontractor relationship that has a centralized managerial configuration (**CEA Managers**), small size and with high interdependency between units implements ***formal controls in a top-down direction through its high managerial implication***. **CEA Managers** promote safety during the Facility's early life-cycle (t=0 years) through ***tight formal controls*** (emphasis of *detective ago-antagonistic pole*) ***to establish and enforce a common safety culture using a transactional leadership style***.
- The Facility with an established contractor-subcontractor relationship (t=3 years) that has a decentralized managerial configuration, large size, high interdependency between and amongst units implements ***flexible informal controls in bottom-up (and top-down) direction, encouraging adaptability and openness to change through facilitated participative decision-making***. Towards the middle of the Facility's life-cycle (t=3 years), **CEA Managers** and **Middle Managers** ***jointly promote safety as a unified contractor-subcontractor unit that balances ago-antagonistic poles through loose informal controls and tight formal controls, which empower actors to innovate, construct and promote a common Safety Culture using a transformational leadership style***.
- The Facility with a developing contractor-subcontractor relationship (t=1.5 years) that has a decentralized managerial configuration, large size and a low inter-dependency between units (top-down controls), and a high inter-dependency within units (both top-down and bottom-up) implements diverse types of controls and leadership that complement each other. Specifically, **CEA Managers** ***use tight non-interactive formal controls*** (emphasis of *detective ago-antagonistic pole*) ***to verify safety objectives and results via a Delegative/ Laissez-faire leadership style***. **Middle Managers** employ ***tight interactive formal controls and the loose interactive informal controls (to a lesser extent) to internally promote safety leadership through a combination of transformational and Delegative/ Laissez-faire leadership styles***, thereby establishing an internal Safety Culture that aligns with the CEA.

Table 19. Use of MCS and Leadership Style at CEA Facilities based on their six Contingent Variables

Contingent Variables		Informal	Formal				Notes on the Types of Controls and the Leadership style employed at CEA Facilities based on the combination of Contingent Variables.
		Social Control (CS)	Behaviour Control (CC)		Output Control (CR)		
		Preventive	Preventive	Detective	Detective		
		Interactive	Auto	Interactive	Interactive	Non-interactive	
(1) External Environment (Information Asymmetry) <i>(the gap between the information required and the information made available to make decisions)</i>	High Information Asymmetry		✓	✓	✓	✓	Use More Formal Controls
	High Information Asymmetry and High Managerial Presence		✓	✓			Increased Behaviour Controls
	High Information Asymmetry and Low Managerial Presence				✓	✓	Increased Output Controls
	Low Information Asymmetry	✓	✓	✓	✓	✓	Increased Informal Controls in addition to the Formal Controls.
	Low Information Asymmetry and High Managerial Presence	✓	✓	✓	✓	✓	Middle Management's presence decreased Information Asymmetry when the distance between the contractor- subcontractor unit was reduced.
	Low Information Asymmetry and Low Managerial Presence	N/A	N/A	N/A	N/A	N/A	N/A
(2) Technology (Work Process and Interdependencies of Units) <i>(ability to measure safety outputs in goal-consistent terms)</i>	High Work process				✓	✓	At a minimum use of Output Controls
	High Work process and low interdependencies		✓			✓	Emphasis on Formal Non-interactive Controls
	High Work process and interdependencies within OR between units			✓	✓		Emphasis on Formal Interactive Controls
	High Work process and interdependencies within AND between units	✓		✓	✓		Emphasis on both Interactive Social Controls (as a package) and Interactive Formal Controls
	Low Work Process	N/A	N/A	N/A	N/A	N/A	N/A
(3) Organizational Structure (Managerial Configuration) <i>(levels of official control and inter-organizational interactions)</i>	Centralized Control		✓	✓	✓	✓	At a minimum use of Formal Controls
	Centralized Control and High Inter-organizational Interaction			✓			Transactional Leadership Style that encourages strong leader-subordinate relationship through high inter-organizational interactions (Emphasis on Detective Behaviour Controls via inspections)
	Centralized Control and Low Inter-organizational Interaction	N/A	N/A	N/A	N/A	N/A	N/A
	Decentralized Control	✓	✓	✓	✓	✓	Use of Formal Controls with an increasing use of Informal Controls
	Decentralized Control and High Inter-organizational Interaction	✓		✓	✓		Transformational leadership empowers subcontractors and opens lines of communication to signal near misses, promote improvements and provide knowledge to make decisions (Balance of Interactive Formal and Informal Controls)
	Decentralized Control and Low Inter-organizational Interaction	✓	✓			✓	Delegative/Laissez-faire Leadership encourages alternative communication alternatives (Mainly non-interactive Behaviour and Output Control by CEA Managers and occasional use of Informal controls by Middle Managers.)
(4) Size <i>(number of actors and inter-organizational interactions)</i>	Small Size		✓	✓	✓	✓	Less complex communication and coordination process and use of Formal Controls
	Small Size and High Inter-organizational Interaction			✓	✓		More direct communication and coordination process (Emphasis on Interactive Formal Controls)
	Small Size and Low Inter-organizational Interaction	N/A	N/A	N/A	N/A	N/A	N/A
	Large Size	✓	✓				More complex communication and coordination process that requires changes in line with <i>preventive controls</i> to implement/facilitate the communication process.
	Large Size and High Inter-organizational Interaction	✓		✓	✓		Daily sophisticated Social Controls (as a package) directly with all system levels to jointly enforce interactive communication and coordination.
	Large Size and Low Inter-organizational Interaction	✓	✓			✓	Sophisticated non-interactive communication and coordination style with limited system levels by CEA Managers. The occasional use of more direct informal controls by Middle Managers.
(5) Strategies <i>(strategies to control and achieve Result and Safety Objectives including leadership style)</i>	Strategies to achieve result objectives				✓	✓	Use of Daily Output Controls
	Strategies to Achieve Safety Objectives	✓	✓	✓	✓		Use of Empowerment Leadership Factors to facilitate the balance between preventive and detective ago-antagonistic poles.
	Transactional Leadership... <i>encourages the planning and execution of exemplary safety records.</i>	✓		✓	✓		Interactive Behaviour Controls (twice a day) provide reactive/adaptive cybernetic feed-back via formalized Interactive output controls yields dominant detective ago-antagonistic pole. Occasional use of Informal controls proactively encourages the development of Empowered Leadership Factors.
	Transformational Leadership... <i>encourages innovation and communication, increasing safety leadership through participative change.</i>	✓		✓	✓		Daily morning informal controls and Daily interactive behaviour and detective output controls jointly carried out by CEA Managers and Middle Managers ensure the balance of both preventive and detective ago-antagonistic poles, developing the Empowerment Leadership Factors and encouraging united contractor-subcontractor business unit.
	Delegative/Laissez-Faire... <i>encourages adaptability, autonomy and accountability to ensure safety leadership within Subcontracting Firm.</i>	✓		✓	✓	✓	Daily non-interactive controls and occasional Informal Controls by CEA Managers emphasizes the Detective ago-antagonistic Pole. Middle Managers employ more proactive social controls in addition to their interactive formal controls to complement CEA Reactive controls, by emphasizing the preventive ago-antagonistic pole.
(6) Safety Culture <i>(CEA Managerial Implication and manner Managers promote safety Culture given the duration of the relationship)</i>	New contractor-subcontractor relationship (t=0 years) with High Managerial Implication and Transactional Leadership		✓	✓	✓	✓	Use of tight formal controls (emphasis on detective ago-antagonistic pole) through High Managerial Implication to establish and enforce a common safety culture via a transactional top-down leadership style.
	Developing contractor-subcontractor relationship (t=1.5 years) with Low Managerial Implication and Delegative/Laissez-faire Leadership	✓	✓	✓	✓	✓	Use of tight non-interactive formal controls (emphasis on detective ago-antagonistic pole) through low CEA managerial top-down Implication. Middle Managers employ a combination of tight interactive formal controls and loose informal controls (to a lesser extent) to internally promote safety leadership bottom-up (and top-up) through a combination of Transformational and Delegative/Laissez-Faire Leadership.
	Established contractor-subcontractor relationship (t=3 years) with High Managerial Implication and Transformational Leadership	✓		✓	✓		Use of loose informal controls and tight formal controls (balance of preventive and detective ago-antagonistic pole) through High Managerial implication on CEA and Middle Managers to empower actors to innovate, construct and promote common safety culture via Transformational bottom-up (and top-down) leadership style.

Conclusion of Chapter 3

Risk management at the CEA can be described as a dynamic system with complex interactions between diverse subsystems including contractor – subcontractor; subcontracting risk-management tools, and preventive – *detective controls* amongst many others. Using systems thinking to model AA forces present in the risk management system, allows managers to identify and balance *preventive and detective controls* used in risk management practices at the three facilities observed; particularly as each Facility emphasizes one or more ago-antagonistic poles (preventive or detective). After analyzing several empirical examples of current CEA practices, a hybrid preventive (Level 1) and detective (Level 2) control system synonymous with *defence in depth* strategy can be identified at all three Facilities through both Relay Controls, and through the Cycle of Control. Relay Controls that consists of a non-interactive auto-control of the *preventive ago-antagonistic pole* followed by an interactive verificative control of the *detective ago-antagonistic pole*. The cycle of control that appears to be most efficient begins with a *preventive social control* prior to the task, shadowed by a *preventive or a detective behavioural control* during the task, a *detective output control* after the task, and finally followed by a *preventive control* that will take place between the end of this activity and the next time the same activity is carried out; thereby preventing future events. In this way, *preventive controls* serve as both the alpha and the omega of risk prevention, thereby enforcing the classic safety approach that focuses on the prevention of barriers and reducing the probability of event occurrence. Such procedures exist to prevent potential and imaginable accidents but overlook inconceivable accidents. Therefore, the development of a template/tool or meta-model to compare accidents would allow a better understanding of accidents that occur either because the prevention barriers did not function (though the event was conceived) or because the prevention barriers did not exist (because the accident was unimagined and unexpected).

Each Facility uses MCS to mitigate safety-related subcontracting risks, but their use of leadership practices varies. The type of controls and leadership style appears to be impacted by the combination of the six contingent variants (*environment, technology, organizational structure, strategy and safety culture*) of the Facilities. A total of 24 categories of MCS, common to both Facility A, Facility B, and Facility E were mapped-out across several systems levels, providing insight as to the distance between the elements and their connection to the five dimensions of the Empowerment Leadership Model (*leading by example, coaching, informing, participative decision making, showing concern and interacting*). Specifically: Social controls (preventive and interactive) and Interactive Output Results (detective) encouraged all five leadership factors, while Behaviour Controls allowed for certain leadership factors. Only, non-interactive output controls failed to allot for any of the leadership factors.

The evolution in MCS practices in Facility B provides examples of how, following a series of nuclear events, CEA Manager and Middle Management use leadership to reinforce risk prevention through the implementation of several procedural changes to obtain safety results that in turn, balance the

mechanisms of the detection and prevention controls. The changes observed alter the sequence of controls moving towards an increase in *preventive controls* thereby balancing both ago-antagonistic poles. Specifically, these changes:

- (1) Allow leaders to *lead by example*, demonstrate their commitment to safety; (2) function as a communication platform for safety concerns and reminders, and to identify areas that require *coaching*, thereby re-enforcing organizational safety commitment and empowering subcontractors through knowledge and education
- (3) Provide a time period to *inform* or disseminate crucial safety references and to voice concerns with the new guidelines, thereby encouraging new ideas and initiatives, while enhancing safety participation behaviours and compliance of safety practices across multiple system levels of the organization.
- (4) Increase *interaction with employees*, allowing subcontractors to voice suggestions for daily operations; and (5) increase *participative decision making*, facilitating discussions of contingencies in case of unexpected Operational Changes, thereby encouraging new safety suggestions and re-enforcing an environment to report near misses/ minor events.

By promoting the 5 dimensions of empowered leaders, managers can detect inadequate safety behaviours or results (through MCS) and transform them using safety leadership practices, thereby encouraging a united contractor-subcontractor business entity. Such knowledge incites Managers to design management control systems that balance Ago-antagonistic tensions between *prevention and detective controls* by learning to identify when agonistic-antagonistic unbalances have occurred. Figure 56 in Chapter 4 provides a decision diagram on how to deal with Ago-antagonistic imbalances at the CEA Facilities and suggestions on how to re-equilibrate and avoid such imbalances. This is further detailed in the academic and managerial contributions of such practices in Chapter 4.

Chapitre 4 - Discussion

(Résumé en Français)

L'objectif de cette recherche était de fournir une compréhension approfondie de la manière dont le CEA gère ses sous-traitants en quasi-intégration, prévient et atténue les risques liés à la sous-traitance. La question de recherche posée était : *Comment le CEA conçoit-il des systèmes de contrôle de gestion (SCG) qui peuvent prévenir et atténuer efficacement les risques de sous-traitance liés à la quasi-intégration, dans le contexte des caractéristiques spécifiques de ses installations nucléaires ?* Quatre sous-questions découlent de cette question principale de recherche et sont détaillées dans le tableau 20 ci-dessous.

La question de recherche met en évidence les difficultés vécues par le CEA, liées à la sous-traitance de quasi-intégration. Face à son recours croissant à la sous-traitance, le CEA est d'une part conscient qu'il doit proposer des évolutions et des axes d'amélioration dans ses méthodes de gestion pour contrôler et surveiller les sous-traitants, mais d'autre part, la nature de la relation de sous-traitance impose des contraintes supplémentaires à la tâche de gestion dans une industrie déjà à haut risque. Plus précisément, le CEA (i) n'est pas en mesure de contrôler et d'observer ses sous-traitants à tout moment, et doit donc utiliser les éléments fournis par le sous-traitant pour contrôler et évaluer leurs performances ; (ii) est légalement responsable des tâches effectuées par le sous-traitant et peut donc encourir des sanctions financières et juridiques en cas de négligence de la part du sous-traitant ; (iii) doit, conformément à la loi sur le "délit de marchandage" (articles L8231 du Code civil), ne pas traiter les sous-traitants comme ses propres employés pour éviter d'être requalifié en employeur direct. Au contraire, le personnel sous-traitant d'un contractant doit rester sous l'autorité de son employeur (l'entreprise sous-traitante) et non sous l'autorité du contractant. Cela implique que l'acteur de l'entreprise contractante chargé de contrôler l'entreprise sous-traitante n'a en principe pas le droit d'interagir directement avec les sous-traitants, mais uniquement avec la direction de l'entreprise sous-traitante (les managers intermédiaires ou « middle managers » en anglais). Par conséquent, la nécessité d'un système efficace de contrôle de la gestion de l'entreprise sous-traitante, qui permet simultanément de prévenir et d'atténuer les risques liés à la sous-traitance, est de plus en plus essentielle pour le CEA. Cette thèse, financée par le CEA, propose une méthode que le CEA peut utiliser pour concevoir efficacement son SCG afin de l'adapter aux caractéristiques spécifiques de chaque installation nucléaire. En réponse aux quatre sous-questions évoquées dans le Tableau 20 ci-dessous, cette thèse : (a) *reconceptualise la définition du SCG et des risques liés à la sous-traitance dans le contexte de l'énergie nucléaire* et montre *les mécanismes de contrôle utilisés par le CEA pour prévenir les risques liés à la sous-traitance et détecter les écarts (sous-*

question 1) ; (b) s'appuie sur les systèmes ago-antagonistes²⁷ (Bernard-Weil, 2002 ; 2003a ; 2003b ; Bernard-Weil et al, 1975), et l'utilisation d'analogies, la recherche propose un modèle pour les managers afin d'équilibrer les différents types de SCG qui préviennent et atténuent les risques et les événements (sous-question 2) ; (c) utilise la théorie des systèmes et la théorie des contingences pour analyser les résultats et identifier les nouvelles caractéristiques et les éléments de contrôle et de leadership (leadership en matière de sécurité) qui améliorent le comportement de sécurité²⁸ (sous-question 3) ; et enfin, (d) identifie comment, à la suite d'un évènement évité de justesse ou d'un évènement mineur, les installations mettent en œuvre de nouvelles approches de contrôle (changements de protocoles, création de nouveaux SCG, mise en œuvre conjointe sous-traitant-contractant) pour soutenir et renforcer les autres contrôles en tant que paquet (sous-question 4). Le tableau 20 ci-dessous détaille chaque question et fournit une brève réponse à ces sous-questions, qui sont discutées plus en détail dans le chapitre 3 et la conclusion de la thèse.

Tableau 20. Bref aperçu des réponses aux quatre sous-questions de recherche

Principale question de recherche	
<p><i>Comment le CEA conçoit-il des systèmes de contrôle de gestion (SCG) qui peuvent prévenir et atténuer efficacement les risques de sous-traitance associés à la quasi-intégration, dans le contexte des caractéristiques spécifiques de ses installations nucléaires ?</i></p> <p>A la lumière des différentes limitations des mécanismes de contrôle dans le contexte industriel spécifique de la sous-traitance, une méthode de conception, de combinaison et de mise en œuvre des SCG "en tant que paquet" pour la gestion des risques a été proposée. Plus précisément, comme les SCG ne suffisent pas à garantir des comportements optimaux en matière de sécurité, il faut tenir compte d'une autre dimension : la manière dont les SCG sont menés qui, dans cette thèse, est considérée comme le style de leadership des installations. La méthode de gestion des risques proposée identifie deux natures de contrôle (de prévention et de détection) et utilise les systèmes ago-antagonistes comme outil systémique pour équilibrer chaque pôle ago-antagoniste. L'introduction de la dimension de leadership en matière de sécurité renforce cet équilibre et encourage en outre une entité contractant-sous-traitant unie qui a un impact sur les comportements de sécurité. Le modèle de Leadership par Responsabilisation (ELM) semble être un outil pour rééquilibrer les contrôles de prévention et de détection à la suite d'événements et de quasi-événements.</p>	
Sous-questions	Réponses aux sous-questions
<p><i>Comment les SCG employés par les Managers du CEA (vis-à-vis des sous-traitants)</i></p>	<p>Les SCG sont utilisés comme couplages contrôle-risque pour prévenir et détecter les risques liés à la sous-traitance en quasi-intégration. Le type spécifique ou la combinaison des couplages contrôle-risque dépendent des facteurs de contingence de l'installation. On a constaté que les contrôles</p>

²⁷ Reportez-vous au document de l'annexe D pour plus de détails sur l'équilibrage de la nature ago-antagoniste des contrôles de prévention et de détection au CEA.

²⁸ Reportez-vous au document de l'annexe C pour plus de détails sur la mise en œuvre du contrôle et du leadership en matière de sécurité au CEA.

<p><i>évitent-ils et atténuent-ils les risques ?</i></p>	<p>informels (contrôle social) étaient utilisés seuls ou en complément des contrôles formels (contrôle comportemental ou par les résultats) dans le processus de gestion des risques de toutes les installations.</p> <p>Il a également été constaté que la conception, la mise en œuvre et l'application spécifiques de ces mécanismes de contrôle dépendent des particularités et de la combinaison des facteurs de contingence de l'installation (<i>environnement externe, technologie, structure organisationnelle, taille et ratio, stratégies, culture</i>).</p> <p>Ces couplages contrôle-risque et la combinaison des facteurs de contingence de l'installation jouent un rôle important dans l'évaluation de la meilleure combinaison de SCG à utiliser pour atténuer les risques liés à la sous-traitance, gérant ainsi la sécurité et les facteurs organisationnels humains.</p>
<p><i>Comment les managers équilibrent-ils le SCG "en tant que paquet" pour éviter et atténuer les risques et les événements liés à la sous-traitance ?</i></p>	<p>Les managers du CEA peuvent identifier les séquences SCG dans le cycle de contrôle, et décomposer le SCG en deux natures de contrôle (<i>prévention et détection</i>) en identifiant leurs effets temporels dans la prévention et l'atténuation des événements. En outre, l'utilisation de <i>systèmes ago-antagonistes</i>²⁹ pour mettre en parallèle les <i>contrôles de prévention</i> et les <i>contrôles de détection</i> en tant que deux pôles ago-antagonistes de contrôle, a permis de compléter le modèle en modélisant et en équilibrant ces relations de contrôle via cet outil systémique. En conséquence, l'approche proposée conçoit et met en œuvre le SCG pour soutenir le cycle de contrôle en aidant les managers à identifier les déséquilibres ago-antagonistes qui se sont produits et à équilibrer les tensions ago-antagonistes entre les contrôles de prévention et les contrôles de détection, car les changements apportés à un seul ou aux deux contrôles peuvent rééquilibrer le système global.</p>
<p><i>Quelle dimension est mise en œuvre pour orchestrer le SCG en tant que paquet pour améliorer les comportements de sécurité au CEA ?</i></p>	<p>Une dimension supplémentaire liée au leadership peut être mise en œuvre au-delà des contrôles de gestion pour améliorer les comportements en matière de sécurité. Cette dimension, identifiée comme facteurs de Leadership par Responsabilisation, favorise les comportements positifs en matière de sécurité chez les sous-traitants. Lorsque ces dimensions sont mises en œuvre par les managers avec une combinaison équilibrée de <i>contrôles de prévention et de détection</i>, la distance entre les activités du contractant et du sous-traitant est réduite (ce qui réduit les limites du contrôle de gestion) et renforce la capacité de l'installation à éviter et à atténuer les risques liés à la sous-traitance (quasi-intégration). En outre, <i>le leadership</i> semble permettre de rééquilibrer les</p>

²⁹ Le terme "Ago-antagoniste" est composé de deux termes : *agoniste* qui signifie "effets positifs parallèles" ; et *antagoniste* qui signifie "effets opposés". Ces deux termes, simultanément opposés et complémentaires, semblent à première vue s'exclure l'un l'autre, mais sont en fait indissociables pour la compréhension du phénomène.

	<p><i>contrôles de prévention et de détection à la suite de plusieurs événements et quasi-événements au sein des installations nucléaires. Comme pour le style de contrôle, la préférence pour le style de leadership dépend également des particularités des facteurs de contingence de chaque installation.</i></p>
<p><i>Quelle(s) approche(s) de mise en œuvre du SCG, à la suite d'un quasi-événement ou d'un événement mineur, permet(tent) aux contrôles de se soutenir et de se renforcer mutuellement "en tant que paquet" ?</i></p>	<p>Plusieurs approches de mise en œuvre du SCG à la suite d'un quasi-événement ou d'un événement mineur fournissent la preuve d'une nouvelle approche de la gestion des risques et de la sécurité qui peut être employée par le CEA, basée sur la "pensée systémique" pour permettre aux contrôles de prévention et de détection de se soutenir et de se renforcer mutuellement. Cette approche systémique de la gestion des risques applique les principes du Leadership par Responsabilisation, à travers un modèle ago-antagoniste, donnant lieu à une approche systémique conjointe du SCG avec une approche systémique du leadership en matière de sécurité via une série de contrôles interactifs. La combinaison appropriée de contrôle et de leadership encourage les nouvelles suggestions en matière de sécurité, renforce l'environnement pour le signalement des quasi-événements ou des événements mineurs, consolide l'engagement de l'organisation en matière de sécurité en responsabilisant les sous-traitants par le biais du partage d'informations, et soutient les sous-traitants dans l'ensemble de l'organisation pour qu'ils signalent continuellement les problèmes de sécurité. Cela encourage les nouvelles idées et initiatives, tout en améliorant la participation et le respect de la sécurité à plusieurs niveaux de l'organisation. Compte tenu de la nature contextuelle du contrôle et du leadership, cette approche systémique conjointe fournit un modèle général qui peut ensuite être adapté aux facteurs de contingence spécifiques de chaque installation. Les dimensions de contrôle et de leadership proposées sont issues des styles de leadership et de SCG contrastés dans les trois installations du CEA étudiées, qui ont des activités similaires mais varient en termes de configurations managériales, de taille et d'autres facteurs de contingence.</p>

Limites de la recherche

Cette thèse démontre que la conception des systèmes de gestion des risques liés à la sous-traitance et leur mise en œuvre par le biais du leadership en matière de sécurité dépendent des facteurs de contingence (variables contextuelles de l'installation) et de la capacité des gestionnaires à équilibrer les pôles ago-antagonistes dans la conception de différents types de contrôles. Plusieurs limites de nature théorique et méthodologique ont été rencontrées tout au long de cette recherche :

Premièrement, les immersions dans les installations nucléaires du CEA ont été limitées à trois installations nucléaires, ce qui réduit la généralisation des résultats et diminue la capacité de contrôler de multiples facteurs. De plus, l'immersion dans l'installation E a été très brève. Une immersion plus

longue dans cette installation, ainsi que des immersions supplémentaires dans d'autres installations, auraient permis d'accroître la généralisation des modèles de gestion des risques en facilitant des combinaisons supplémentaires de variables contingentes dans d'autres installations et en élargissant la compréhension de leur rôle dans la conception du SCG et le choix des styles de leadership. De tels résultats pourraient aider à valider la relation entre les facteurs de contingence organisationnels, le style de leadership et les contrôles dans le but de prévenir et de détecter les risques.

Deuxièmement, les immersions dans chacune des installations ont eu lieu à différents moments du cycle de vie de l'installation en ce qui concerne le processus de transition entre deux sous-traitants (installation A à $t = 0$ an ; installation B à $t = 3$ ans ; installation E à $t = 1,5$ an). Par conséquent, les données obtenues ne reflètent pas le même instant sur l'ensemble du cycle de vie des trois installations, mais fournissent plutôt un aperçu de ce que l'on pourrait attendre d'une étude longitudinale sur l'ensemble du cycle de vie d'une installation nucléaire.

Troisièmement, les entretiens ont été menés principalement avec des responsables du CEA et les managers intermédiaires de l'entreprise sous-traitante dans les trois installations. Cependant, les personnels sous-traitants de terrain n'ont été interviewés que dans les installations A et B, ce qui limite, à deux installations, les opinions, comportements et attitudes des personnes interviewées au niveau des sous-traitants. Par conséquent, un temps d'immersion supplémentaire dans l'installation E aurait permis une évaluation plus large de la narration des événements par les sous-traitants dans les trois installations. De plus, les entretiens menés à l'installation B ont eu lieu une fois que les changements avaient déjà été apportés à la conception du SCG suite à plusieurs événements. Une immersion avant les changements aurait été un atout pour mieux comprendre les facteurs entourant ces changements, au-delà des comptes rendus post-facto fournis par les personnes interviewées, limitant ainsi le biais rétrospectif. De telles données permettraient également d'améliorer l'évaluation de la combinaison stratégique et de l'ordre des contrôles de prévention et de détection qui permettent un équilibre optimal des deux pôles ago-antagonistes pour un événement ou un quasi-accident donné.

Quatrièmement, les concepts étudiés dans cette thèse ont été évalués de manière qualitative. Un développement plus poussé avec des mesures quantitatives des constructions théoriques (leadership, risque, performance en matière de sécurité) aurait permis d'évaluer ces mesures par rapport aux échelles de mesure existantes, fournissant ainsi une comparaison quantitative des constructions théoriques entre les trois établissements. Des données supplémentaires auraient également fourni des informations additionnelles sur les caractéristiques des relations entre les concepts ainsi que sur les effets médiateurs possibles entre les variables. Par exemple, la conception et l'équilibre entre les contrôles de prévention et de détection sont liés à un style de leadership plus transformationnel (comme on le voit dans l'installation B), et le type de style de leadership a également un impact sur la conception et la préférence des contrôles de prévention et de détection (comme on le voit avec le style de leadership transactionnel dans l'installation A).

Cinquièmement, les entretiens et les observations ont été réalisés en français, qui n'est pas la langue maternelle de l'auteur, puis traduits en anglais.

Malgré ces limites, les résultats de cette recherche soutiennent la manière contingente dont les variables contingentes au sein des installations nucléaires affectent la conception du SCG et le choix du style de leadership employé dans la relation contractant - sous-traitant. Les managers, qui emploient des facteurs de Leadership par Responsabilisation (via des contrôles interactifs) et qui équilibrent les contrôles de prévention et de détection tout au long du cycle de contrôle, favorisent les comportements de sécurité et améliorent les pratiques de gestion des risques. Il a été constaté que le style de leadership est influencé par l'implication des managers du CEA (liée à la *structure organisationnelle*, à la *taille et au ratio*, à la *technologie* de l'installation) et par la manière dont les managers du CEA promeuvent la *culture de sécurité* (liée à l'*environnement externe et aux stratégies de l'installation*).

Chapter 4 – Discussion

The aim of this study was to provide an in-depth understanding of how the CEA manages their quasi-integration subcontractors, prevents and mitigates subcontracting-related risks. The research question pondered: *How does the CEA design Management Control Systems (MCS) that can effectively avert and mitigate subcontracting risks associated with quasi-integration, in the context of the specific characteristics of its nuclear facilities?* Four sub-questions arise from this main research question and are detailed in Table 20 below.

The research question highlights the legal predicaments and managerial conundrums experienced by the CEA, linked to quasi-integration subcontracting. Faced with their growing use of subcontractors, the CEA on one hand is aware that they need to propose evolutions and axes of improvement in their management methods to control and oversee the subcontractors, but on the other hand, the nature of the subcontracting relationship imposes additional constraints on the task of managing in an already high-risk industry. Specifically, the CEA: (i) is unable to monitor and observe their subcontractors at all times, and must therefore use the elements provided by the subcontractor to monitor and evaluate their performance; (ii) is legally responsible for the tasks performed by the subcontractor and thus may incur financial and legal sanctions should there be negligence on the part of the subcontractor; (iii) must, as per the Law on equal treatment of contractors and employees “*délit de marchandage*” (Articles L8231 of the Civil Code), avoid treating the subcontractors as their own employee to avoid being requalified as the direct employer. Instead, the subcontractor of a contractor must remain under the authority of their employer (the subcontracting firm) and not under the authority of the contractor. This implies that the actor from the contracting firm assigned to control the subcontracting firm is in principle not entitled to interact directly with the subcontractors, but rather only to the subcontracting firm’s management (Middle Managers). As a result, the need for an effective contractor-subcontractor management control system that simultaneously averts and mitigates subcontracting-related risks is ever more essential for the CEA. This thesis, financed by the CEA, proposes a method that the CEA can use to effectively design their MCS to fit to the specific characteristics of each nuclear facility. In response to the four sub questions evoked in Table 20 below, this thesis: (a) *reconceptualizes the definition of MCS and Subcontracting related risks in the Nuclear Energy Context* and shows *the mechanisms of control used by the CEA to prevent subcontracting related risks and detect deviations (Sub-question 1)*; (b) *Draws on Ago-antagonistic Systems*³⁰ (Bernard-Weil, 2002; 2003a; 2003b; Bernard-Weil et al., 1975), and the use of analogies, the research proposes a model for managers to *balance the different types of MCS that prevent and mitigate risks and events (Sub-question 2)*; (c) *employs Systems Theory and Contingency Theory to analyze the findings further identifying new features and elements of control*

³⁰ Refer to the paper in Appendix D for details of balancing the Ago-Antagonistic nature of Preventive and Detective Controls at the CEA

and leadership (Safety Leadership) that enhance safety behaviour³¹(Sub-question 3); and finally,(d) identifies how following a near miss or a minor event, facilities implement new approaches of control (changes in protocols, creation of new MCS, joint subcontractor-contractor implementation) to support and reinforce other controls as a package (Sub-question 4). Table 20 below details each question and provides a brief answer to these sub-question, that are discussed more in-detail within Chapter 3 and the Conclusion of the thesis.

Table 20. Brief Overview of the answers to the four Sub-Research Questions

Main Research Question	
<p><i>How does the CEA design Management Control Systems (MCS) that can effectively avert and mitigate subcontracting risks associated with quasi-integration, in the context of the specific characteristics of its nuclear facilities?</i></p> <p>In light of the different limitations of the control mechanisms within the specific industrial context of subcontracting a method to design, combine and implement MCS “as a package” for Risk Management was proposed. Specifically, as MCS are not enough to ensure optimal safety behaviours and hence require taking into account another dimension: how the MCS are conducted which in this thesis are viewed as the facilities leadership style. The proposed Risk Management method identifies two natures of control (preventive and detective) and uses Ago-Antagonistic Systems as a systemic tool to balance each ago-antagonistic pole. The introduction of the Safety Leadership dimension further enhances this balance and additionally encourages a united contractor-subcontractor entity that impacts safety behaviours. The Empowerment Leadership Model (ELM) appears to be a gearshift to rebalance preventive and detective controls following events and near misses.</p>	
Sub-questions	Answers to the sub-questions
<p><i>How do the MCS employed by CEA Managers (on subcontractors) avert and mitigate risks?</i></p>	<p>MCS are used as control(s)-risk couplings to avert and detect risks related to quasi-integration subcontracting. The specific type or combination of control-risk couplings are contingent on the facility’s contingency factors. Informal controls (Social Control) were found to be used on their own or in complement with Formal controls (Behaviour or Output Control) in the Risk Management process of all facilities.</p> <p>The specific design, implementation, and enforcing of these control mechanisms was also found to be contingent on the particularities and the combination of the Facility’s contingency factors (<i>external environment, technology, organizational structure, size and ratio, strategies, culture</i>).</p> <p>These control-risk couplings and the combination of contingency factors of the facility play an important role in assessing the best combination of MCS to use to mitigate the subcontracting-related risks thereby managing safety and Human Organizational Factors.</p>

³¹ Refer to the paper in Appendix E for further details of the implementation of control and safety leadership at the CEA.

<p><i>How do CEA managers balance MCS “as a package” to avert and mitigate subcontracting-related risks and events?</i></p>	<p>CEA Managers can identify the sequences MCS within the control cycle, and breakdown the MCS into the two natures of control (<i>Prevention and Detection</i>) identifying their temporal effects in averting and mitigating events. Additionally, the use of <i>Ago-Antagonistic Systems</i>³² to parallel <i>Preventive Controls</i> and <i>Detective Controls</i> as two ago-antagonistic poles of Control, further complemented the model by modelling and balancing these control relationships via this systemic tool. As a result, the proposed approach designs and implements MCS to support the cycle of control by supporting Managers to identify when ago-antagonistic imbalances have occurred and balance ago-antagonistic tensions between preventive and detective controls, as changes on a single or both controls may rebalance the overall system.</p>
<p><i>What dimension is implemented to orchestrate MCS as a package to enhance safety behaviours at the CEA?</i></p>	<p>An additional dimension in connection to Leadership can be implemented beyond the scope of Management Controls to enhance safety behaviours. Such dimension identified as Empowerment Leadership Factors promotes positive safety behaviours amongst subcontractors. When these dimensions of Empowerment are implemented by Leaders (Managers) in unison with a balanced combination of <i>preventive and detective controls</i>, the distance between the contractor-subcontractor business is reduced (which reduces the limits of MCS) and fortifies the Facility’s capability of averting and mitigating subcontracting (quasi-integration) related risks. Additionally, <i>Empowerment Leadership</i>, appears to be a gearshift for several changes to rebalance <i>Preventive and Detective Controls</i> following several events and near misses within the Nuclear Facilities. As with control style, the leadership style preference is also contingent on the particularities of each Facility’s contingency factors.</p>
<p><i>What implementation approach(es) of MCS, following a near miss or a minor event, enable the controls to support and reinforce each other “as a package”?</i></p>	<p>Several implementation approaches of MCS following a near miss or a minor event provide evidence of a new approach to Risk Management and Safety Management that can be employed by the CEA based on “Systems thinking” to enable preventive and detective controls to support and reinforce each other. This systemic approach to Risk Management applies principles of Empowerment Leadership, through an ago-antagonistic model, yielding a joint systemic approach to MCS with a systemic approach to safety leadership via a series of interactive controls. The appropriate combination</p>

³² The term “Ago-antagonistic” is composed of two terms: *agonistic* meaning “parallel positive effects”; and *antagonistic* meaning “opposite effects”. These two terms that are simultaneously opposite and complementary, and at first glance appear to exclude one another, but are in fact indissociable to the understanding of the phenomenon.

	<p>of control and leadership encourages new safety suggestions, reinforces the environment for reporting near-misses or minor occurrences, fortifies the organization's commitment to safety by empowering subcontractors through information sharing, and supports subcontractors throughout the organization to continuously report safety concerns. This encourages new ideas and initiatives, while improving safety participation and compliance at multiple levels of the organization. Given the contextual nature of both control and leadership, this joint systemic approach provides a general model that can then be adapted to “fit” the specific contingency factors of each Facility. These proposed control and leadership dimension originate from the contrasting leadership and MCS styles in the three CEA Facilities studied that execute similar subcontracting activities but vary in managerial configurations, size and other contingency factors.</p>
--	---

This chapter presents the discussion and conclusion of this dissertation in three sections. The first section elaborates on the managerial implications of the research. The second details the Academic Contributions of the study and positions them with regards to existing research. The third section presents the limitations of the study and proposes avenues for further research.

1. Managerial Implications

Six managerial implications were provided from this study and are presented in three subsections: The first subsection details three managerial implications of the entire business entity of the CEA; the second subsection details an additional three managerial implications for the Directorate of Nuclear Safety and Security (DSSN), a branch of the CEA responsible for nuclear safety, and Health and Occupational Safety (H and OS) of the workers. Finally, the third subsection details the managerial implications at the Facility level as a proposal for CEA Managers and Middle Managers whenever applicable.

1.1. Managerial Implications for the CEA

The French Alternative Energies and Atomic Energy Commission (CEA) is a key player in research, development and innovation and actively participates in collaborative projects with a large number of academic and industrial partners. Its nine research centres throughout France work in partnership with research bodies, local authorities and universities in areas of defence and security, nuclear and renewable energies, technological research for industry, and fundamental research in the sciences.

This study combines a systemic approach to MCS with a systemic approach to safety leadership, through an Ago-Antagonist model. More specifically, the study provides a series of Systemic models of the management approach used at the CEA, to avert and mitigate subcontracting-related risks, in light of Contingency Theory and Systems Theory. It highlights management practices used at the different

facilities based on their specific contingency factors, and the ago-antagonistic balance of the risk management practices that arose in several facilities as a response to near misses and events. From a practical point of view, the research makes it possible to formulate suggestions for improving the managerial control of subcontractors, intended for the managerial actors in the risk management process: The CEA Managers made up of the Facility Chief (or RCI or Chief) and the CEA supporting staff (Health and Safety Engineers, HOF Specialists, Nuclear Safety Engineers), while simultaneously taking into account the role and impact of the Middle Managers in implementing these suggestions. This study reviews three Nuclear Facilities which does not by any means provide a macro-level representation of all the Facilities of the CEA but rather provides a widespread application to similar Facilities at the CEA. The following provides three managerial implications for the CEA:

Firstly, this study provides an understanding for the CEA of how CEA Managers design and employ Management Control Systems at different Nuclear Facilities, thereby providing a new perspective on the commonalities and differences of controls employed throughout the Facilities observed.

Secondly, this study categorizes for CEA Managers the types of MCS that are employed to avert and mitigate subcontracting related risks, and the combinations of MCS that have been effective in preventing and mitigating those risks. This highlights the internal functioning of each facility and the contingent variables that impact the type of control and the type of leadership. This provides CEA managers with a guide of the contingent combinations of MCS that have been observed to be effective in reducing risks in Facilities with similar contingent variables, thereby suggesting how to make changes to those combinations to balance and employ these controls to encourage strong safety behaviours and reduce risks. As a result, this study proposes a rigorous system of control management guidelines, adapted to the particularities and specificities of the nuclear industry, an industry that upholds a strong standard of excellence in safety.

Thirdly, this study proposes ways, through the control loop, to reduce the distance of contractor-subcontractor relationship through interactive controls (such as the morning social controls as a package) that are led by both CEA Managers and Middle Managers. The package of morning social controls encourages subcontractors to voice concerns and suggestions for daily operations thereby inducing a safety mindset that sets the tone for the remainder of the day. The daily behaviour controls and output controls that ensue, address potential concerns from both parties on-site. Any concerns or suggestions made by either party are re-discussed in a morning social control (the next morning or prior to the next time the activity is carried out) encouraging the voicing of future concerns. Additionally, by encouraging the five Empowerment Leadership Factors (*show concern and interact, lead by example, inform, coach, participative decision making*) throughout the control loop, the CEA can re-align the subcontractors' safety culture (if required) towards a safety culture that is shared by a united contractor-subcontractor business entity. This is critical as CEA Managers must foster safety behaviours through the use of the

ELM to ensure that subcontractors (who are the first line workers) notify managers of near misses, concerns or areas where they do not understand and require coaching.

These managerial contributions detailed above as well as those defined in the subsection below align with the appeals made by the International Atomic Energy Agency (IAEA) following three major nuclear accidents: Three Mile Island in 1979, Chernobyl in 1986, and Fukushima Daiichi in 2011. Specifically, the (IAEA) *firstly* stresses the importance of human factors in nuclear safety; *secondly*, calls for effective leadership practices considered as "levers of change" for the safety culture; and *thirdly*, accentuates the need to complement traditional safety approaches through a systems approach.

1.2. Managerial Implications for the Directorate of Nuclear Safety and Security (DSSN) of the CEA

The Directorate of Nuclear Safety and Security (DSSN) » known in French as « *La Direction de la Sécurité et de la Sûreté Nucléaire* », is a branch within the CEA. DSSN oversees the CEA's control of natural and industrial risks, nuclear safety, radiation protection, Human and Organizational Factors (HOF), environment protection, and the Health and Safety of workers. The Directorate defines and asserts the CEA's policy in these matters and serves as the interlocutor with the French Nuclear Safety Authority (ASN) and its military counterpart, the French Defense Nuclear Safety Authority (ASND). DSSN, advises and assists all Nuclear Facilities of the CEA in areas relating to nuclear safety and occupational safety including the coordination of local training, the Return of Experience (REX) feedback exchanges with other nuclear operators, and the management of near misses, events, and crises situations.

As a result, the contributions of this study may be employed during training sessions organized by DSSN. The following provides three managerial implications for DSSN at the CEA:

Firstly, DSSN can teach CEA managers of quasi-integration facilities to identify different preventive and detective controls and their role within the cycle of control. CEA Managers can then design and balance the MCS employed based on the temporal aspect of the controls and the needs of the actor performing the task (Activity Preparation CS7, Procedure validation CS6, Verification of Procedure validation CC6bis, Debriefing Activities CR5, Implementation of Return of Experience CS8). The balance of interactive controls and non-interactive controls will provide a platform to exchange and encourage safety leadership.

Secondly, DSSN can instruct CEA managers of quasi-integration facilities to identify the ago-antagonistic forces and virtues of preventive and detective controls and show how to balance these ago-antagonistic controls for improved prevention and mitigation of subcontracting-related risks and events. Specifically, ago-antagonistic forces are ubiquitous and found in many systems including the following pairs that have been identified in the literature: *Network and Hierarchy*; *Centralized and Decentralized*; *Cooperation and Competition*; *Reflection and Action*; *Short and Long*; *Individual and Collective*;

Evaluation and Control. Specifically, in the case of this dissertation: The CEA facilities are comprised of a **network** of actors, organized in a **hierarchical** society of multiple system levels. Within this hierarchy, **centralized** decisions or actions take place that have a direct impact on **decentralized** operational activities like subcontracting. The CEA creates value by subcontracting (through **cooperation** with subcontractors) but this also yields subcontracting risks that arise from **competition** or **conflict**. Managers need to continuously maintain the tension between two AA forces, as balancing tensions between opposite and complementary poles can help managers cope with the safety complexities of subcontracting relationships. However, these processes are not easy to conceptualize and design, and are even harder to implement. Particularly as it is very easy to lose track of the AA couple and instead focus the attention on the more demanding ago-antagonistic pole. Therefore, MCS should be designed and implemented to combine **short-term** and **long-term** concerns, reward **individual** and **collective** performance, **evaluate** and **control** operational and safety standards. These safety standards can be **evaluated subjectively** or **objectively** through the use of **controls** that **avert or detect events**. As a result, CEA managers that have been taught to identify Ago-antagonistic Pairs and how to balance them, can apply this knowledge to their Risk Management Procedures. Dialogical pairs which are similar to Ago-Antagonistic couples have also been discussed in Blatter *et al.* (2016).

Thirdly, DSSN can highlight to all actors the different types of subcontracting risks present at the quasi-integration facilities that occur despite the use of Managerial Controls. The minimization of risk is essential in the nuclear field and of great importance in safety management practices. By presenting the MCS risk couplings present at these types of CEA Facilities, through the use of analogies, actors can be aware of the need for continuous controls that may prevent and detect potential risks. The analogies, like metaphors, guide perceptions and interpretations of reality (Cornelissen, 2005) thereby assist the actors in understanding how the different types of control work together to mitigate risks and how these controls are linked to leadership.

A focus on the importance of Social Controls either on their own or in conjunction with other types of controls (Behaviour or Output) highlights the importance of promotion of ELM behaviours throughout the daily contractor-subcontractor relationship. The need for a more safety performance-oriented Risk Management culture within the Facilities may require Managers (CEA Managers and Middle Managers) to adopt a leadership style that corresponds to their contingency variables and foster values and behaviours that mitigate risks and promote safety behaviours during high-risk procedures.

While a leader can display a Transactional, Delegative/Laissez-faire and/or Transformational leadership style during their daily tasks (Avolio, Bass and Jung, 1999; Jansen, 2011; Vera and Crossan, 2004), this study shows that in the case of Facility B and E, Middle Managers both employ a transformational leadership style (regardless of contractors leadership style) that encourages subcontractors (who are the first line workers) to notify managers of near misses, concerns or areas where they do not understand and propose new ideas and solutions for improved safety performance.

1.3. Managerial Implications for Managers (CEA Managers/ Middle Managers) at the Facilities at the CEA

Several Strategies to balance Ago-antagonistic pairs has been proposed for the Facilities at the CEA and are detailed in Figure 56 below. These strategies originate from the three Endocrinological strategies that are employed within the Medical Field to re-introduce a balance of imbalanced AA pairs (Nunez, 1997). The specifics of these strategies (*supplementary, bipolar, unipolar paradoxical*) can be found in Subsection 1.6.2 of Chapter 1. Please note, these strategies are named according to the theory of Ago-antagonistic Systems. As with re-equilibration of hormones, Managers in the Nuclear Field re-equilibrate preventive and detective controls through their implementation of new controls following an event. Additionally, Managers can implement the recommended Joint Systemic Approach to Risk and Safety Management proposed in this thesis and summarized in Figure 56 below to discourage future events while ensuring that the Controls fit to the specific context of each Facility.

In applying these strategies, Managers must consider several disturbances in all AAS (Nunez, 1997) associated with the re-balance of the preventive and detective AA poles:

- “*the equilibrium constant is altered*” (changes to the controls will alter the equilibrium of detective and preventive controls);
- “*one of the components is less synthesized, more synthesized or destroyed*” (changes to one pole may result in changes to the other pole (controls augment, diminish, or are no longer performed)
- “*the agonistic or antagonistic receptor is naturally or therapeutically deficient*” (the subcontractor is not receptive or present to the change of controls) ;
- “*the two [forces] are no longer present, an inadequate time or location to exert their action*” (a control was missed or carried out at the wrong time or location).

This approach incites managers to balance ago-antagonistic tensions between *preventive* and *detective controls* by learning to identify when agonistic-antagonistic unbalances have occurred and to react to an event by augmenting resources and controls. The following sections provide generic and CEA illustrations of the application of such Endocrinological strategies to balance ago-antagonistic Preventive Control and Detective Control under two circumstances: *firstly*, if the event takes place; and *secondly*, if the event does not occur:

If the event took place, it is possible that the *preventive controls* and/or the *detective controls* present were ineffective, as the disparities were neither prevented nor detected. Often the system did not function as intended either because: (a) the detective control was ineffective as in the first example or (b) the detective control was missing as in the second and third example. In fact, during analyses of the root cause of the event, analysts at times perceive that there were disparities that were overlooked and that may have been potentially identified and corrected. Other times, and in the case of a new phenomenon, the present detective controls may not be able to detect this new phenomenon either because: (a) the

detectors are not calibrated to detect this new phenomenon or (b) because the detectors detect a specific value but does not detect the disparity in the detected measure and the accepted measure. For this latter point, an actor is required to identify such discrepancies in obtained measures and the acceptable measures. Therefore, a strategy to deal with such ago-antagonistic imbalances is to augment *detective controls*. *Preventive controls* also need to be increased in order to minimize the need for exponentially increasing *detective controls* (of each event). In this case, a “**bipolar strategy**” is recommended whereby both forces are augmented.

- **Generic Example:** During the Three Mile Island accident (TMI) in 1979, whereby the position of a valve was incorrectly detected by workers, the detective control (display on the control board providing workers with a confirmation that the order to close the valve via the automaton had been sent and not the current position of the valve) was ineffective (a). The valve was partly closed while the information that the actor received indicated that the valve was completely closed, and as a result, the actors interpreted the situation based on this misinformation. Following this accident, the proposed bipolar strategy would propose a change to both the detective and preventive controls by: *first*, correcting of the detective control (the type of information sent to workers: a feed back information of the position of the valve rather than the feed forward information of the order that was sent) to ensure that in future, information obtained from this control represents the reality of the situation; and second implementing a new preventive control that consists of re-designing the system. In fact, following the TMI accident the nuclear industry made changes to both the *detective controls* and *preventive controls* that respectively corrected the human-machine-interfaces in nuclear power plants and began to develop more user-centred design approaches that consist of ergonomically human-machine-interface displays in the control rooms of Nuclear Facilities. This accident and the changes that ensued, incidentally marked the origins of the Human and Organizational Factors discipline.
- **CEA Example:** Following the discovery that keys lent out on a daily were missing from the **key locker** at the end of the day, the CEA managers implemented the following new controls as these controls were missing (b): First subcontractors were informed of the breach in key protocols and reminded that all keys are to be returned at the end of the activity (*preventive control*); Second managers performed a *detective control* post-activity at the end of each day to ensure that all keys have been returned to the key locker; and finally management sent a follow-up email every 2 to 3 months (*preventive control*) to remind subcontractors of the key protocols. As such, a **bipolar strategy** was implemented augmenting both *preventive* and *detective controls* prior to the task, after the task and once again prior to the next task (*Projection from afar Meeting, Technical Observation, 2TO-17*).
- **Generic Example:** During the accident investigation of the Titanic that sank in 1912, it was indicated that the lookouts did not have access to the “night glasses” or binoculars and as such

the detective control of lookout for objects in the water at a significant distance could not be carried out. Even though the individual detective controls functioned independently, this resulted in an ineffective system of observation. A bipolar strategy could have been employed by the other ships of the company. For example, a *detective control* in the form of a checklist that included “verify the key was returned” prior to the departure of the ship from the port. Similarly, a *preventive control* in the form of a *preparation meeting* and by referring to a *document* that pre-defines the location of the key locker, the size and the colour of the key ring in order to *discuss important elements prior to departure and to better detect any changes to the location (presence or absence) of the keys respectively*.

If the event did not occur but the disparity was detected, then the two options are possible.

In the first option, *preventive controls* are augmented to continue to fortify these controls by injecting more resources prior to or during the task. The quantity of *detective controls* does not need to be altered, as it was effective in detecting the disparity. This is synonymous with a “**supplement strategy**”.

- **CEA Example**: Typically, when a temporary subcontracting team is hired by a nuclear facility, a **safety welcome** is administered to the team leader who is then responsible to disseminate the information obtained during this safety welcome to the rest of their team. However, following several instances where it was noted that the safety information had not correctly reached the rest of the personnel on the temporary subcontracting, a new procedure was enforced at Facility B where by all personnel would be present during the safety welcome (not only the team leader as was the case before). This safety welcome (*Preventive control for all*) ensures safety performance of the operating process but does not result in actions directly on the process. Instead, it serves as a prevention control for all actors to inform them of potential errors ensuring that each subcontractor understands safety parameters to follow and provides a designated time to voice such concerns. In this case, a “**supplementary strategy**” is implemented augmenting only the Prevention controls prior to the task, as the detective controls were effective in detecting the disparities. (*Corsaro, P18, Facility B Occupational Safety Animator, Middle Management Subcontractor, Interview 2P18Int1*).

Alternatively, the second option is to use a “**unipolar paradoxical strategy**” in which *detective controls* are augmented, despite already being at a significant level, in order to stimulate the rise of *preventive controls*. In this case, it would appear that by augmenting the *detective controls* (*by the CEA and Middle Managers for example*) this will result in the augmentation of preventive controls (*by the subcontractors for example*).

- **CEA Example**: Manon (*P08, Facility A Occupational Safety Assistant, Subcontractor, Interview 1P08Int1, *4*) indicates that despite the prevention plan and the occupational safety visits carried out by Elektra (*P06, Facility A Occupational Safety Engineer*), there are times that

the subcontractors fail to follow the pre-designed safety rules. By increasing the number of Health and Safety Inspections at Facility A (CC3) to twice a day (and hence increasing the number of *detective controls*), the subcontractors in turn augment the number of *preventive controls* (Procedural validation - auto controls CC6) in order to improve the results obtained during the Health and Safety Inspections (CC3). In this case, a “**unipolar paradoxical strategy**” is implemented by augmenting only the Detective Controls (Inspections) on the part of the CEA Managers, which has an effect on the number of Prevention controls (auto controls) on the part of the subcontractors.

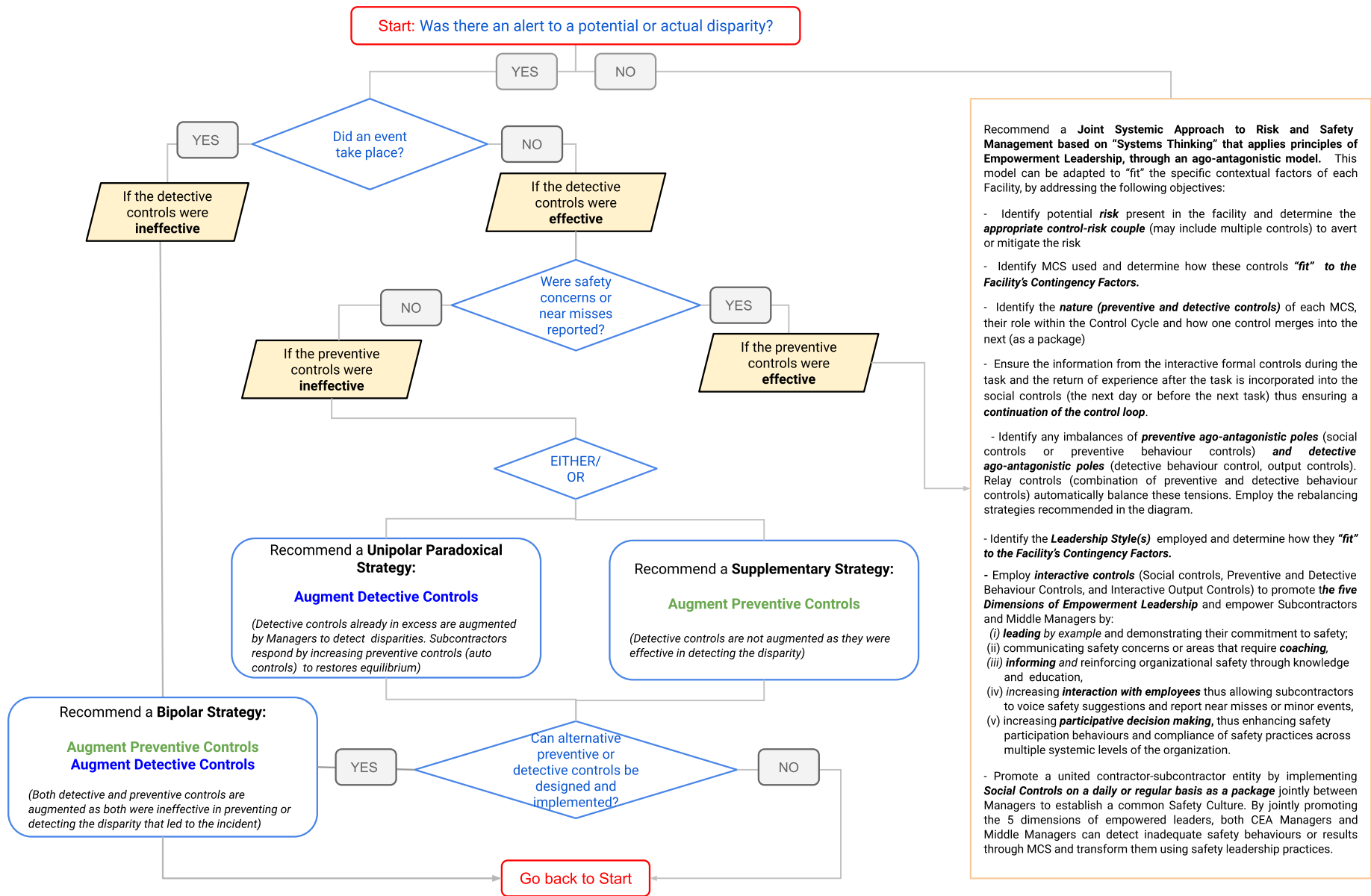


Figure 56. Recommendations on how to deal with Ago-antagonistic Imbalances at the CEA Facilities

2. Academic Contributions

This dissertation makes contributions to the literature in three main fields: Management Control Systems (MCS), Enterprise- Risk Management (ERM) Literature and Inter-organizational (IOR) Control. This second section of chapter four presents the academic contributions in two sub-sections. The *first* section presents the contributions made to MCS literature, including contributions to Simons' (1995) Locus of Control Model; Chenhall's (2003, 2006) Contingency Framework of MCS, and Malmi and Brown's (2008) MCS Packages Model. The *second* section presents the contributions made to ERM literature and specifically the empirical contributions of Naedaei et al. (2015) Contingency Model of Enterprise Risk Management and Hollnagel's (2013) Safety 1 and Safety 2 Model. The contributions in the first and second section also includes the contributions made to IOR literature, as "*the scope of the activity of management control is enlarged and no longer confined within the legal boundaries of the organization*" (D. Otley, 1994, p. 293). Finally, this dissertation also makes transversal academic contributions to the field of Safety Science and Human and Organizational Factors (HOF) Literature that are discussed throughout each of the following sections.

2.1. Contributions to Management Control Systems (MCS) Literature

This section presents the contributions made to Management Control Systems (MCS) literature. Given the interconnectivity of research in Inter-organizational (IOR) Control Literature with MCS, the theoretical contributions of IOR research will also be addressed within this sub-section.

Contributions to research on Management Control

This study contributes to Management Control literature by the reconceptualization of MCS typology used in Risk Management and proposes two natures of control: ***Preventive Controls*** and ***Detective Controls***³³ that are both fundamental elements of Risk Management at the CEA. These two natures of control evoke the first two levels of control, prior to a nuclear accident, detailed in Defense in Depth (INSAG 10) and the Decree of February 7, 2012. In this dissertation, both natures of control are defined based on the contrast of four factors: the aim of the control, the description of the task, the position of the actor performing the task and the timing of the control. To the author's knowledge, no other MCS typology in the literature considers the timing of the control nor the position of the actors, nor considers the complexity of their interaction.

Prior research (Leveson et al., 2009; Jary, 2007; Vautier et al., 2018) calls for system-oriented approaches to technical and organizational safety. This study responds to this request by combining both proactive and reactive/adaptive risk management, as proposed by Paries (2021), through a holistic

³³ See Section 2.2 in Chapter 3 for further information including the definition of Preventive and Detective Controls.

approach that contributes to safety by considering the interactions between organizational, human and technological factors and how they affect management controls. This systemic approach mirrors previous study's (Ferreira and Otley, 2009; D. Otley, 1999) views concerning information flow, systems and networks as the binding agents that hold the system together. The findings on Preventive and Detective Controls are synonymous with Ferreira and Otley's (2009, p. 273) view of feed-forward and feedback of information by distinguishing between information flows that aim to “*anticipate future events and respond in advance of their occurrence*” from information flows that aim to “*[correct] past shortcomings*”. Specifically:

- *Preventive controls* consist of a proactive control via a feed-forward loop during which corrective measures are made to anticipate errors or events, to achieve dynamic equilibrium (Chikere and Nwoka, 2015) by impeding risks and identifying the elements required when the situation “goes right” to optimize the system design (Leveson, 2011). This notion supports Ferreira and Otley's (2009, p. 273) view that feed-forward information “*enables the organization to learn from its experience, to generate new ideas and to recreate strategies and plans*”.
- *Detective controls*, on the other hand, consist of a reactive/adaptive control in which information of the controlled variable is provided back to the process through a feedback loop (Chikere and Nwoka, 2015) to ensure the process continues within the pre-defined limits (Leveson, 2011). This includes the identification of near-misses and events that allow actors to identify when the situation “goes wrong”, thereby eliminating and mitigating the cause. This notion mirrors Ferreira and Otley's (2009, p. 273) view on feed-back information that “*enables the undertaking of corrective and/or adaptive courses of action*” as well as Paries' (2021, p.4) view on Safety Management that “*is bipolar. One pole is proactive [...] The other is reactive.*”

In line with Systems Thinking, the causal factors (component failures, external disturbances and dysfunctional interactions) of what “went right” and “what went wrong” are considered at multiple-levels of the organization (Leveson, 2004; Leplat, 1987), integrating both proactive and reactive/adaptive perspectives to provide a more comprehensive account of the Risk Management Strategies within the French Nuclear Industry.

[Contributions to Simons' \(1995\) Levers of Control Model](#)

The findings extend Simons' (1995) ***Levers of Control (LOC) framework*** through several contributions by aligning the four control elements (*beliefs, boundary, diagnostic and interactive controls*) with the preventive and detective controls proposed in this research. As such, this research responds to the limits of LOC evoked by several scholars and demonstrates how the LOC framework can be used by managers to promote the organization's Risk Management Strategy.

The findings in Figure 57 below illustrating how the LOC contrasts the three types of MCS (*Social/Input, Behaviour/Process, Output/Outcome*) conceptualized in Merchant and Van der Stede's

(2007) typology, employed in ERM and IOR Literature. As a result, the LOC can be integrated into the Cycle of Control proposed in this study:

Firstly, **Belief Systems** under the original framework consist of *explicit beliefs communicated by management formally to reinforce the values, purpose and direction of the organization* (Simons, 1995), which aligns to the definition of Social Controls provided by Kraus and Lind (2007) (*values, norms and culture that influence behaviour*) and minimize goal discrepancies by establishing common culture and values (Anderson et al., 2014; Christ et al., 2014; Ouchi, 1979b). The definition of **Social or Input Controls (CS)** proposed in this thesis that accounts for the particularities of the French Nuclear industry, divides Social Controls into two items: the first ensures *that safety objectives of the CEA and the subcontractor are convergent with one another and the second ensures that non-convergent objectives combine well with each other* which are solely preventive in nature. Figure 57 presents Belief Systems as an extension of this study's definition of Social Controls (CS) encircled under the preventive controls.

Secondly, **Boundary Systems** as intended by Simons (1995) include *formal rules, and limits that discourage opportunity-seeking behaviours and control business risk*. According to Kraus and Lind (2007), Behaviour Controls *specify and evaluate how parties should act* which helps managers identify the type of behaviours desired throughout a task (Anderson et al., 2014; Christ et al., 2014). This study defines **Behaviour** i.e. **Process Controls (CC)** within the French Nuclear industry as controls that *ensure procedures are performed according to the pre-determined specifications prescribed by the CEA or the external authorities* which are both preventive and detective in nature. As a result, Figure 57 presents Boundary Systems as an extension of this study's definition of Behavior Controls (CC) delimited by both preventive and detective controls.

Thirdly, **Diagnostic Control Systems** under the original 1995 framework consists of *feedback systems that monitor organizational outcomes and correct deviations from pre-set standards*. This concept resembles the definition of **Output Controls** provided by Kraus and Lind (2007) (*measure, evaluate and reward the results of inter-organizational relationships*) which allow managers to quickly react to changes in those measurements (Anderson et al., 2014; Christ et al., 2014). The definition of **Output or Outcome Controls (CR)** proposed in this study, consists of controls that *ensure the subcontractor obtains results that comply with their commitments*; which are solely detective in nature. As a result, Figure 57 presents Diagnostic Control Systems as an extension of this study's definition of Output Controls (CR) demarcated within the detective controls.

Finally, **Interactive control systems** according to Simons (1995) allow managers to *involve themselves regularly and personally in the decision activities of the subordinates at every level of the organization, provoking the emergence of new strategies and initiatives*. The findings in this study determine that MCS within all three MCS categories have the potential to be interactive controls, and hence by extension, certain controls within all three aforementioned LOC can be categorized as interactive. These findings are consistent with Ferreira (2002) who observed that at any moment a single control can be classified under more than one level of control. Specifically, Social Controls (CS) are entirely preventive

and interactive, only Detective Behavior Controls (CC) are interactive, and Output Controls (CR) are entirely detective and have the potential of being interactive. By extension, certain Belief systems, Boundary Systems and Diagnostic Control Systems can also be classified under the Interactive Control Systems LOC. The study's Cycle of Control, employed on a daily basis, contains all four LOC supporting Widener's (2007) claims that the four LOC are interdependent and complementary and should be considered in combination when designing control systems, in order to produce effective results.

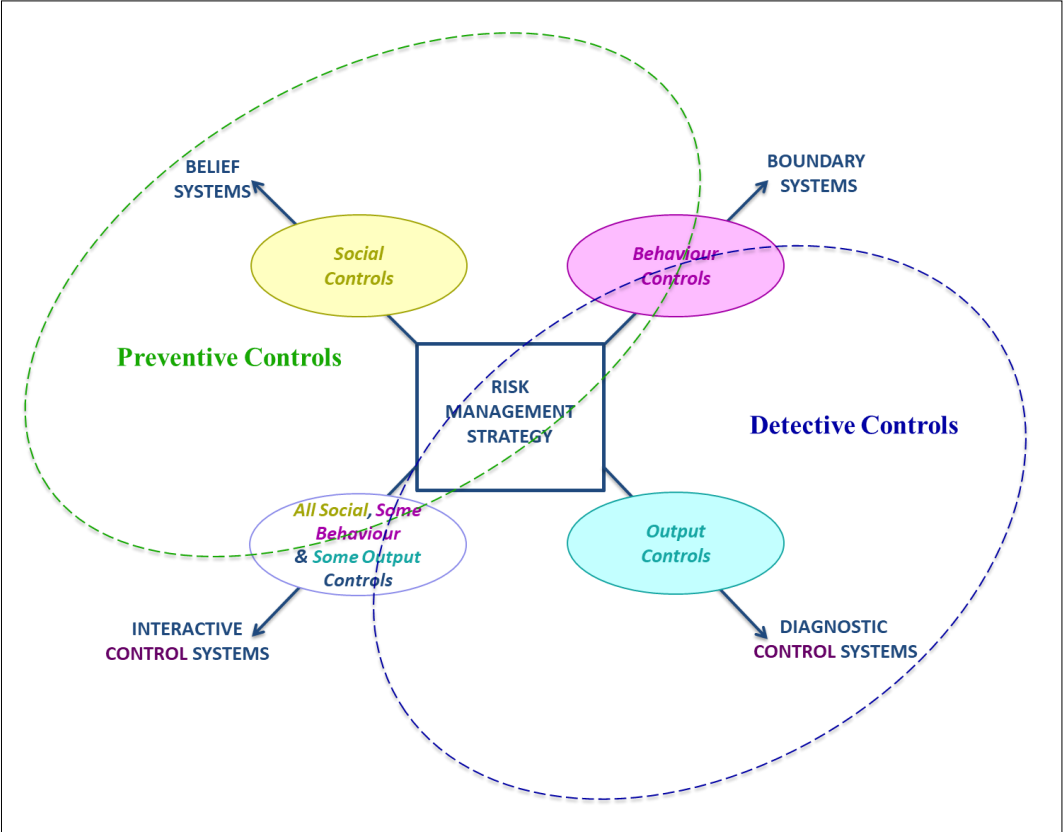


Figure 57. Applying Preventive and Detective Controls, defined in this study's Risk Management Strategy, to Simons' (1995) Levers of Control (LOC) Framework [Adapted from Simons' (1995)].

The findings emphasize the connection between interactive controls and the Five **Empowerment Leadership Factors** (Arnold, 2000), which are consistent with Mundy's (2010) findings that interactive processes and other LOC aim to direct and empower subordinates. Specifically, Social Controls (CS) (*all interactive and preventive*) and Interactive Output Controls (CR) (*all detective*) allot for all five leadership factors. Behaviour Controls (CC) allow for certain leadership factors while *non-interactive* Output Controls (CR) (*detective*) are the sole controls that do not allot any of the five Empowerment Leadership Factors.

This research employs an Ago-antagonistic Systems (Bernard-Weil, 2002; 2003) approach to fill in the gaps in the literature to determine the appropriate combination of controls, as according to several scholars (Ahrens and Chapman, 2004; Ferreira and Otley, 2009). Simons' (1995) framework fails to

give clear instructions on how to combine and balance the four potentially conflicting levers. Specifically, the research proposes a systemic approach that allows managers to design MCS strategies that balance the tension of the preventive and detective ago-antagonistic poles, identify when imbalances have occurred and proposes strategies to rebalance them. Additionally, the study employs the LOC initially limited to top-level management controls (Ahrens and Chapman, 2004; Ferreira and Otley, 2009) and provides a framework that is applicable to all system levels of the organization and that details the control interactions that occur between CEA Managers, Middle Managers and Subcontractors. See the paper in Appendix D for details on the use of an Ago-Antagonistic Approach to Risk Management via Preventive and Detective Controls at the CEA.

The research findings bring clarity to the *feed-forward (non-cybernetic) and feed-back (cybernetic)* debate of the LOC in the literature, through the lens of preventive and detective controls. According to Simons (1995), *Belief Systems (Social Controls) and Boundary Systems (Behaviour Controls)* are classified as *non-cybernetic* as they lack feedback loops in their search for new opportunities. In contrast, Simons (1995) views *Diagnostic (Output Controls) and Interactive Controls (all Social, Some Behaviour and Some Output Controls)* as increasing *cooperation* through feedback loops (*cybernetic*). He adds that Interactive controls engage the most pronounced feedback loops that promote the sharing of information, learning and emergent modes of obtaining strategic goals, while Diagnostic controls merely confirm the organization is on track. In contrast, Ferreira and Otley (2009) indicate that Diagnostic Controls (Output Controls) follow a mechanistic, repressive, traditional control approach, while Interactive controls take an organic, constructive, learning-oriented control approach. Similarly, Widener (2007), contrasts Diagnostic and Interactive controls stating that interactive controls are based on measurement and coordination and are more forward-looking than diagnostic controls. If constructive, learning-oriented and forward-looking controls are categorized as feed-forward (non-cybernetic), then Ferreira and Otley (2009) and Widener (2007) categorize Interactive controls as non-cybernetic; which is contrary to Simons (1995) cybernetic classification. Additionally, if a control can be classified as both interactive and any of the other three LOC, this poses a challenge to classify a single control as simultaneously cybernetic and non-cybernetic. This discrepancy may be partly explained by considering the preventive and detective nature of the LOC and hence their demarcations within each LOC presented in Figure 57. Specifically, the two Preventive Controls: Preventive Social Controls (Belief Systems) and Preventive Behaviour Controls (Auto-controls that include some Boundary Systems) can be classified as non-cybernetic, loose, enabling and feed-forward controls. Similarly, the two Detective Controls: Detective Behaviour Controls (that include some Boundary Systems) and Detective Output Controls (Diagnostic Controls) can be classified as cybernetic, tight, coercive and feed-back controls. As a result, some interactive controls can be categorized as non-cybernetic (Social controls) while the other Interactive controls can be categorized as cybernetic (Detective Behaviour Controls and Interactive Output Controls) depending on their preventive or detective nature. Similarly, this new demarcation also impacts Boundary Systems which contrary to

previous authors, can under this new definition also be classified as non-cybernetic in the case of Preventive Behaviour Controls (Auto-controls and hence non-interactive).

The research's use of Ago-antagonistic poles of control mirrors [Simons \(1995\)](#) Dynamic Interplay of Positive and Negative Forces “the Yang and Yin” between the LOC. [Simons' \(1995\)](#) view of the Yang, Belief Systems and Interactive Controls procure a positive informational environment that encourages information sharing and learning and hence “innovation” in line with the findings in this study of Preventing controls. The Yin, or negative forces, are attributed to Boundary Systems and Diagnostic Control Systems as they eliminate desired behaviour by imposing extrinsic restrictions to delimit opportunity seeking and hence “efficiency”, synonymous with this study's Detective Controls. It could be pondered if [Simons \(1995\)](#) was unknowingly proposing innovation and efficiency as potential Ago-antagonistic pairs. His book also refers to other potential Ago-antagonistic forces including freedom and constraint, empowerment and accountability, top-down direction and bottom-up creativity, and experimentation and efficiency.

The study finds that the interactive controls, encourage the use of Empowerment Leadership Factors, which help to balance controlling and enabling uses of MCS. This supports [Mundy's \(2010\)](#) findings, that managers must balance the competing demands of management and empowerment through the appropriate combination of LOC and the 5 control elements that affect a firm's ability to balance between controlling and enabling the use of MCS.

[Contributions to Malmi and Browns' \(2008\) MCS Packages Model](#)

This research provides empirical evidence of MCS as a Package in the form of daily controls within the Cycle of control that commences with a morning set of informal controls during the Co-Activity Meeting (Cultural, Planning, Administrative, and Rewards and Compensation) that takes place prior to the task, followed by Preventive and Detective Behaviour Controls (the latter which is Cybernetic and Administrative) during the task, and finally with Output Controls (Cybernetic) after the task. The subsequent Social Controls ensure continuity of the cycle. The implementation of Malmi and Brown's (2008) packages framework, to the proposed Design of MCS for Risk Management and Safety Management, ensures that all of the elements within the cycle support and reinforce each other; particularly as controls do not operate in isolation making any independent assessment of them irrelevant (Malmi and Brown, 2008). As a result, designing MCS as a package, allows managers to envision and account for the impact of different types of controls and how they complement each other. The results also demonstrate the capacity of Social Controls under certain situations to mitigate all three subcontracting related risks (substituting Behaviour and Output Control) and under other situations to be implemented in unison with any of the other two controls (complementing Behaviour or Output Controls). The proposed informal and formal MCS approach encourages Managers to design MCS as a package using the most appropriate combination of MCS given the situations (Merchant and Van der Stede, 2007) thus supporting organization objectives and control activities that drive performance.

Contributions to Chenhall's (2003;2006) Contingency Theory of MCS Framework

This research provides empirical evidence of Chenhall's (2003, 2006) Contingency Framework, providing an empirical study to validate contingency research. While previous studies have examined a few of the six contingent variables, this study reviews all six contingent variables across three Nuclear Facilities that subcontract and hence are exposed to intra-organizational and inter-organizational controls. Specifically,

In terms of the *External Environment*, the study finds that Facilities with high information asymmetry implement more formal controls, while Facilities with less information asymmetry implement informal controls in addition to their formal controls. The presence and hence the implication of Middle Managers decreased information asymmetry only in the case where the distance between contracting-subcontracting unit was reduced. Facility B's integration of informal controls following several near-misses are consistent with Chenhall and Morris' (1986) findings that organizations facing uncertainty due to their external environment should balance the formal tight controls with loose controls to ensure that the formal controls can adapt to the changing and uncertain environment.

With regards to *Technology*, the study's findings demonstrate that facilities with high work process employ formal controls consistent with Hirst (1983). With regards to the interdependencies, the findings are consistent with scholars (Chenhall, 2003, 2006; Macintosh and Daft, 1987) that find that organizations with low-interdependencies employ more formal controls, and those with high interdependencies utilise more loose controls. However, the findings shed light on the impact of interdependencies on the use of interactive controls, not previously discussed within the Framework. As the level of interdependencies increase, the use of interactive controls develops in a progressive manner, beginning with the use of mainly non-interactive formal controls, then moving onto more interactive formal controls and finally progressing to the use of highly interactive informal and formal controls.

With regards to *Size*, the results are consistent with the Chenhall's (2003, 2006) findings as larger facilities employed more complex communication and coordination processes and employed a decentralized hierarchy. However, the findings provide evidence that the type of communication and coordination style and hence the type of managerial control, varies according to the inter-dependencies of the contracting and subcontracting firm. Specifically, the Facility with high inter-organizational interactions (similar to interdependencies) use more sophisticated interactive controls and informal controls on a daily basis, while facilities with less inter-organizational interactions employ more non-interactive formal controls. The use of more sophisticated interactive controls in the Facility with high interactions arose due to the implementation of more informal controls (an increase in preventive controls) in conjunction with the empowerment leadership by both CEA Managers and Middle Managers; providing empirical evidence that larger organizations make modifications to their MCS in order to achieve organizational cohesion (Chenhall, 2003).

With regards to **Organizational Structure**, the two largest facilities observed employed a decentralized managerial structure, however, only the facility with low inter-organizational interactions utilized more formal MCS consistent with Merchant's (1981) claim. Contrary to this case, the large facility with high inter-organizational interactions employed both informal and formal controls, which does not support Merchant's (1981) claim. This discrepancy may be partially explained by the difference in the managerial leadership style of the two large facilities. Specifically, the CEA Managers and Middle Managers of the large facility with high inter-organizational interactions, that uses both formal and informal controls, employed a consideration (Stogdill and Coon, 1957), transformational (Bass Avolio, 2000), or charismatic (Waldman et al., 1999) leadership style. This leadership style ensured open lines of communication (Albernathy et al., 2010), encouraged the participation of subordinates (Chenhall, 2003), and suggestions from subordinates (Waldman and Yammarino, 1999) commencing with a morning Co-activity meeting (informal set of controls), and a forward-looking control that encouraged interactive communication throughout the remainder of the day (Cycle of Control). The CEA Managers from the centralized facility, employed an initiating (Stogdill and Coon, 1957), transactional (Bass Avolio, 2000; Waldman et al., 1999) leadership style and consistent with Albernathy et al. (2010) also employed forward-looking controls in the form of a weekly Co-activity meeting but to a lesser extent.

With regards to **Strategy**, the Contingency Framework refers to the organizational strategies related to financial strategies that are not applicable to this study. Instead, because of the importance of achieving result objectives and safety objectives given the Nuclear context, the findings propose MCS that fit with these strategic organizational objectives and the leadership style of each Facility. This study investigates the strategies employed to achieve and control safety and result objectives, thus responding to the calls made in organization and accounting literature (Abernathy, Bouwens, and Lent, 2010; Scherr and Jensen, 2007; Yukl, 2005) to further investigate the relationships between leadership styles, organizational control mechanisms and organizational outcomes.

With regards to **Culture**, the research findings reveal that Organizational Culture which translates to Safety Culture in the Nuclear Context impacts the types of MCS implemented and the manner that Managers promote Safety. These results may shed light on whether culture affects aspects of MCS, as according to Chenhall (2003) few studies are able to draw clear comparisons and generalizations. Additionally, this study emphasizes the importance of Safety Culture and its connection between all five aforementioned contingent variables. Specifically, Managers' Choice of MCS and Managerial implication appear to be contingent on the Organizational Structure, Size and Technology; while the manner that Managers promote Safety, that is their leadership style, appears to be linked to the External environment and the Facility's Strategy to obtain Safety objectives.

[Contributions to Abernathy et al. \(2010\) Leadership and Control Systems Design Framework](#)

This research provides empirical evidence of the effects of leadership style on explaining the choice of three integral elements of an organization's MCS: *the use of Planning and Control Systems (PCS) and Performance Measurement Systems (PMS)* (Abernathy et al., 's 2010). This framework employs Stogdill

and Coon's (1957) leadership typology to demonstrate how the type of Managerial Leadership Style (*consideration vs initiating structure*) impacts how a Manager *communicates* via interactive PCS and *executes the vision of the firm* via PMS (Bolton et al, 2008; Abernethy, et al., 2010). Specifically,

Planning and Control Systems (PCS) refer to Simons' (1995) interactive and diagnostic LOC (Interactive Output Controls within this study), that communicate a firm's expected goals and objectives (Abernethy, et al., 2010). The findings confirm that Managers with a Consideration Leadership style (Transformational) employ planning and control systems via Interactive Output Controls as a communication device that obtains feedback from subcontractors consistent with (Abernethy, et al., 2010). Additionally, this study identifies that Managers with a Consideration Leadership Style also implemented interactive controls that communicate strategic preferences and managerial vision via Interactive Social Controls (Belief Systems) which encourages subcontractors to voice queries, eliminate concerns and encourage suggestions. As a result, the findings indicate that Managers with a Consideration Leadership style address planning and control systems through a balance of preventive and detective ago-antagonistic poles via the use of formal and informal controls. On the other hand, Managers with an Initiating structure (Transactional) also employed planning and control systems via Output controls consistent with Abernethy, et al. (2010), but contrary to the Consideration leadership style they do not employ a great number of Interactive Social Controls. As a result, the findings indicate that Managers with an Initiating Structure address planning and control systems by focusing on the detective ago-antagonistic pole via the use of formal controls.

Performance Measurement Systems (PMS), monitor the behaviour and evaluate performance (Abernethy, et al., 2010) which relates to Behaviour Controls employed in this study. The predicted relation between an Initiating Structure and the use of Performance Measurement Systems (Abernethy, et al., 2010), was observed in the Facility that employs twice daily Behaviour Controls in the form of inspections to monitor behaviour and evaluate performance. However, the framework refers to the use of PMS for compensation and promotion, while the study, given the context, refers to the use of PMS to attain safety behaviour and evaluate safety performance. As a result, consistent with the framework, the study finds that Managers with an Initiating Structure manage PMS through the use of formal systems that focus on the detective ago-antagonistic pole.

2.2. Contributions to Enterprise Risk Management (ERM) Literature

This study contributes to Enterprise Risk Management literature by providing new definitions for Subcontracting-related risks and the Management Control Systems employed to avert and mitigate those risks, that account for the particularities of the French Nuclear Industry. The contributions made to the specific Models and Frameworks in ERM literature are detailed below.

Contributions to Das and Teng (1999; 2001) and Anderson et al. (2014) Alliance Risk Framework

The findings are consistent with the Alliance Risk Framework and demonstrate that Behaviour Control mitigates Relational Risk, Output Control mitigates Performance Risk (Das and Teng, 1999; 2001) and that Social Control has the ability to simultaneously mitigate Relational Risk, Performance Risk and compliance and regulatory risk. However, this study provides evidence of a simultaneous combination of an informal and a formal control (Social Control and either a Behaviour or an Output Control) to mitigate Relational or Performance Risk; a concept which has not been detailed in the Alliance Risk Framework. The findings further demonstrate how this coupling of formal and informal controls yields a balance of preventive and detective controls (see the paper on balancing ago-antagonistic controls in Appendix D).

The findings also suggest that the type of Managerial risk model employed in the Facility influences how managers implicitly (March and Simon, 1958) or explicitly (Weick, 1996) identify and mitigate organizational risks. This study extends this concept by adding that the type of Leadership Style also influences how managers implicitly or explicitly identify and mitigate organizational risks. The CEA Managers within the Facility with a transactional leadership style (centralized control) operate with implicit models of the world (March and Simon, 1958) while the CEA Managers and Middle Managers with the Facility with a transformational Leadership Style (decentralized control) operate in “enacted environments” in which their environmental perception is dependent on a variety of individual and organizational factors (Weick, 1969).

Additionally, two potential subcontracting risks (worker polyvalence and mechanical automatism) that were not observed at the facilities but that were proposed as potential risks could not be categorized into any of the three subcontracting risks discussed within the IOR and ERM literature. They are briefly discussed in Section 3.1 of this Chapter and may provide future avenues for the ERM literature.

Contribution to research on the use of MCS during the life cycle of the organization

The study did find that due to the dynamic nature of the controls, the type of MCS employed changed over time supporting Dekker's (2004) prediction. It is important to note that although this is not a longitudinal study of a single Facility, the observations obtained at the three Facilities of the embedded Case Study of the CEA over three instances (t=0 years, t=1.5 years, t=3 years) of the life-cycle of the contractor-subcontractor relationship, may shed light on the types of controls that are potentially employed over this time period in a single Facility. Specifically, these observations can provide insight into the changes in MCS employed in response to the timing along the life cycle of the organization (Kraus and Lind, 2007). Specifically:

Social controls, contrary to Dekker (2004) and Kraus and Lind (2007) that observed they were of most importance at the beginning of the life-cycle, were found in the study to be of most importance at t=3 years (the closest measure towards the end of the life cycle). This discrepancy may be

explained by this Facility's use of Transformational Leadership style and informal controls delivered jointly by CEA Manager and Middle Manager.

Behaviour controls, in this study, did not gain importance over time, as stipulated by Dekker (2004) and instead were of most importance in the Facility observed at the beginning of the life cycle of the contractor-subcontractor relationship (t=0 years).

Output controls, in the findings, were found to be important throughout the three Facilities and hence throughout all three time periods (t=0 years, t=1.5 years, t=3 years) of the contractor-subcontractor relationship. These findings differ from Kraus and Lind (2007) that found that output controls are employed most often when companies learn about processes and activities, as they allow managers to specify the intended outcome measures and the standards required to meet those measures.

Finally, this study responds to the call by Kraus and Lind (2007) for further research to determine the appropriate combination of controls by demonstrating in the proposed Cycle of Control how each of the controls follow a temporal cycle pattern where one control merges into the next. Additionally, this study shows how events and near-misses have a significant impact on the dynamic nature of controls, as MCS demonstrated the highest evolution in response to the identification of potential and actual risks or disparities. Similarly, Bourrier's (1999) research also showed the impact of the occurrence of the event on the safety politics throughout lifecycle of nuclear power plants.

[Contributions to Nadeai's et al \(2015\) Contingency Model of Enterprise Risk Management](#)

This research provides empirical evidence of Nadeai et al.,'s (2015) Contingency Model of Enterprise Risk Management that evaluates the fit of three contingent variables (*Decentralization, Size and Enterprise Resource Planning*) with the sophistication of the ERM systems of an organization and the Organizational Performance. Specifically,

With regards to **Structure** (decentralization), the research findings reveal that Facilities with a greater level of decentralization utilize more complex information to coordinate and control the activities of the Facility, supporting the findings of other empirical studies (Abdel-Kader and Luther, 2008; Chenhall and Morris, 1986). The decentralized Facility with less inter-organizational interactions created an intra-organizational software system that allows subcontractors at any level to inform Middle Managers of any minor disparities or concerns, which are then filtered by Middle Management and decidedly (or not) passed onto the CEA. This sophisticated ERM reporting and control system provides CEA Managers with the necessary information to comprehend the issues, consider multiple resolutions, and thus make enhanced decisions to rectify the problems (Chenhall and Morris, 1986; Chong and Chong, 1997) and mitigate the risks (Nadeai et al., 2015).

With regards to **Size**, the findings support Nadeai et al. (2015) framework as the larger Facilities employed more sophisticated ERM methods. However, all Facilities regardless of their size implement sophisticated risk management practices, which contradicts Colquitt et al.,'s (1999) finding that larger

organizations are more likely to implement risk management procedures. This discrepancy may be due to the nature of Nuclear Power Plants and the need for Facilities to implement ERM procedures regardless of size.

With regards to ***Enterprise Resource Planning (Technology)***, only a single Facility employs an internal sophisticated IT-data control system to identify, evaluate and handle the complexities and risks of the huge quantity of data consistent with Nadaei et al. (2015). This intra-organizational software system was created in response to the Managerial Configuration of the Facilities (reduced number of CEA Managers despite its large size) and proposes an organizational-wide data system that allows both Middle and CEA Managers to coordinate and manage resources from any location within the firm (Rom and Rohde, 2006), thereby leading to improved firm effectiveness and efficiency (Nicolaou, 2004) in dealing with potential or actual risks. The other facilities employ the standard Enterprise Resource Planning implemented in all Facilities at the CEA. These facilities of a small and a large size identify, evaluate and handle the complexities and risks of the large quantity of data internally and through interactive facility-wide controls.

With regard to ***Organizational Performance***, Nadaei et al. (2015) suggest that the probability of attaining firm objectives increases when risks and strategic changes are carried out proactively. This notion is supported by the findings in the study that reveal an increase in preventive controls (balance of ago-antagonistic poles) following near misses and events suggesting that these proactive controls are a strong contributor to attaining safety objectives.

This study extends this Framework by proposing Safety Culture and its fit with the Sophistication of ERM as an additional contingency variable; particularly as Safety culture is an essential attribute in Organizational Performance by means of event prevention. The findings in this study provide evidence that the three Facilities which embody Henriqson et al. (2014) identified attributes of safety culture in event prevention, all contain Strong Safety Culture as an essential component in ERM. Specifically, each Facility accentuates the importance of safety as a core value, and the implication of Managerial and subcontractor's commitment to safety (Henriqson et al., 2014) using Sophisticated ERM that encourage Empowerment Leadership Factors. A united contractor-subcontractor unit further allows the facility to co-construct an organization-wide safety-leadership culture through joint managerial implications.

[Contributions to Hollnagel's \(2013; 2014;2018\) Safety 1 and Safety 2 Framework](#)

The findings in this thesis surrounding the ago-antagonistic nature of preventive and detective controls provide an interesting link to Hollnagel's (2013; 2014; 2018) juxtaposition of Safety 1 and Safety 2, detailed in Table 21 below. From a historical perspective, safety concerns have originated from "*the occurrence, potential, or actual, of some kind of adverse outcome, whether it has been categorized as a risk, a hazard, a near miss, an accident or an incident*" (Hollnagel, 2013). Despite this dominating

Safety 1 perspective, Safety Management is a balance of Safety 1 and Safety 2, particularly as socio-technical systems increase in complexity.

The results in this study concerning both *Preventive controls* and *Detective controls* support certain aspects of Hollnagel's (2013; 2014) *Safety 1 perspective* that aims to ensure that the number of adverse outcomes is maintained as low as possible. The findings on the 24 MCS controls illustrated in Figure 58 below support this approach to safety management that is both proactive and reactive/adaptive in its aim to eliminate the cause(s) that have been found, or control the risk by identifying the causes and eliminating them or by improving the options for prevention, detection, and recovery (Hollnagel, 2013; 2014). Safety 1 highlights the importance of understanding the temporality of events in order to recognize anomalies and initiate the prepared response with minimal delays (Hollnagel, 2013; 2014). However, this Safety 1 perspective cannot be the sole manner of risk prevention as Managers cannot wait until a catastrophe occurs before trying to prevent it (Leveson, 2020).

Both the findings of *Preventive controls* and *Detective controls* in this thesis support certain aspects of Hollnagel's (2013; 2014; 2018) *Safety 2 perspective*, which aims to ensure that as much as possible goes right. The findings of the 24 MCS illustrated in Figure 58 below show that controls for Safety 2 aim to continuously anticipate developments and events by understanding how the conditions of the system and the environment evolve and where performance variability may be difficult to monitor and control (Hollnagel, 2013; 2014; 2018). Safety 2 highlights the importance of humans in providing flexible solutions to potential problems; which in this study were carried out through interactive controls that promote Empowerment Leadership Factors to encourage solutions across all levels of the organization.

In conclusion, this thesis incorporates notions of both Safety 1 and Safety 2, that are different and complementary Types of Risk Management, using notions of both proactive and reactive/adaptive controls; by subscribing to a combination of certain aspects of both perspectives. In reality, the proposed Systemic Approach centres around designing and conceiving a balance between preventive and detective systems from the conception of the MCS and re-designing or adjusting any imbalances throughout the lifecycle of the contractor-subcontractor relationship. This balance of controls is achieved via an ago-antagonistic model that recognizes that "*change and adaptation to change are both inevitable and healthy in the system's lifetime*" (Leveson, 2020.p.105). Nonetheless, the proposed changes to management controls should *firstly* be analyzed for ago-antagonistic imbalances and anomalies to ensure the adaptation does not introduce new hazards or risks, and *secondly*, be considered in light of the Facility's contingent variables (to ensure fit). Through the use of the five Empowerment Leadership Factors employed during informal and interactive controls, Safety Culture and Leadership are fortified and nurtured by the behaviour and participation of all members of the organization (subcontractors, Middle Managers, and CEA managers). This systemic approach that designs control

systems to avert, mitigate or control hazards is perhaps more synonymous with Nancy Leveson's (2020) *Safety 3 perspective*.

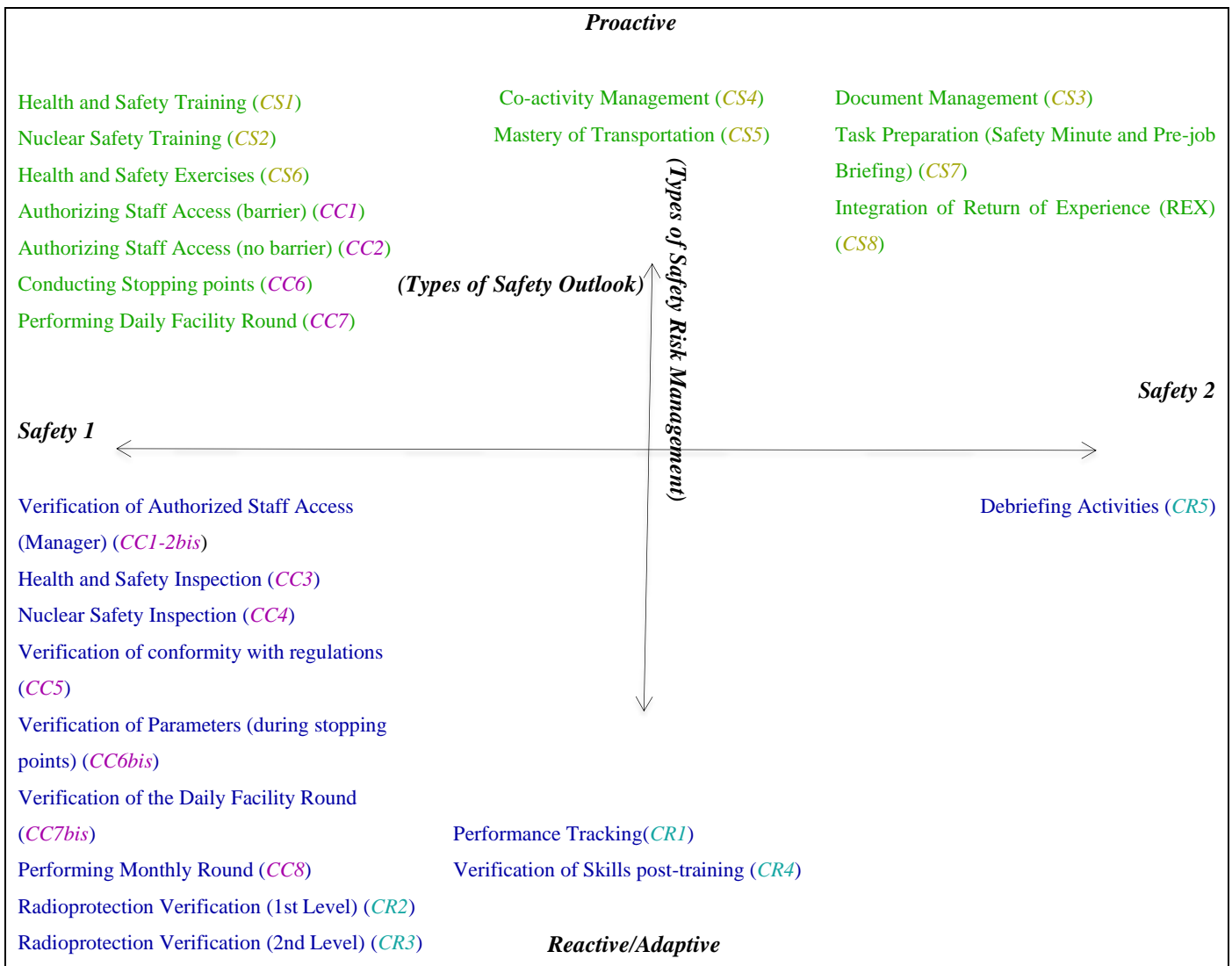


Figure 58. Proactive and Reactive/ Adaptive Controls for Safety 1 and for Safety 2 at the CEA Facilities

Table 21. Overview of Safety I and Safety II in relation to this study (Adapted from Hollnagel 2013, p.26)

	Safety I	Safety-II
Safety definition:	That as few things as possible go wrong.	That as many things as possible go right.
Safety Management Principle	Reactive, respond when something happens or is categorized as an unacceptable risk.	Proactive, continuously trying to anticipate developments and events.
Attitude to the Human Factor in Safety Management	Humans are predominantly seen as a liability or hazard. They are a problem to be fixed.	Humans are seen as a resource necessary for system flexibility and resilience. They provide flexible solutions to many potential problems
Explanation of Accidents	Accidents are caused by failures and malfunctions. The purpose of an investigation	Things essentially happen in the same way, regardless of the outcome. The purpose of an investigation is to understand how things usually

	is to identify the causes and contributory factors.	go right as a basis for explaining how things occasionally go wrong.
Risk Assessment	Accidents are caused by failures and malfunctions. The purpose of an investigation is to identify causes and contributory factors.	To understand the conditions where performance variability can become difficult or impossible to monitor and control.
Role of Performance Variability	Harmful, should be prevented as much as possible.	Inevitable but also useful. Should be monitored and managed.
With regards to this Study	<p>The <i>Preventive Controls</i> in both Safety 1 and Safety 2 found in all Social Controls and some Behaviour Control. Preventive controls highlight the importance of <i>interactive controls</i> that promote <i>Empowerment Leadership Factors</i> to encourage solutions to prevent potential/future problems.</p> <p>The <i>Detective Controls</i> in both Safety 1 and Safety 2 found in Some Behaviour Controls and all Output Controls. Detective controls highlight the importance of understanding the <i>temporality of events</i>, recognizing events quickly and initiate the prepared response with minimal delays.</p> <p>The systemic approach proposed designs control systems to avert, mitigate and control hazards by: (1) Designing MCS with a balance between preventive and detective systems from the conception and re-designing or adjusting imbalances (via an ago-antagonistic model) throughout the lifecycle of the contractor-subcontractor relationship;</p> <p>(2) ensuring that changes to MCS fit to the Facility's contingent variable and not introduce new hazards or risks;</p> <p>(3) Implementing MCS via the Cycle of Control to include elements of Empowerment Leadership Factors (via informal and interactive controls) that nurture Safety Culture and Safety Leadership throughout all members of the organization.</p>	

3. Limitations and Suggestions for Future Research

This thesis had several limitations that are to be considered when evaluating the theoretical framework and methodology of the research. These limitations open several avenues for further research. As a result, this third subsection first details the Limitations of the Study and then secondly proposes three categories of suggestions for further research: *short-term, medium-term and long-term research avenues*.

3.1. Limitations of the Research

This thesis dissertation demonstrates that the design of MCS for Risk Management and their implementation through safety leadership are contingent on the contingency factors (contextual variants) of the Facility and the ability of Managers to balance the Ago-Antagonistic Poles within the design of these controls. Several limitations of both theoretical and methodological nature were encountered throughout this study:

Firstly, the immersions within the Nuclear Facilities of the CEA were limited to three Nuclear Facilities which reduces the generalization of the results and decreases the ability to control for multiple factors. Additionally, immersion at Facility E, consisted of an incredibly brief immersion. A longer immersion at this facility as well as additional immersions at other Facilities would have increased the

generalization of the Risk Management models by facilitating additional combinations of contingent variables within other Facilities and extending the current understanding of their role in the design of MCS and choice of Leadership Styles. Such findings could help validate the relationship between organizational contingency factors, leadership style and controls with the aim of preventing and detecting risks.

Secondly, the immersions of each of the Facilities occurred at different times of the lifecycle of the Facility with regards to the transition process between two subcontractors (Facility A at $t=0$ years; Facility B at $t=3$ years; Facility E at $t=1.5$ years). As a result, the data obtained do not reflect the same instant across the lifecycle of all the three Facilities but instead provide an overview of what could be expected in a longitudinal study over the entire lifecycle of a Nuclear Facility.

Thirdly, the interviews were mainly conducted with CEA Managers, and Middle Managers from the subcontracting firm at all three Facilities. However, Subcontractors (OTI-Technical Industrial Operators) were only interviewed at Facility A and Facility B thus limiting the opinions, behaviours and attitudes of the respondents at the subcontractors' level to two facilities. As a result, additional immersion time at Facility E would have provided a broader assessment of the Subcontractor's narration of events at all three Facilities. Particularly, it is conceivable that the subcontractors' perception of control practices at Facility E diverges from the CEA Managers and Middle Managers assessment. Additionally, the interviews conducted at Facility B took place once the changes had already been made to the design of MCS following several events. An immersion prior to the changes would have been an asset to better comprehend the promoting factors and the effects surrounding these changes, beyond the accounts post-facto provided by the interviewees thereby limiting the retrospective bias. Such data would also acquiesce an improved assessment of which strategic combination and order of preventive and detective controls delivers an optimal equilibration of both Ago-antagonistic Poles for a given near miss or event.

Fourthly, the concepts studied in this dissertation were assessed qualitatively. Further development of quantitative measurements of the theoretical constructs (leadership, risk, safety performance) would have permitted such measurements to be evaluated against existing measurement scales; thereby providing a quantitative comparison of the theoretical constructs amongst the three Facilities. Further data would also provide additional information as to the directionality of the relationships of the constructs as well as possible mediating effects between the variables. For example, the design and balance of detective controls with preventive controls are linked to a more transformational leadership style (as seen in Facility B), and the type of leadership style also impacts the design and preference of preventive and detective MCS (as seen with the Transactional leadership style in Facility A).

Fifthly, the interviews and observations were conducted in French which is not the author's native tongue and then translated into English.

Finally, two potential risks that could impact the subcontractor's activities, "*worker polyvalence*"³⁴ and "*mechanical automatism*"³⁵ were not observed at the Facilities but were discussed with subcontractors at Facility A as potential risks that could impact their work. Additionally, it was interesting to note that they could not be categorized into any of the three general subcontracting risks categories discussed within the IOR and ERM literature. These risks were not included in this dissertation as they were not observed at any of the three Facilities, but their potential to yield the same consequences highlights their importance. Additional research on these risks and how to prevent or mitigate them could elucidate the limits of the current risk categories and control-risk couplings. These risks may be related to "*habituation*" described by scholars as: a "*response decrement as a result of repeated stimulation*" (Harris, 1994 in Hollnagel, 2013.p.2), and a "*habit that diminishes conscious attention with which our acts are performed*" (Thompson and Spencer, 1966 in Hollnagel, 2013.p.2). Through habituation, Hollnagel (2013.p.2) explains that "*we learn to disregard things that happen regularly, simply because they happen regularly*".

Despite these limitations, the results of this study support the contingent manner in which contingent variables within the Nuclear Facilities affect the design of MCS and the choice of leadership style employed in the contractor-subcontractor relationship. The Managers that employ Empowerment Leadership Factors (via interactive controls) and that balance the preventive and detective controls as a package throughout the Control Cycle promote safety behaviours and improve Risk Management Practices. Leadership style was found to be influenced by the implications of CEA Managers (linked to the *Organizational Structure, Size and Ratio, Technology* of the Facility) and the manner in which CEA Managers promote *Safety Culture* (linked to *External Environment and Strategies* of the Facility). The aforementioned limitations open new avenues to further research of varying duration (*short-term, medium-term and long-term*) which are detailed in the following sections.

3.2. Avenues for Further Research

This section proposes several suggestions for further research categorized by a varying duration (*short-term, medium-term and long-term*) of the research interest.

³⁴ *Worker polyvalence* may result from accumulation of tasks and responsibilities (operators wearing multiple hats) that may in theory lead to a potential subcontracting risk. This is neither an example of a relational risk, nor a performance risk nor a compliance or regulatory risk in itself but may lead to inadvertent lack of cooperation, an involuntary poor performance and actions that are incompliant with regulations. Specifically: (a) There is no element of poor cooperation from the subcontractor (relational risk) but given the addition of responsibilities the subcontractor may unintentionally give more importance to one task over the other. (b) The subcontractor is capable and competent to perform each of the tasks individually but when accumulated, may result in a performance risk. (c) The aforementioned actions may, individually or combined, yield a disparity from a safety authority regulation and hence present a compliance and regulatory risk.

³⁵ *Mechanical automatism* may result from the automation of daily and repetitive tasks. The use of relay controls in the form of (1) documents with pre-designated stopping points that force the subcontractor to halt production and obtain an additional control and (2) a managerial inspection in real-time that requires a signature to continue the task and minimizes this potential risk. However, not all daily repetitive tasks benefit from a relay control thereby posing potential issues, affirming the importance of additional controls to mitigate such risks.

3.2.1. Short-term Research Interest

This section proposes a short-term research plan that would require several months, as a continuation of the results presented in this dissertation. The first of these suggestions for further research relays the quantitative measurement of numerous constructs within one Facility and across multiple facilities. Further research may quantitatively measure the empowering leader behaviour of both Managers from the contracting firm (CEA Managers) and Managers from the subcontracting firm (Middle Managers) using the Empowerment Leadership Questionnaire (Arnold *et al.*, 2000). Further research would determine a manner to measure Risk Management Performance and contrast this measurement with the quantitative measure of Empowerment Leadership to determine which leadership factors and style appears to be most effective in minimizing risk and maximizing Risk Management Performance. Additionally, the distribution (percentage) of prevention and detection controls in a Facility's Risk Management Strategy can be contrasted with the Facility's Risk Management performance measurement to determine a model for the optimal preventive/detective ratio.

3.2.2. Medium-term Future Research Interests

This section proposes a mid-term research plan of approximately a one-year duration that consists of a comparative case-study of other firms that subcontract within the French Nuclear Energy Sector (EDF, Orano) or other High-Risk Industries (Petrol, Gas). Such research would provide valuable insight as to the replicability of the results across other organizational settings, thereby reinforcing the validation of the models presented in this existing study. Additionally, a comparative study within the Nuclear Energy Sector may further identify contrasting managerial control and leadership practices between the companies thus identifying or clarifying the factors that impact these differences within a similar context. Such research would provide poignant data as to each firm's Risk Management methods or strategies to design, implement and balance the preventive and detective poles or other Ago-antagonistic elements of their Risk Management Processes. This data would allow for comparison with the current findings and determine if the control-risk-leadership framework proposed is universalistic within the High-Risk Industry or rather particular to the CEA.

3.2.3. Long-term Future Research Interests

This section proposes a long-term research plan that complements the research methods and findings of the present study. The individual immersions at the three CEA Facilities took place over a short duration of time and at a varying point of the lifecycle of each Facility. Facilities prove to be resilient as they evolve with challenges (near misses, risks) and nuclear events. The greatest evolution of changes to management practices was observed at Facility B, which was visited at a later stage of the life cycle (t=3 years) compared to the other two facilities (Facility A at t=0 years and Facility E at t=1.5years). Facility E saw a small evolution of MCS with the creation of an inter-organizational communication software system. The implementation of these evolutions in Facility B appears to be due to or facilitated by the participative leadership style (Transformational and Empowerment) which reinforces or is reinforced

by the implication of both CEA and Middle Managers in promoting a safety culture. The strategic role of Middle Managers in facilitating information exchange and supporting knowledge based resources throughout the organization has been discussed by Bieder and Callari (2020), highlighting the Middle Managers' ability to have a strategic influence *vertically* (upwards by championing alternatives to support top management decisions, and downwards by channelling operational needs towards organizational goals), *laterally* (through the exchange of information via formal and informal activities with colleagues and other departments), and *externally* (with suppliers and customers). Numerous internal and external organizational conditions contribute to either support or hinder the middle managers' contribution to safety through "*managing information, making decisions, and influencing others*" (Bieder and Callari, 2020; Callari et al., 2019). As a result, a longitudinal case study of the CEA (with a focus on Middle Managers role in Safety Management) that observes the evolution of MCS and leadership practices over a long duration would track the evolution of control over a Facility's entire life cycle (Davila 2000) and uncover optimal control combinations of preventive and detective controls in light of such organizational conditions. Additionally, the use of an action research methodology within this longitudinal case study would allow the implementation of varying Risk Management Strategies (varying combinations of MCS and methods to balance the controls) in response to events at one or multiple Facilities. The long duration would also provide a period following their implementation to observe the impact of the MCS tools and their effects on the Risk Management Performance of the Facility/Facilities. This study may also elucidate the factors that influence leadership and safety culture (Atwater, Dionne, Avolio, Camobreco, and Lau, 1999; Keller, 2006; Nielsen, Randall, Yarker, and Brenner, 2008) and how they further evolve over time. Particularly as the evolution of management practices (leadership style and types of MCS employed) within all facilities across time may indicate that certain contingency variables (such as size and the activity) may not have a strong influence on management practices, while the context of the nuclear industry may be a stronger influencing variable.

Conclusion

(Résumé en Français)

A la lumière des objectifs spécifiques élaborés dans l'introduction (voir sections 2 et 5), on peut conclure que les **objectifs de cette thèse** ont été atteints. Plus précisément :

Les mécanismes de contrôle utilisés par le CEA pour prévenir et détecter les risques liés à la sous-traitance de quasi-intégration ont été identifiés. Des couplages contrôle-risque spécifiques ont été observés, un contrôle spécifique ou une combinaison de contrôles étant utilisés pour éviter et atténuer des risques spécifiques. Il a été constaté que des contrôles informels (contrôle social) étaient utilisés seuls ou en complément de contrôles formels (contrôle comportemental ou par les résultats) dans le processus de gestion des risques de toutes les installations. La conception spécifique, la mise en œuvre et l'application de ces mécanismes de contrôle dépendaient des particularités et de la combinaison des facteurs de contingence de l'installation (*environnement externe, technologie, structure organisationnelle, taille et ratio, stratégies, culture*). Ces couplages contrôle-risque et la combinaison des facteurs de contingence de l'installation jouent un rôle important dans l'évaluation de la meilleure combinaison de SCG à utiliser pour atténuer les risques liés à la sous-traitance, gérant ainsi la sécurité et les facteurs organisationnels humains.

A la lumière des différentes limitations des mécanismes de contrôle dans le contexte industriel spécifique (les SCG utilisés ne sont pas suffisants pour garantir des comportements de sécurité optimaux des sous-traitants et nécessitent donc la prise en compte d'une autre dimension : le leadership en matière de sécurité), une méthode de conception, de combinaison et de mise en œuvre des SCG "en tant que paquet" pour la gestion des risques a été proposée. L'identification du cycle de contrôle, des deux natures de contrôle (*prévention et détection*) au sein du cycle de contrôle, et de leurs effets temporels dans la prévention et l'atténuation des événements a fourni un modèle plus robuste pour la gestion des risques. En outre, l'utilisation de *systèmes ago-antagonistes*³⁶ pour mettre en parallèle les *contrôles de prévention* et les *contrôles de détection* en tant que deux pôles ago-antagonistes de contrôle, a complété le modèle en modélisant et en équilibrant ces relations de contrôle via cet outil systémique. En conséquence, l'approche proposée conçoit et met en œuvre le SCG pour soutenir le cycle de contrôle en aidant les managers à identifier les déséquilibres ago-antagonistes qui se sont produits et à équilibrer les tensions ago-antagonistes entre les contrôles de prévention et les contrôles de détection, car les changements apportés à un seul ou aux deux contrôles peuvent rééquilibrer le système global.

³⁶ Le terme "*Ago-antagoniste*" est composé de deux termes : *agonistique* qui signifie "effets positifs parallèles" ; et *antagoniste* qui signifie "effets opposés". Ces deux termes, simultanément opposés et complémentaires, semblent à première vue s'exclure l'un l'autre, mais sont en fait indissociables pour la compréhension du phénomène.

Des éléments supplémentaires qui améliorent les comportements de sécurité au-delà de la portée des contrôles de gestion et des procédures de gestion des risques ont été identifiés. Ces éléments, identifiés comme des facteurs de *Leadership par Responsabilisation*, favorisent les comportements positifs en matière de sécurité. Lorsque ces dimensions sont mises en œuvre par les managers à l'unisson avec une combinaison équilibrée de *contrôles de prévention et de détection*, la distance entre les activités du contractant et du sous-traitant est réduite (ce qui réduit les limites du SCG) et renforce la capacité de l'installation à éviter et à atténuer les risques liés à la sous-traitance (quasi-intégration). En outre, *le leadership permet de rééquilibrer les contrôles de prévention et de détection* à la suite de plusieurs événements et quasi-événements au sein des installations nucléaires. Comme pour le style de contrôle, la préférence pour le style de leadership dépend également des particularités des facteurs de contingence de chaque installation.

Une nouvelle approche de la gestion des risques et de la sécurité pour le CEA basée sur la "pensée systémique" englobant les objectifs susmentionnés a été proposée. Cette approche systémique de la gestion des risques applique les principes du *Leadership par Responsabilisation*, à travers un modèle ago-antagoniste, donnant lieu à une approche systémique conjointe du SCG avec une approche systémique du leadership en matière de sécurité via une série de contrôles interactifs. La combinaison appropriée de contrôle et de leadership encourage les nouvelles suggestions en matière de sécurité, renforce l'environnement pour le signalement des quasi-événements ou des événements mineurs, consolide l'engagement de l'organisation en matière de sécurité en responsabilisant les sous-traitants par le biais du partage d'informations, et soutient les sous-traitants dans l'ensemble de l'organisation pour qu'ils signalent continuellement les problèmes de sécurité. Cela encourage les nouvelles idées et initiatives, tout en améliorant la participation et le respect de la sécurité à plusieurs niveaux de l'organisation. Étant donné la nature contextuelle du contrôle et du leadership, cette approche systémique conjointe fournit un modèle général qui peut ensuite être adapté aux facteurs de contingence spécifiques de chaque installation. Les éléments de contrôle et de leadership proposés sont issus des différents styles de leadership et de SCG dans les trois installations du CEA étudiées, qui ont des activités similaires mais varient en termes de configurations managériales, de taille et d'autres facteurs de contingence.

Les principaux résultats de cette thèse peuvent être résumés comme suit :

- De nouvelles définitions³⁷ ont été adaptées à partir de la littérature actuelle sur les SCG, GRE et RIO pour les trois catégories de contrôles de gestion et les trois catégories de risques liés à la sous-traitance, afin de tenir compte des particularités de l'industrie nucléaire française.
- Il existe une préférence pour certains types de contrôles pour atténuer certains types de risques. Ces couplages contrôle-risque mettent en évidence la prédominance du contrôle informel (contrôle social) qui a la capacité d'atténuer les trois catégories de risques liés à la sous-traitance (*risque*

³⁷Voir la section 1.1 et la section 1.3 du chapitre 3 pour les définitions industrielles des risques et des contrôles.

relationnel, risque lié à la performance ou risque de non-conformité) à lui seul ou qui peut *être couplé* aux deux autres types de contrôle (contrôle comportemental ou contrôle par les résultats) pour atténuer efficacement les trois types de risques. Plus précisément, le contrôle social, lorsqu'il est couplé au contrôle comportemental, atténue conjointement les risques relationnels, tandis que le contrôle social et le contrôle par les résultats atténuent le risque lié à la performance. Ce couplage d'un contrôle informel et d'un contrôle formel permet d'obtenir un équilibre entre les contrôles de prévention et les contrôles de détection.

- Les SCG utilisés dans la gestion des risques peuvent être caractérisés selon :
 - (i) Le moment du contrôle (avant, pendant et après la tâche) qui indique le type de contrôle (social, comportemental ou de sortie).
 - (ii) La position (interne/externe) de l'acteur qui exécute la tâche qui indique la nature du contrôle (contrôle par prévention / contrôle par détection)³⁸. Les *contrôles de prévention* évitent les risques et les *contrôles de détection* identifient les écarts et atténuent les risques.
 - (iii) Le niveau du système (sous-traitant, sous-traitant et manager, manager) qui indique le niveau d'interaction des acteurs (autocontrôle, contrôle interactif, ni interactif ni autocontrôle).
- Les contrôles sociaux, qui ont lieu avant l'action, sont *uniquement de prévention*. Les contrôles comportementaux, qui ont lieu pendant l'action, peuvent être à la fois de prévention et de détection en fonction de la position de l'acteur qui exécute la tâche (*de prévention lorsque l'acteur est interne* à la tâche et *de détection lorsque l'acteur est externe à la tâche*). Les contrôles de sortie, qui ont lieu après l'exécution de la tâche, sont *uniquement de détection*.
- Le choix du moment des contrôles est un facteur important de la gestion des risques. Les événements potentiels peuvent être évités au mieux avant la tâche (*contrôle de prévention*) ou pendant la tâche (*contrôle de prévention et/ou contrôle de détection*). En revanche, l'utilisation de contrôles après la tâche (*contrôles de détection*) est efficace pour détecter l'événement, mais est inutile pour prévenir les événements potentiels ou corriger les actions qui ont déclenché l'événement (puisqu'ils ont généralement lieu après l'événement).
- Les *contrôles de prévention et de détection*, selon les 8 caractéristiques principales des systèmes ago-antagonistes, sont deux pôles ago-antagonistes de contrôles. Ils sont *antagonistes* (*actions croisées dans des directions opposées*) dans le timing des contrôles (avant/après la tâche) et la position de l'acteur (interne faisant partie du processus opérationnel /externe ne faisant pas partie du processus opérationnel). Ils sont *agonistes* (*actions parallèles dans la même direction*) avec les efforts conjoints du *régulateur* (contractant) et du *récepteur* (sous-traitant) pour renforcer les pratiques de sécurité et diminuer les risques et les événements. Un équilibre des deux pôles ago-antagonistes est essentiel dans les pratiques de gestion des risques. Le mouvement vers un équilibre des *pôles ago-antagonistes* a été observé suite à plusieurs événements et quasi-événements. Les

³⁸ Voir la section 2.2 du chapitre 3 pour la définition des contrôles de prévention et de détection.

pôles ago-antagonistes déséquilibrés peuvent être rééquilibrés en utilisant des stratégies supplémentaires, des stratégies bipolaires ou des stratégies paradoxales unipolaires.

- Le cycle de contrôle³⁹ explique comment les contrôles suivent un modèle cyclique temporel où un contrôle se fonde dans le suivant :
 - Tout d'abord, les **contrôles sociaux de prévention** (*formations, briefings avant le travail, mise en œuvre du retour d'expérience-REX*) évoquent les exigences de sécurité et encouragent le respect des procédures de sécurité de manière **interactive** et informelle avant la tâche.
 - Ensuite, les **contrôles comportementaux de prévention** (*points d'arrêt, rondes quotidiennes, mensuelles*) sont des **autocontrôles**, où le sous-traitant (interne au processus) utilise les compétences et les connaissances acquises lors des **contrôles sociaux** pour évaluer l'opération pendant la tâche. Les **contrôles comportementaux de détection** (*inspections, audits ou vérification des points d'arrêt*) détectent et arrêtent les comportements à risque grâce à l'échange **interactif** entre le récepteur (interne au processus) et le régulateur (externe à la tâche). Le régulateur peut ainsi informer le récepteur *in-vivo* de tout risque ou écart potentiel pendant la tâche.
 - Les contrôles relais⁴⁰ (*bis*), l'amalgame des **contrôles comportementaux de prévention** (*points d'arrêt*) et **de détection** (*vérification des points d'arrêt*) en un contrôle conjoint, l'équilibre automatique des deux *pôles ago-antagonistes*.
 - Ensuite, les **contrôles par les résultats de détection**, identifient les écarts entre les résultats obtenus et les résultats attendus. Ces contrôles peuvent impliquer uniquement la présence d'un Manager (**non interactif**) ou intégrer également le sous-traitant (**interactif**). Le premier type de contrôle (*suivi des performances*) permet aux managers (du CEA et intermédiaires) de vérifier les résultats de manière indépendante. Le second (*activités de débriefing, retour d'information REX*) offre un moment pour établir un dialogue immédiatement après la tâche entre les managers et les sous-traitants afin de discuter de tout problème observé pendant la tâche (inspection ou autre contrôle comportemental de détection).
 - Enfin, le retour d'expérience (REX) est mis en œuvre lors du prochain **contrôle social de prévention**, ce qui complète le cycle de contrôle et renforce la participation à la sécurité et encourage les comportements de travail sûrs.
- **Lors de la conception et de la mise en œuvre d'une approche systémique de la gestion des risques et du leadership en matière de sécurité, les managers du CEA doivent prendre en compte de nombreux éléments interconnectés dans la conception et la mise en œuvre du SCG qui ont été divisés ci-dessous en deux catégories (éléments relatifs à la conception et éléments relatifs à la mise en œuvre de la conception) :**

³⁹ Voir la section 2.6 du chapitre 3 pour le cycle de contrôle.

⁴⁰ Voir la section 2.8 du chapitre 3 pour plus d'informations sur les commandes de relais.

En ce qui concerne la conception, les managers du CEA devraient prendre en compte les éléments suivants :

- Identifier les **types de risques liés à la sous-traitance** présents dans l'installation et le **couple contrôle-risque approprié** (pouvant inclure des contrôles multiples) pour éviter et atténuer ces risques. Il peut s'agir de contrôles multiples tels que la **combinaison de contrôles sociaux et d'un contrôle formel (contrôle comportemental ou par les résultats) en fonction du type de risque**.
- Employer une combinaison de **contrôles formels et informels qui "s'adapte" à la combinaison des facteurs d'imprévus de l'installation** (voir le tableau 19 pour un résumé).
- La mise en œuvre des **contrôles sociaux sur une base quotidienne ou régulière en tant que paquet** pour promouvoir une relation adéquate entre le contractant et le sous-traitant afin d'établir une culture de sécurité commune.
- Identifier la **nature (contrôles de prévention et de détection)** de chaque SCG, leur rôle dans le cycle de contrôle et la manière dont un contrôle se fonde dans le suivant (en tant que paquet).
- S'assurer que les informations provenant des contrôles formels interactifs pendant la tâche et du retour d'expérience après la tâche sont incorporées dans les contrôles sociaux (le jour suivant ou avant la prochaine tâche), assurant ainsi la **continuité de la boucle de contrôle**.
- Assurer l'**équilibre des pôles ago-antagonistes de prévention et de détection** par l'équilibrage d'un contrôle de prévention (contrôles sociaux ou contrôles comportementaux de prévention) et d'un contrôle de détection (contrôles comportementaux de détection, contrôles par les résultats). Les contrôles relais, qui sont une combinaison d'un contrôle comportemental de prévention et d'un contrôle comportemental de détection, équilibrent automatiquement ces tensions.
- Recourir à des stratégies de rééquilibrage (stratégies de complément, stratégies bipolaires ou stratégies paradoxales unipolaires) en cas de déséquilibre suite à un événement (voir figure 56).
 - **Si l'événement a eu lieu**, les **contrôles de détection** présents ont été inefficaces, car les écarts n'ont pas été détectés. Il est recommandé d'adopter une **stratégie bipolaire** consistant à renforcer à la fois les **contrôles de prévention** et les **contrôles de détection**, car il est possible que les **contrôles de prévention** aient également été inefficaces.
 - **Si l'événement ne s'est pas produit mais que l'écart a été détecté**, deux lignes d'action sont alors possibles : La première est une **stratégie de complément** dans laquelle seuls les **contrôles de prévention** sont augmentés car les **contrôles de détection** ont été efficaces pour détecter l'écart. La deuxième option est la **stratégie paradoxale unipolaire** par laquelle la variété des **contrôles de détection** (malgré leur efficacité) augmentent pour compenser les **contrôles de prévention** non fonctionnels. Dans ce cas, un autre **contrôle de prévention** plus efficace peut être conçu en réaction et mis en œuvre ultérieurement.

En ce qui concerne la mise en œuvre du SCG, les managers du CEA devraient considérer les éléments suivants :

- Employer le *style de leadership qui "correspond" à la combinaison des facteurs de contingence de l'installation (voir le tableau 19 pour un aperçu).*
- Promouvoir les cinq principes du *Leadership par Responsabilisation* par l'utilisation de contrôles interactifs (contrôles sociaux, contrôles comportementaux de prévention et de détection, et contrôles interactifs de sortie) permettant ainsi de responsabiliser les sous-traitants et les managers intermédiaires en :
 - o *donnant l'exemple* et en démontrant leur engagement en matière de sécurité
 - o communiquant les problèmes de sécurité ou les domaines qui nécessitent un *encadrement*
 - o *informant et* renforçant la sécurité organisationnelle par la connaissance et la formation
 - o augmentant *l'interaction avec les employés*, ce qui permet aux sous-traitants d'exprimer des suggestions en matière de sécurité et de signaler les évènements évités de justesse ou les évènements mineurs,
 - o augmentant la *prise de décision participative*, améliorant ainsi les comportements de participation à la sécurité et la conformité des pratiques de sécurité à travers les multiples niveaux du système de l'organisation.
- En promouvant les 5 dimensions du leadership, les managers du CEA et les managers intermédiaires peuvent détecter les comportements ou les résultats inadéquats en matière de sécurité (par le biais du SCG) et les transformer en utilisant des pratiques de leadership en matière de sécurité, favorisant ainsi l'existence d'une "entité contractant-sous-traitant unie" qui renforce les échanges descendants et ascendants au sein de la structure organisationnelle. Les managers intermédiaires agissent alors en tant qu'ambassadeurs dans cette unité contractant-sous-traitant. Cela permet de :
 - réduire la distance entre les sous-traitants et les managers du CEA,
 - réduire les risques de sous-traitance liés à l'asymétrie d'information,
 - établir des qualités de leadership et des comportements de sécurité positifs via une "perspective de leadership pluriel" (Denis, Langley et Sergi, 2012),
 - surmonter certaines des limites du contrôle de la qualité, afin de parvenir à un contrôle efficace de la qualité dans le cadre des exigences en constante évolution de l'industrie nucléaire.

Conclusion

In light of the Specific Objectives elaborated in the Introduction (see sections 2 and 5), it can be concluded that the **objectives of this dissertation** were accomplished. Specifically:

The Mechanisms of Control used by the CEA to avert and detect risks related to quasi-integration subcontracting were identified. Specific control-risk couplings were observed whereby a specific control, or a combination of controls were used to avert and mitigate specific risks. Informal controls (Social Control) were found to be used on their own or in complement with Formal controls (Behaviour or Output Control) in the Risk Management process of all facilities. The specific design, implementation, and enforcing of these control mechanisms was contingent on the particularities and the combination of the Facility's contingency factors (*external environment, technology, organizational structure, size and ratio, strategies, culture*). These control-risk couplings and the combination of contingency factors of the facility play an important role in assessing the best combination of MCS to use to mitigate the subcontracting-related risks thereby managing safety and Human Organizational Factors.

In light of the different limitations of the control mechanisms within the specific industrial context (MCS used are not enough to ensure optimal safety behaviours of subcontractors and hence require taking into account another dimension: safety leadership) a method to design, combine and implement MCS “as a package” for Risk Management was proposed. The identification of the control cycle, the two natures of control (*Prevention and Detection*) within the control cycle, and their temporal effects in averting and mitigating events provided a more robust Model for Risk Management. Additionally, the use of *Ago-Antagonistic Systems*⁴¹ to parallel *Preventive Controls* and *Detective Controls* as two ago-antagonistic poles of Control, further complemented the model by modelling and balancing these control relationships via this systemic tool. As a result, the proposed approach designs and implements MCS to support the cycle of control by supporting Managers to identify when ago-antagonistic imbalances have occurred and balance ago-antagonistic tensions between preventive and detective controls, as changes on a single or both controls may rebalance the overall system.

Additional elements that enhance safety behaviours beyond the scope of Management Controls and Risk Management procedures were identified. These elements identified as Empowerment Leadership Factors promote positive safety behaviours. When these dimensions of Empowerment are implemented by Leaders (Managers) in unison with a balanced combination of *preventive and detective controls*, the distance between the contractor-subcontractor business is reduced (which reduces the limits of MCS) and fortifies the Facility's capability of averting and mitigating subcontracting (quasi-integration) related risks. Additionally, *Empowerment Leadership*, appears to be a gearshift for several

⁴¹ The term “*Ago-antagonistic*” is composed of two terms: *agonistic* meaning “parallel positive effects”; and *antagonistic* meaning “opposite effects”. These two terms that are simultaneously opposite and complementary, and at first glance appear to exclude one another, but are in fact indissociable to the understanding of the phenomenon.

changes to rebalance *Preventive and Detective Controls* following several events and near misses within the Nuclear Facilities. As with control style, the leadership style preference is also contingent on the particularities of each Facility's contingency factors.

A new approach to Risk Management and Safety Management for the CEA based on “Systems thinking” encompassing the aforementioned objectives was proposed. This systemic approach to Risk Management applies principles of Empowerment Leadership, through an ago-antagonistic model, yielding a joint systemic approach to MCS with a systemic approach to safety leadership via a series of interactive controls. The appropriate combination of control and leadership encourages new safety suggestions, reinforces the environment for reporting near-misses or minor occurrences, fortifies the organization's commitment to safety by empowering subcontractors through information sharing, and supports subcontractors throughout the organization to continuously report safety concerns. This encourages new ideas and initiatives, while improving safety participation and compliance at multiple levels of the organization. Given the contextual nature of both control and leadership, this joint systemic approach provides a general model that can then be adapted to “fit” the specific contingency factors of each Facility. These proposed control and leadership elements originate from the contrasting leadership and MCS styles in the three CEA Facilities studied that execute similar subcontracting activities but vary in managerial configurations, size and other contingency factors.

The main results of this dissertation can be summarized as follows:

- New definitions⁴² were adapted from the current MCS, ERM, and IOR literature of the three categories of Management Controls and the three categories of subcontracting-related risks, to account for the particularities of the French Nuclear Industry.
- There is a preference for certain types of controls to mitigate certain types of risks. These Control-risk couplings highlight the predominance of informal control (Social controls) which have the capacity to mitigate all three categories of subcontracting-related risk (*relational risk, performance risk or compliance and regulatory risk*) **on their own** or can **be coupled** with the other two types of control (Behaviour Control or Output Control) to effectively mitigate all three types of risks. Specifically, Social control, when coupled with behaviour control, jointly mitigates relational risks, while social and output control mitigates performance risk. This coupling of an informal and a formal control yields a balance of preventive and detective controls.
- MCS used in Risk Management can be characterized according to:
 - (i) The timing of the control (before, during and after the task) indicates the type of control (social, behavioural or output).

⁴²See Section 1.1 and Section 1.3 of Chapter 3 for the industrial definitions of the risks and the controls.

- (ii) The position (internal/external) of the actor performing the task that indicates the nature of the control (Control by Prevention / Control by Detection)⁴³. **Controls for prevention** avert risks and **Controls for detection** identify deviations and mitigate risks.
 - (iii) The system level (subcontractor, subcontractor and Manager, Manager) that indicates the level of interaction of the actors (Auto-control, Interactive Control, neither interactive nor auto-control).
- Social controls, which take place prior to the action, are **solely preventive in nature**. Behaviour controls, which occur during the action, can be both preventive and detective in nature depending on the position of the actor performing the task (**preventive when the actor is internal** to the task and **detective when the actor is external to the task**). Output controls, which take place after the task, are **solely detective in nature**.
 - The timing of controls is an important factor in Risk Management. Potential events can best be averted prior to the task (*preventive control*) or during the task (*preventive control and/or detective control*). However, the use of controls after the task (*detective controls*) are effective in detecting the event, but are futile to prevent potential events or correct the actions that set the event into motion (since they generally take place after the event).
 - *Preventive and detective controls*, according to the 8 principal characteristics of Ago-antagonistic Systems, are two ago-antagonistic poles of controls. They are **antagonistic** (*crossed actions in opposite directions*) in the timing of the controls (before/after the activity) and the position of the actor (internal and part of the operating process/ external and not part of the operating process). They are **agonistic** (*parallel actions in the same direction*) with the joint efforts of the **regulator** (contractor) and the **receptor** (subcontractor) to strengthen safety practices and to decrease risks and events. A balance of both ago-antagonistic poles is essential in Risk Management practices as the movement towards a balance of *ago-antagonistic poles* was observed following several events and near misses. Unbalanced ago-antagonistic poles can be rebalanced using supplementary strategies, bipolar strategies or unipolar paradoxical strategies.
 - The Cycle of Control⁴⁴ elucidates how controls follow a temporal cyclical pattern where one control merges into the next:
 - First, **Preventive Social Controls** (*trainings, pre-job briefings, implementation of Return of Experience -REX*) evoke safety requirements and encourage compliance with safety procedures in an informal **interactive** manner before the task.

⁴³ See section 2.2 of Chapter 3 for the definition of Preventive and Detective Control.

⁴⁴ See Section 2.6 of Chapter 3 for the Cycle of Control.

- Next, **Preventive Behaviour Controls** (*stop-points, daily, monthly rounds*) are **auto-controls**, where the subcontractor (internal to the process) uses the skills and knowledge obtained during the **social controls** to evaluate the operation during the task. **Detective Behaviour Controls** (*inspections, audits or the verification of the stop points*) detect and halt risky behaviours through the **interactive** exchange between the receptor (internal to the process) and the regulator (external to the task). This allows the regulator to inform the receptor *in-vivo* of any potential risks or deviations during the task.
 - Relay⁴⁵ (*bis*) controls, the amalgamation of **Preventive (stop points)** and **Detective Behaviour Controls (verification of the stop points)** into a joint control, the automatic balance of both *ago-antagonistic poles*.
 - Then, **Detective Output Controls** identify discrepancies between the results obtained and the expected results. These controls can involve solely the presence of a regulator or Manager (**non-interactive**) or also incorporate the receptor or subcontractor (**interactive**). The former (*performance tracking*) allows Managers to independently verify the results. The latter (*debriefing activities, REX feedback*) provides a moment to establish a dialogue immediately after the task between Managers and subcontractors to discuss any concerns observed during the task (inspection or other Detective Behaviour Control).
 - Finally, REX feed-back is implemented during the next **Preventive Social Control** completing the cycle of control and enhancing safety participation and fostering safe work behaviours.
- **In designing and implementing a systemic approach to Risk Management and Safety Leadership, CEA Managers need to consider numerous interconnected elements in the design and the implementation of MCS that have been divided below into two categories (*elements pertaining to the design and elements pertaining to the design's implementation*):**

With regards to the design, CEA Managers should consider:

- Identifying the **types of Subcontracting-related risks** present in the facility and the **appropriate control-risk couple** (may include multiple controls) to avert and mitigate these risks. This may include multiple controls such as the combination of social controls and a formal control (Behaviour or Output Control) depending on the type of Risk.
- Employing a combination of formal and informal **controls that “fits” the combination of the Facility's contingency factors** (see Table 19 for a summary).
- Implementing **Social Controls on a daily or regular basis as a package** to promote a united contractor-subcontractor business entity with a common Safety Culture.
- Identifying the **nature (preventive and detective controls)** of each MCS, their role within the Control Cycle and how one control merges into the next (as a package)

⁴⁵ See Section 2.8 of Chapter 3 for more information on Relay Controls.

- Ensuring that the information from the interactive formal controls during the task and the return of experience after the task are incorporated into the social controls (the next day or before the next task) thus ensuring a *continuation of the control loop*.
- Ensuring a *balance in the preventive and detective ago-antagonistic poles* by equilibration of a preventive control (social controls or preventive behaviour controls) and a detective control (detective behaviour control, output controls). Relay controls, which are a combination of a preventive and a detective behaviour control, automatically balance these tensions.
- Employing re-balancing strategies (supplementary strategies, bipolar strategies or unipolar paradoxical strategies) in the case of an imbalance following an event (see Figure 56).
 - *If the event took place*, the *detective controls* present were ineffective, as the disparities were not detected. A *bipolar strategy* is recommended where both *preventive* and *detective controls* are augmented, as the *preventive controls* were possibly also ineffective.
 - *If the event did not occur but the disparity was detected*, then two courses of action are possible: The first is a *supplement strategy* whereby only *preventive controls* are augmented as the *detective controls* were effective in detecting the disparity. Alternatively, the second option is the *unipolar paradoxical strategy* whereby a variety of *detective controls* (despite their effectiveness) are augmented to compensate for the non-functional *preventive controls*. In this case, an alternative more-efficient *preventive control* can be designed and implemented at a later time.

With regards to the implementation of the MCS, CEA Managers should consider:

- Employing the *Leadership Style that “fits” the combination of the Facility’s contingency factors* (see Table 19 for an overview).
- Promoting the five principles of *Empowerment Leadership* through the use of interactive controls (Social controls, Preventive and Detective Behaviour Controls, and Interactive Output Controls) thus empowering Subcontractors and Middle Managers by:
 - *leading by example* and demonstrating their commitment to safety
 - communicating safety concerns or areas that require *coaching*
 - *informing and reinforcing* organizational safety through knowledge and education
 - *increasing interaction with employees* thus allowing subcontractors to voice safety suggestions and report near misses or minor events,
 - increasing *participative decision making*, thus enhancing safety participation behaviours and compliance of safety practices across multiple system levels of the organization.
- By promoting the 5 dimensions of empowered leaders, both CEA Managers and Middle Managers can detect inadequate safety behaviours or results (through MCS) and transform them using safety leadership practices, thereby encouraging a “united contractor-subcontractor entity” that reinforces descending and ascending exchanges within the organizational structure. Empowered Middle

Managers act as ambassadors in this contractor-subcontractor business unit thereby:

- reducing the distance between the subcontractors and CEA Managers
- reducing subcontracting-risks related to information asymmetry
- establishing positive leadership qualities and safety behaviours via a “plural leadership perspective” (Denis, Langley and Sergi, 2012)
- overcoming some of the limits of MCS, thereby achieving effective MCS in the ever-changing demands of the nuclear industry

Bibliography

- Abdel-Kader, M., & Luther, R. (2008). The impact of firm characteristics on management accounting practices: A UK-based empirical analysis. *The British Accounting Review*, 40(1), 2–27.
- Abernethy, M. A., & Brownell, P. (1997). Management control systems in research and development organizations: The role of accounting, behavior and personnel controls. *Accounting, Organizations and Society*, 22(3–4), 233–248.
- Abernethy, M. A., & Brownell, P. (1999). The role of budgets in organizations facing strategic change: An exploratory study. *Accounting, Organizations and Society*, 24(3), 189–204. [https://doi.org/10.1016/S0361-3682\(98\)00059-2](https://doi.org/10.1016/S0361-3682(98)00059-2)
- Abernethy, M. A., & Chua, W. F. (1996). A Field Study of Control System “Redesign”: The Impact of Institutional Processes on Strategic Choice*. *Contemporary Accounting Research*, 13(2), 569–606. <https://doi.org/10.1111/j.1911-3846.1996.tb00515.x>
- Abernethy, M. A., & Lillis, A. M. (1995). The impact of manufacturing flexibility on management control system design. *Accounting, Organizations and Society*, 20(4), 241–258.
- Adams, J. (1999). The management of risk and uncertainty. *Policy Analysis*, 355.
- Ahrens, T., & Chapman, C. S. (2004). Accounting for flexibility and efficiency: A field study of management control systems in a restaurant chain. *Contemporary Accounting Research*, 21(2), 271–301.
- Alvesson, M., & Kärreman, D. (2004). Interfaces of control. Technocratic and socio-ideological control in a global management consultancy firm. *Accounting, Organizations and Society*, 29(3–4), 423–444.
- Amat, J.M. (1991). *Los sistemas de control en las empresas de alta tecnología: El caso de dos empresas del sector químico-farmacéutico*. Ministerio de Economía y Competitividad. <https://dialnet.unirioja.es/servlet/libro?codigo=15912>
- Anderson, S. W., Christ, M. H., Dekker, H. C., & Sedatole, K. L. (2014). The Use of Management Controls to Mitigate Risk in Strategic Alliances: Field and Survey Evidence. *Journal of Management Accounting Research*, 26(1), 1–32. <https://doi.org/10.2308/jmar-50621>
- Anthony, R. N. (1965). *Planning and Control Systems: A Framework for Analysis* (First Edition edition). Division of Research, Harvard Business School.
- Anthony, R. N., & Govindarajan, V. (2001). *Management Control Systems*, 10. Auflage, New York et Al.
- Arnold, J. A., Arad, S., Rhoades, J. A., & Drasgow, F. (2000). The empowering leadership questionnaire: The construction and validation of a new scale for measuring leader behaviors. *Journal of Organizational Behavior*, 21(3), 249–269. [https://doi.org/10.1002/\(SICI\)1099-1379\(200005\)21:3<249::AID-JOB10>3.0.CO;2-#](https://doi.org/10.1002/(SICI)1099-1379(200005)21:3<249::AID-JOB10>3.0.CO;2-#)
- Arnold, R. D., & Wade, J. P. (2015). A Definition of Systems Thinking: A Systems Approach. *Procedia Computer Science*, 44, 669–678. <https://doi.org/10.1016/j.procs.2015.03.050>
- Ashby, W. R. (1961). *An introduction to cybernetics*. Chapman & Hall Ltd.
- Auzair, S. M., Amiruddin, R., Majid, A. A., & Maelah, R. (2013). Linking Business Strategy to Management Accounting: A Study in Malaysian Service Organizations. *Jurnal Pengurusan*, 37.
- Baines, A., & Langfield-Smith, K. (2003). Antecedents to management accounting change: A structural equation approach. *Accounting, Organizations and Society*, 28(7), 675–698. [https://doi.org/10.1016/S0361-3682\(02\)00102-2](https://doi.org/10.1016/S0361-3682(02)00102-2)
- Baird, I. S., & Thomas, H. (1990). What is risk anyway? Using and measuring risk in strategic management. *Risk, Strategy, and Management*, 5, 21–54.
- Bannister, J. E., & Bawcutt, P. A. (1981). *Practical risk management*. Witherby.

- Barley, S. R., Meyer, G. W., & Gash, D. C. (1988). Cultures of culture: Academics, practitioners and the pragmatics of normative control. *Administrative Science Quarterly*, 24–60.
- Baudry, B. (2013). Quasi-intégration et relation de sous-traitance industrielle: Une évaluation des travaux de Jacques Houssiaux. *Revue d'économie industrielle*, 142, 11–39.
- Baumgartner, E., & Ménard, P. (1996). *Dictionnaire étymologique et historique de la langue française (Les Usuels de Poche)*. La Pochothèque.
- Beasley, M., Branson, B., & Hancock, B. (2010). Report on the current state of enterprise risk oversight. *The ERM Initiative at North Carolina State University, Raleigh, NC*.
- Beasley, M. S., Clune, R., & Hermanson, D. R. (2005). Enterprise risk management: An empirical analysis of factors associated with the extent of implementation. *Journal of Accounting and Public Policy*, 24(6), 521–531. <https://doi.org/10.1016/j.jaccpubpol.2005.10.001>
- Bedford, D. S., & Malmi, T. (2015). Configurations of control: An exploratory analysis. *Management Accounting Research*, 27, 2–26.
- Bedford, D. S., Malmi, T., & Sandelin, M. (2016). Management control effectiveness and strategy: An empirical analysis of packages and systems. *Accounting, Organizations and Society*, 51, 12–28. <https://doi.org/10.1016/j.aos.2016.04.002>
- Bernard-Weil, E. (1992). Agonistic Antagonistic Systemics: An Introduction To Bilateral — and Paradoxically Unilateral — Strategies. *Kybernetes*, 21(4), 47–66. <https://doi.org/10.1108/eb005935>
- Bernard-Weil, E. (1999). La théorie des systèmes ago-antagonistes. *Le Débat*, 106(4), 106. <https://doi.org/10.3917/deba.106.0106>
- Bernard-Weil, E. (2002). Approche des systèmes ago-antagonistes. *Techniques de l'ingénieur. L'Entreprise Industrielle*, AG1575, AG1575-1.
- Bernard-Weil, E. (2003a). Ago-antagonistic systems. In *Quantum mechanics, mathematics, cognition and action* (pp. 325–348). Springer.
- Bernard-Weil, E. (2003b). *Theorie et Praxis des Systemes Ago-Antagonistes*. 11.
- Bernard-Weil, E., Duvelleroy, M., & Droulez, J. (1975). Analogical study of a model for the regulation of ago-antagonistic couples. Application to adrenal-postpituitary interrelationships. *Mathematical Biosciences*, 27(3–4), 333–348.
- Berry, A. J., Coad, A. F., Harris, E. P., Otley, D. T., & Stringer, C. (2009). Emerging themes in management control: A review of recent literature. *The British Accounting Review*, 41(1), 2–20. <https://doi.org/10.1016/j.bar.2008.09.001>
- Berry, A. J., Collier, P. M., & Helliard, C. (2005). Risk and control: The control of risk and the risk of control. *Management Control: Theories, Issues and Performance*, 279–299.
- Bettis, R. A., & Thomas, H. (1990). Risk, Strategy, and Management. *Research Collection Lee Kong Chian School Of Business*. https://ink.library.smu.edu.sg/lkcsb_research/4003
- Bhimani, A. (1999). Mapping methodological frontiers in cross-national management control research. *Accounting, Organizations and Society*, 24(5–6), 413–440.
- Bhimani, A. (2003). A study of the emergence of management accounting system ethos and its influence on perceived system success. *Accounting, Organizations and Society*, 28(6), 523–548. [https://doi.org/10.1016/S0361-3682\(02\)00025-9](https://doi.org/10.1016/S0361-3682(02)00025-9)
- Bhimani, A. (2009). Risk management, corporate governance and management accounting: Emerging interdependencies. *Management Accounting Research*, 20(1), 2–5. <https://doi.org/10.1016/j.mar.2008.11.002>
- Bijlsma-Frankema, K., & Koopman, P. (2004). The oxymoron of control in an era of globalisation. *Journal of Managerial Psychology*.
- Bisbe, J., Batista-Foguet, J.-M., & Chenhall, R. (2007). Defining management accounting constructs: A methodological note on the risks of conceptual misspecification. *Accounting, Organizations and Society*, 32(7–8), 789–820.

- Bisbe, J., & Otley, D. (2004). The effects of the interactive use of management control systems on product innovation. *Accounting, Organizations and Society*, 29(8), 709–737. <https://doi.org/10.1016/j.aos.2003.10.010>
- Bleeke, J., & Ernst, D. (1990). The way to win in cross-border alliances. *Harvard Business Review*, 69(6), 127–135.
- Blois, K. J. (1972). Vertical Quasi-Integration. *The Journal of Industrial Economics*, 20(3), 253–272. <https://doi.org/10.2307/2098058>
- Bonner, S. E., & Sprinkle, G. B. (2002). The effects of monetary incentives on effort and task performance: Theories, evidence, and a framework for research. *Accounting, Organizations and Society*, 27(4–5), 303–345.
- Bourrier, M. (1999). *Le Nucléaire à l'épreuve de l'organisation*. PUF.
- Bromiley, P., McShane, M., Nair, A., & Rustambekov, E. (2015). Enterprise Risk Management: Review, Critique, and Research Directions. *Long Range Planning*, 48(4), 265–276. <https://doi.org/10.1016/j.lrp.2014.07.005>
- Brooks, D. W. (2009). Creating a risk-aware culture. *Enterprise Risk Management*, 87–95.
- Brownell, P. (1983). Leadership style, budgetary participation and managerial behavior. *Accounting, Organizations and Society*, 8(4), 307–321.
- Brownell, P. (1985). Budgetary systems and the control of functionally differentiated organizational activities. *Journal of Accounting Research*, 502–512.
- Bruns, W. J., & Waterhouse, J. H. (1975). Budgetary control and organization structure. *Journal of Accounting Research*, 177–203.
- Burns, J., & Scapens, R. W. (2000). Conceptualizing management accounting change: An institutional framework. *Management Accounting Research*, 11(1), 3–25.
- Burns, T., & Stalker, G. M. (1961). *The management of innovation*. London (Vol. 62).
- Caglio, A., & Ditillo, A. (2008). A review and discussion of management control in inter-firm relationships: Achievements and future directions. *Accounting, Organizations and Society*, 33(7–8), 865–898. <https://doi.org/10.1016/j.aos.2008.08.001>
- Carenys, J. (2010). Management control systems: A historical perspective. *International Bulletin of Business Administration*, 7(1), 37–54.
- Chaillou, B. (1977). Définition et typologie de la sous-traitance. *Revue Économique*, 28(2), 262–285. <https://doi.org/10.2307/3501059>
- Chapman, C. S. (1997). Reflections on a contingent view of accounting. *Accounting, Organizations and Society*, 22(2), 189–205.
- Checkland, P. (1981). *Systems thinking, systems practice* Wiley.
- Chenhall, R. H. (1986). Authoritarianism and participative budgeting: A dyadic analysis. *Accounting Review*, 263–272.
- Chenhall, R. H. (1997). Reliance on manufacturing performance measures, total quality management and organizational performance. *Management Accounting Research*, 8(2), 187–206.
- Chenhall, R. H. (2003). Management control systems design within its organizational context: Findings from contingency-based research and directions for the future. *Accounting, Organizations and Society*, 28(2–3), 127–168. [https://doi.org/10.1016/S0361-3682\(01\)00027-7](https://doi.org/10.1016/S0361-3682(01)00027-7)
- Chenhall, R. H. (2006). Theorizing contingencies in management control systems research. *Handbooks of Management Accounting Research*, 1, 163–205.
- Chenhall, R. H., & Langfield-Smith, K. (1998). The relationship between strategic priorities, management techniques and management accounting: An empirical investigation using a systems approach. *Accounting, Organizations and Society*, 23(3), 243–264.

- Chenhall, R. H., & Langfield-Smith, K. (2003). Performance Measurement and Reward Systems, Trust, and Strategic Change. *Journal of Management Accounting Research*, 15(1), 117–143. <https://doi.org/10.2308/jmar.2003.15.1.117>
- Chenhall, R. H., & Morris, D. (1986). The impact of structure, environment, and interdependence on the perceived usefulness of management accounting systems. *Accounting Review*, 16–35.
- Chenhall, R. H., & Morris, D. (1995). Organic decision and communication processes and management accounting systems in entrepreneurial and conservative business organizations. *Omega*, 23(5), 485–497.
- Chikere, C. C., & Nwoka, J. (2015). The systems theory of management in modern day organizations- A study of Aldgate congress resort limited Port Harcourt. *International Journal of Scientific and Research Publications*, 5(9), 1–7.
- Chong, V. K., & Chong, K. M. (1997). Strategic choices, environmental uncertainty and SBU performance: A note on the intervening role of management accounting systems. *Accounting and Business Research*, 27(4), 268–276.
- Christ, M. H., Mintchik, N., Chen, L., & Bierstaker, J. L. (2014). Outsourcing the Information System: Determinants, Risks, and Implications for Management Control Systems. *Journal of Management Accounting Research*, 27(2), 77–120. <https://doi.org/10.2308/jmar-50847>
- Collier, P. M. (2005). Entrepreneurial control and the construction of a relevant accounting. *Management Accounting Research*, 16(3), 321–339.
- Collier, P. M., & Berry, A. J. (2002). Risk in the process of budgeting. *Management Accounting Research*, 13(3), 273–297.
- Cooper, M., & Finley, L. (2013). Strategic safety culture road map. *Franklin, IN: BSMS*.
- Cooper, R., & Slagmulder, R. (2004). Interorganizational cost management and relational context. *Accounting, Organizations and Society*, 29(1), 1–26.
- Corbel, P., Denis, J.-P., & Payaud, M. A. (2007). *Ago-antagonisme positivisme/constructivisme: Quelques formes de travail épistémique*.
- Corbel, P., & Terziovski, M. (2008). Organizational excellence, knowledge and the theory of the firm: To what extent can we build on the Knowledge-Based View of the firm? *THE THEORIES AND PRACTICES OF ORGANIZATION EXCELLENCE: NEW PERSPECTIVES*, 177.
- Coso, I. (2004). Enterprise risk management-integrated framework. *Committee of Sponsoring Organizations of the Treadway Commission*, 2.
- Cowton, C. J., & Dopson, S. (2002). Foucault's prison? Management control in an automotive distributor. *Management Accounting Research*, 13(2), 191–213. <https://doi.org/10.1006/mare.2001.0173>
- Currie, W. L. (1998). Using multiple suppliers to mitigate the risk of IT outsourcing at ICI and Wessex Water. *Journal of Information Technology*, 13(3), 169–180.
- Dambrin, C. (2005). *Le Contrôle à distance ou l'autocontrôle par les technologies: Le cas des commerciaux* [Université Paris Dauphine-Paris IX]. <https://tel.archives-ouvertes.fr/tel-00472687/>
- D'arcy, S. P., & Brogan, J. C. (2001). Enterprise risk management. *Journal of Risk Management of Korea*, 12(1), 207–228.
- Das, T. K., & Teng, B.-S. (1996). RISK TYPES AND INTER-FIRM ALLIANCE STRUCTURES*. *Journal of Management Studies*, 33(6), 827–843.
- Das, T. K., & Teng, B.-S. (1998). Between Trust and Control: Developing Confidence in Partner Cooperation in Alliances. *Academy of Management Review*, 23(3), 491–512. <https://doi.org/10.5465/AMR.1998.926623>
- Das, T. K., & Teng, B.-S. (1999). Managing risks in strategic alliances. *The Academy of Management Executive*, 13(4), 50–62. <https://doi.org/10.5465/AME.1999.2570554>

- Das, T. K., & Teng, B.-S. (2000). A Resource-Based Theory of Strategic Alliances. *Journal of Management*, 26(1), 31–61. <https://doi.org/10.1177/014920630002600105>
- Das, T. K., & Teng, B.-S. (2001a). Trust, Control, and Risk in Strategic Alliances: An Integrated Framework. *Organization Studies*, 22(2), 251–283. <https://doi.org/10.1177/0170840601222004>
- De Rosnay, J. (1975). *Le macrocosme: Vers une vision globale*. Éditions du Seuil.
- De Rosnay, J. (2014). *Le macroscope. Vers une vision globale*. Le seuil.
- Dekker, H. C. (2004). Control of inter-organizational relationships: Evidence on appropriation concerns and coordination requirements. *Accounting, Organizations and Society*, 29(1), 27–49. [https://doi.org/10.1016/S0361-3682\(02\)00056-9](https://doi.org/10.1016/S0361-3682(02)00056-9)
- Denis, J.-L., Langley, A., & Sergi, V. (2012). Leadership in the Plural. *The Academy of Management Annals*, 6(1), 211–283. <https://doi.org/10.1080/19416520.2012.667612>
- Dent, J. F. (1990). Strategy, organization and control: Some possibilities for accounting research. *Accounting, Organizations and Society*, 15(1–2), 3–25.
- Dickinson, G. (2001). Enterprise risk management: Its origins and conceptual foundation. *The Geneva Papers on Risk and Insurance. Issues and Practice*, 26(3), 360–366.
- Donaldson, L. (1987). Strategy and structural adjustment to regain fit and performance: In defence of contingency theory. *Journal of Management Studies*, 24(1), 1–24.
- Donaldson, L. (1995). *Contingency theory* (Issue 9). Dartmouth Publishing Company.
- Donaldson, L. (2001). *The contingency theory of organizations*. Sage.
- Donnadieu, G., & Karsky, M. (2002). Systemic: Think and act in complexity. *Liaisons*.
- Drazin, R., & Van de Ven, A. H. (1985). Alternative forms of fit in contingency theory. *Administrative Science Quarterly*, 514–539.
- Dubois, A., & Gadde, L.-E. (2002). Systematic combining: An abductive approach to case research. *Journal of Business Research*, 55(7), 553–560. [https://doi.org/10.1016/S0148-2963\(00\)00195-8](https://doi.org/10.1016/S0148-2963(00)00195-8)
- Dubois, A., & Gadde, L.-E. (2014). “Systematic combining”—A decade later. *Journal of Business Research*, 67(6), 1277–1284. <https://doi.org/10.1016/j.jbusres.2013.03.036>
- Dumez, H. (2016). *Méthodologie de la recherche qualitative: Les questions clés de la démarche compréhensive*. Vuibert.
- Dunk, A. S. (1993). The effect of budget emphasis and information asymmetry on the relation between budgetary participation and slack. *Accounting Review*, 400–410.
- Durand, D. (2006). *La systémique* (10e éd.). Paris: Presses Universitaires de France (PUF).
- Efferin, S., & Hopper, T. (2007). Management control, culture and ethnicity in a Chinese Indonesian company. *Accounting, Organizations and Society*, 32(3), 223–262.
- Eisenhardt, K. M. (1985a). Control: Organizational and Economic Approaches. *Management Science*, 31(2), 134–149. <https://doi.org/10.1287/mnsc.31.2.134>
- Eisenhardt, K. M. (1985b). Control: Organizational and economic approaches. *Management Science*, 31(2), 134–149.
- Eisenhardt, K. M. (1989a). Agency theory: An assessment and review. *Academy of Management Review*, 14(1), 57–74.
- Eisenhardt, K. M. (1989b). Building Theories from Case Study Research. *Academy of Management Review*, 14(4), 532–550. <https://doi.org/10.5465/AMR.1989.4308385>
- Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of Management Journal*, 50(1), 25–32.
- Falkenberg, L., & Herremans, I. (1995). Ethical behaviours in organizations: Directed by the formal or informal systems? *Journal of Business Ethics*, 14(2), 133–143.
- Fayol, H. (1916). *Administration Industrielle et Générale*. [Reprinted as *General and Industrial Management*, trans. C. Storrs. London: Pitman, 1949].

- Fayol, H. (1949). General and industrial management (C. Storrs, trans. From French). *London: Pitman.[Originally Published 1916]*.
- Feldman, M. S., & March, J. G. (1981). Information in organizations as signal and symbol. *Administrative Science Quarterly*, 171–186.
- Ferreira, A. M. F. (2002). *Management accounting and control systems design and use: An exploratory study in Portugal*.
- Ferreira, A., & Otley, D. (2009). The design and use of performance management systems: An extended framework for analysis. *Management Accounting Research*, 20(4), 263–282. <https://doi.org/10.1016/j.mar.2009.07.003>
- Fisher, J. (1995). Contingency-based research on management control systems: Categorization by level of complexity. *Journal of Accounting Literature*, 14, 24–53.
- Fisher, J. G. (1998). Contingency Theory, Management Control Systems and Firm Outcomes: Past Results and Future Directions - ProQuest. *Behavioral Research in Accounting*, 10, 47–64.
- Fitoussi, D., & Gurbaxani, V. (2012). IT outsourcing contracts and performance measurement. *Information Systems Research*, 23(1), 129–143.
- Flamholtz, E. G. (1983). Accounting, budgeting and control systems in their organizational context: Theoretical and empirical perspectives. *Accounting, Organizations and Society*, 8(2–3), 153–169.
- Flamholtz, E. G., Das, T. K., & Tsui, A. S. (1985). Toward an integrative framework of organizational control. *Accounting, Organizations and Society*, 10(1), 35–50.
- Galbraith, J. (1973). *Designing complex organizations*. Reading, Mass.
- Galbraith, J. R. (1977). *Organization design*. Prentice Hall.
- Garbolino, E., Chéry, J.-P., & Guarnieri, F. (2019). The Systemic Approach: Concepts, Method and Tools. In F. Guarnieri & E. Garbolino (Eds.), *Safety Dynamics: Evaluating Risk in Complex Industrial Systems* (pp. 1–30). Springer International Publishing. https://doi.org/10.1007/978-3-319-96259-7_1
- Gerdin, J. (2005). The impact of departmental interdependencies and management accounting system use on subunit performance. *European Accounting Review*, 14(2), 297–327.
- Gerdin, J., & Greve, J. (2004). Forms of contingency fit in management accounting research—A critical review. *Accounting, Organizations and Society*, 29(3), 303–326. [https://doi.org/10.1016/S0361-3682\(02\)00096-X](https://doi.org/10.1016/S0361-3682(02)00096-X)
- Goh, Y. M., Brown, H., & Spickett, J. (2010). Applying systems thinking concepts in the analysis of major incidents and safety culture. *Safety Science*, 48(3), 302–309. <https://doi.org/10.1016/j.ssci.2009.11.006>
- Gordon, L. A., Loeb, M. P., & Tseng, C.-Y. (2009). Enterprise risk management and firm performance: A contingency perspective. *Journal of Accounting and Public Policy*, 28(4), 301–327. <https://doi.org/10.1016/j.jaccpubpol.2009.06.006>
- Govindarajan, V. (1988). A Contingency Approach to Strategy Implementation at the Business-Unit Level: Integrating Administrative Mechanisms with Strategy. *The Academy of Management Journal*, 31(4), 828–853. <https://doi.org/10.2307/256341>
- Govindarajan, V., & Fisher, J. (1990). Strategy, control systems, and resource sharing: Effects on business-unit performance. *Academy of Management Journal*, 33(2), 259–285.
- Govindarajan, V., & Gupta, A. K. (1985). Linking control systems to business unit strategy: Impact on performance. In *Readings in accounting for management control* (pp. 646–668). Springer.
- Grabner, I., & Moers, F. (2013). Management control as a system or a package? Conceptual and empirical issues. *Accounting, Organizations and Society*, 38(6), 407–419. <https://doi.org/10.1016/j.aos.2013.09.002>
- Green, S. G., & Welsh, M. A. (1988). Cybernetics and Dependence: Reframing the Control Concept. *The Academy of Management Review*, 13(2), 287. <https://doi.org/10.2307/258578>

- Haimes, Y. Y. (1992). Toward a holistic approach to total risk management. *Geneva Papers on Risk and Insurance. Issues and Practice*, 314–321.
- Håkansson, H., & Lind, J. (2004). Accounting and network coordination. *Accounting, Organizations and Society*, 29(1), 51–72.
- Håkansson, H., & Lind, J. (2006). Accounting in an Interorganizational Setting. In *Handbooks of Management Accounting Research* (Vol. 2, pp. 885–902). Elsevier.
[https://doi.org/10.1016/S1751-3243\(06\)02017-7](https://doi.org/10.1016/S1751-3243(06)02017-7)
- Hared, B. A., Abdullah, Z., & Huque, S. M. R. (2013). Management Control Systems: A review of literature and a theoretical framework for future researches. *Management*, 5(26).
[http://pakacademicsearch.com/pdf-files/ech/517/1-13%20Vol%205,%20No%2026%20\(2013\).pdf](http://pakacademicsearch.com/pdf-files/ech/517/1-13%20Vol%205,%20No%2026%20(2013).pdf)
- Henri, J.-F. (2006). Management control systems and strategy: A resource-based perspective. *Accounting, Organizations and Society*, 31(6), 529–558.
- Henriqson, É., Schuler, B., van Winsen, R., & Dekker, S. W. (2014). The constitution and effects of safety culture as an object in the discourse of accident prevention: A Foucauldian approach. *Safety Science*, 70, 465–476.
- Hewege, C. R. (2011). Acculturation and Management Control-‘Japanese Soul in Sri Lankan Physique.’ *Contemporary Management Research*, 7(1).
- Hewege, C. R. (2012). A critique of the mainstream management control theory and the way forward. *SAGE Open*, 2(4), 2158244012470114.
- Holmes, J. (1986). The organization and locational structure of production subcontracting. *Production, Work, Territory: The Geographical Anatomy of Industrial Capitalism*, 80–106.
- Holton, G. A. (1996). Closed form value at risk. *Contingency Analysis*, 1–10.
- Hopper, T., Tsamenyi, M., Uddin, S., & Wickramasinghe, D. (2009). Management accounting in less developed countries: What is known and needs knowing. *Accounting, Auditing and Accountability Journal*, 22(3), 469–514. <https://doi.org/10.1108/09513570910945697>
- Hopwood, A. G. (1976). *Accounting and human behavior*. Prentice Hall.
- Hopwood, A. G. (1996). Looking across rather than up and down: On the need to explore the lateral processing of information. *Accounting, Organizations and Society*, 21(6), 589–590.
[https://doi.org/10.1016/0361-3682\(96\)81805-8](https://doi.org/10.1016/0361-3682(96)81805-8)
- Hopwood, T. (1994). *Accounting as social and institutional practice* (Vol. 24). Cambridge University Press.
- Hoque, Z. (2002). *Strategic management accounting*. Spiro press.
- Hoque, Z. (2004). A contingency model of the association between strategy, environmental uncertainty and performance measurement: Impact on organizational performance. *International Business Review*, 13(4), 485–502. <https://doi.org/10.1016/j.ibusrev.2004.04.003>
- Hoque, Z., & Hopper, T. (1997). Political and industrial relations turbulence, competition and budgeting in the nationalised jute mills of Bangladesh. *Accounting and Business Research*, 27(2), 125–143.
- Houssiaux, J. (1957a). Le concept de “quasi-integration” et le role des sous-traitants dans l’industrie. *Revue Économique*, 8(2), 221–247. <https://doi.org/10.2307/3498702>
- Houssiaux, J. (1957b). Quasi-integration croissance des firmes et structures industrielles. *Revue Économique*, 8(3), 385–411. <https://doi.org/10.2307/3498549>
- Hutter, B., & Power, M. (2005). *Organizational Encounters with Risk*. Cambridge University Press.
- IAEA Report. (2013). *Human and Organizational Factors in Nuclear Safety in Light of Accident at Fukushima Daiichia Nuclear Power Plant*.
<http://www.iaea.org/sites/default/files/enhancetransparency2012.pdf>
- INTERNATIONAL ATOMIC ENERGY AGENCY. (2014). *IAEA Report on Human and Organizational Factors in Nuclear Safety in the Light of the Accident at the Fukushima*

- Daiichi Nuclear Power Plant*. IAEA. <http://www-pub.iaea.org/books/IAEABooks/10757/IAEA-Report-on-Human-and-Organizational-Factors-in-Nuclear-Safety-in-the-Light-of-the-Accident-at-the-Fukushima-Daiichi-Nuclear-Power-Plant>
- INTERNATIONAL ATOMIC ENERGY AGENCY. (2016). *Leadership and Management for Safety, IAEA Safety Standards Series No. GSR Part 2*. IAEA.
- International Federation of Accountants. Financial & Management Accounting Committee. (1999). *Enhancing Shareholder Wealth by Better Managing Business Risk* (Vol. 9). International Federation of Accounts.
- ISO 31000. (2018). *ISO 31000*. ISO.
<https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/06/56/65694.html>
- ISO Guide 73. (2009). *ISO Guide 73*. ISO.
<https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/04/46/44651.html>
- Ittner, C. D., & Larcker, D. F. (2001). Assessing empirical research in managerial accounting: A value-based management perspective. *Journal of Accounting and Economics*, 32(1–3), 349–410.
- Jari Kettunen, T. R. (2007). Safety management challenges and tensions in the European nuclear power industry. *Scandinavian Journal of Management*, 23(4), 424–444.
<https://doi.org/10.1016/j.scaman.2007.04.001>
- Jensen, M. C., & Meckling, W. H. (1976). Theory of the firm: Managerial behavior, agency costs and ownership structure. *Journal of Financial Economics*, 3(4), 305–360.
- Johnson, R. A., Kast, F. E., & Rosenzweig, J. E. (1964). Systems Theory and Management. *Management Science*, 10(2), 367–384.
- Kanu, M. S. (2020). Integrating Enterprise Risk Management with Strategic Planning for Improved Firm Performance. *European Journal of Business and Management Research*, 5(5).
- Khandwalla, P. N. (1972). The effect of different types of competition on the use of management controls. *Journal of Accounting Research*, 275–285.
- Khandwalla, P. N. (1977). *The design of organizations*.
- Khurana, R., Florida, R., Slywotzky, A., & Coutu, D. L. (2004). Breakthrough ideas for 2004. *Harvard Business Review*, 82(2), 13–13.
- Kirsch, L. J. (1996). The management of complex tasks in organizations: Controlling the systems development process. *Organization Science*, 7(1), 1–21.
- Klaas, P. (2004). *Towards a concept of dynamic fit in contingency theory*. 25–29.
- Klir, G. J. (1986). Les multiples visages de la complexité. *Science et Pratique de La Complexité*, 101–120.
- Kloman, H. F. (1976). The risk management revolution. *Fortune Magazine* (July).
- Kraus, K., & Lind, J. (2007). Management control in inter-organisational relationships. *Issues in Management Accounting*, 269–296.
- Lam, A. (1997). Embedded Firms, Embedded Knowledge: Problems of Collaboration and Knowledge Transfer in Global Cooperative Ventures. *Organization Studies*, 18(6), 973–996.
<https://doi.org/10.1177/017084069701800604>
- Lam, J. (2006). Managing risk across the enterprise: Challenges and benefits. In *Risk Management* (pp. 3–19). Elsevier.
- Langfield-Smith, K., & Smith, D. (2003a). Management control systems and trust in outsourcing relationships. *Management Accounting Research*, 14(3), 281–307.
[https://doi.org/10.1016/S1044-5005\(03\)00046-5](https://doi.org/10.1016/S1044-5005(03)00046-5)
- Langfield-Smith, K., & Smith, D. (2003b). Management control systems and trust in outsourcing relationships. *Management Accounting Research*, 14(3), 281–307.
[https://doi.org/10.1016/S1044-5005\(03\)00046-5](https://doi.org/10.1016/S1044-5005(03)00046-5)

- Larsson, A. (1999). *Proximity Matters? Geographical aspects of changing strategies in automotive subcontracting relationships: the case of domestic suppliers to Volvo Troslanda assembly plant*. <https://gupea.ub.gu.se/handle/2077/2508>
- Le Moigne, J.-L. (1987). *Qu'est-ce qu'un modèle*. Université d'Aix-Marseille III, Faculté d'économie appliquée.
- Leifer, R., & Mills, P. K. (1996). An Information Processing Approach for Deciding Upon Control Strategies and Reducing Control Loss in Emerging Organizations. *Journal of Management*, 22(1), 113–137. <https://doi.org/10.1177/014920639602200105>
- Leveson, N. (2004). A new accident model for engineering safer systems. *Safety Science*, 42(4), 237–270. [https://doi.org/10.1016/S0925-7535\(03\)00047-X](https://doi.org/10.1016/S0925-7535(03)00047-X)
- Leveson, N., Dulac, N., Marais, K., & Carroll, J. (2009). Moving Beyond Normal Accidents and High Reliability Organizations: A Systems Approach to Safety in Complex Systems. *Organization Studies*, 30(2–3), 227–249. <https://doi.org/10.1177/0170840608101478>
- Leveson, N. G. (2011). Applying systems thinking to analyze and learn from events. *Safety Science*, 49(1), 55–64. <https://doi.org/10.1016/j.ssci.2009.12.021>
- Lowe, E. (1970). Budgetary control: An evaluation in a wider managerial perspective. *Accountancy*, November, 765.
- Lukka, K. (2007). Management accounting change and stability: Loosely coupled rules and routines in action. *Management Accounting Research*, 18(1), 76–101.
- Lukka, K., & Granlund, M. (2004). *Paradoxes of Management and Control in a New Economy Firm*.
- Luthans, F. (1973). The contingency theory of management. *Business Horizons*, 16(3), 67–72. [https://doi.org/10.1016/0007-6813\(73\)90026-8](https://doi.org/10.1016/0007-6813(73)90026-8)
- Macintosh, N. B., & Daft, R. L. (1987). Management control systems and departmental interdependencies: An empirical study. *Accounting, Organizations and Society*, 12(1), 49–61.
- Macintosh, N. B., & Hopper, T. (2005). *Accounting, the social and the political: Classics, contemporary and beyond*. Elsevier.
- Macintosh, N. B., & Quattrone, P. (2010). *Management accounting and control systems: An organizational and sociological approach*. John Wiley & Sons.
- Malmi, T., & Brown, D. A. (2008a). Management control systems as a package—Opportunities, challenges and research directions. *Management Accounting Research*, 19(4), 287–300. <https://doi.org/10.1016/j.mar.2008.09.003>
- Malmi, T., & Brown, D. A. (2008b). Management control systems as a package—Opportunities, challenges and research directions. *Management Accounting Research*, 19(4), 287–300. <https://doi.org/10.1016/j.mar.2008.09.003>
- March, J. G., & Shapira, Z. (1987). Managerial perspectives on risk and risk taking. *Management Science*, 33(11), 1404–1418.
- March, J. G., & Simon, H. A. (1958). *Organizations*. New York/London/Sidney: John Wiley.
- Martinet, A. C., & Payaud, M. A. (2006). Absorption d'incertitude, enrichissement des stratégies et cadres intermédiaires: Une modélisation ago-antagoniste. *Management International Montréal*, 10(2), 29–14.
- McNamee, D. (2000). Targeting business risk. *Internal Auditor*, 57(5), 46–46.
- McShane, S. L., & Von Ginow, M. A. (2003). Organizational Behavior: Emerging Realities for The Workplace. *McGraw Hill Companies*.
- Merchant, K. A. (1981). The design of the corporate budgeting system: Influences on managerial behavior and performance. *Accounting Review*, 813–829.
- Merchant, K. A. (1985). *Control in business organization*. Financial Times/Prentice Hall.
- Merchant, K. A., & Stede, W. A. V. der. (2007). *Management Control Systems: Performance Measurement, Evaluation and Incentives*. Pearson Education.

- Merchant, K. A., & Van der Stede, W. A. (2007). *Management control systems: Performance measurement, evaluation and incentives*. Pearson Education.
- Mikes, A. (2009). Risk management and calculative cultures. *Management Accounting Research*, 20(1), 18–40. <https://doi.org/10.1016/j.mar.2008.10.005>
- Mikes, A., & Kaplan, R. S. (2012). Managing risks: A new framework. *Harvard Business Review*, 90(6).
- Mikes, A., & Kaplan, R. S. (2014). *Towards a contingency theory of enterprise risk management*.
- Milgrom, P., & Roberts, J. (1995). Complementarities and fit strategy, structure, and organizational change in manufacturing. *Journal of Accounting and Economics*, 19(2–3), 179–208.
- Miller, D. (1992). Environmental fit versus internal fit. *Organization Science*, 3(2), 159–178.
- Miller, K. D. (1998). Economic exposure and integrated risk management. *Strategic Management Journal*, 19(5), 497–514.
- Miller, K. D., & Waller, H. G. (2003). Scenarios, real options and integrated risk management. *Long Range Planning*, 36(1), 93–107.
- Miller, P. (1994). Accounting as social and institutional. *Accounting as Social and Institutional Practice*, 24, 1–39.
- Mockler, R. J. (1970). Theory and practice of planning. *Harvard Business Review*, 48(2), 148.
- Moreno Alarcon, D. P., Vautier, J. F., Hernandez, G., and Guarnieri, F. (2020). Applying Safety Leadership and Systems Thinking to the Formal and Informal Controls Approach Used in Safety and Risk Management Within the French Nuclear Sector. In J. I. Kantola and S. Nazir (Eds.), *Advances in Human Factors, Business Management and Leadership* (pp. 481–492). Springer International Publishing. https://doi.org/10.1007/978-3-030-20154-8_44
- Moreno Alarcon, D. P., Vautier, J. F., Hernandez, G., and Guarnieri, F. (2019). Systems Thinking in Risk Management by Preventive and Detective Controls as an Ago-Antagonistic Systems Approach in the French Nuclear Sector. *Proceedings of the 29th European Safety and Reliability Conference (ESREL)*, 3866–3873. https://doi.org/10.3850/978-981-11-2724-3_0243-cd
- Mundy, J. (2010). Creating dynamic tensions through a balanced use of management control systems. *Accounting, Organizations and Society*, 35(5), 499–523. <https://doi.org/10.1016/j.aos.2009.10.005>
- Nedaei, B. H. N., Rasid, S. Z. A., Sofian, S., Basiruddin, R., & Kalkhouran, A. A. N. (2015). A Contingency-Based Framework for Managing Enterprise Risk. *Global Business and Organizational Excellence*, 34(3), 54–66. <https://doi.org/10.1002/joe.21604>
- Nunez, E. (1997). What are ago-antagonistic couples? Their role in normal and pathological situations. Therapeutical consequences. *Psychoneuroendocrinology*, 22, S95–S101. [https://doi.org/10.1016/S0306-4530\(97\)00010-3](https://doi.org/10.1016/S0306-4530(97)00010-3)
- Otley, D. (1980). The Contingency Theory of Management Accounting: Achievement and Prognosis. *Accounting, Organizations, and Society*, 413–428.
- Otley, D. (1994). Management control in contemporary organizations: Towards a wider framework. *Management Accounting Research*, 5(3), 289–299. <https://doi.org/10.1006/mare.1994.1018>
- Otley, D. (1999). Performance management: A framework for management control systems research. *Management Accounting Research*, 10(4), 363–382. <https://doi.org/10.1006/mare.1999.0115>
- Otley, D. (2001). *Extending the boundaries of management accounting research: Developing systems for performance management.* *British Accounting Review* 33.
- Otley, D., Broadbent, J., & Berry, A. (1995). Research in management control: An overview of its development. *British Journal of Management*, 6, S31–S44.
- Otley, D., & Emmanuel, K. (2013). *Accounting for Management Control*. Springer.
- Otley, D. T. (1980). The contingency theory of management accounting: Achievement and prognosis. In *Readings in accounting for management control* (pp. 83–106). Springer.

- Otley, D. T., & Berry, A. J. (1980). Control, organization and accounting. In *Readings in Accounting for Management Control* (pp. 28–48). Springer, Boston, MA. https://doi.org/10.1007/978-1-4899-7138-8_2
- Ouchi, W. G. (1977). The Relationship Between Organizational Structure and Organizational Control. *Administrative Science Quarterly*, 22(1), 95–113. <https://doi.org/10.2307/2391748>
- Ouchi, W. G. (1979a). A conceptual framework for the design of organizational control mechanisms. In C. Emmanuel, D. Otley, & K. Merchant (Eds.), *Readings in Accounting for Management Control* (pp. 63–82). Springer US. https://doi.org/10.1007/978-1-4899-7138-8_4
- Ouchi, W. G. (1979b). A conceptual framework for the design of organizational control mechanisms. *Management Science*, 25(9), 833–848.
- Ouchi, W. G. (1980). Markets, Bureaucracies, and Clans. *Administrative Science Quarterly*, 25(1), 129–141. <https://doi.org/10.2307/2392231>
- Ouchi, W. G., & Maguire, M. A. (1975). Organizational control: Two functions. *Administrative Science Quarterly*, 559–569.
- Perrow, C. (1970). *Organizational Analysis: A Sociological View* (Belmont, CA: Wadsworth, 1970). 161.
- Power, M. (2007). *Organized Uncertainty: Designing a World of Risk Management*. OUP Oxford.
- Ramo, S. (1973). *Systems Concepts: Lectures on Contemporary Approaches to Systems*. John F. Wiley & Sons. <https://ntrs.nasa.gov/citations/19730050770>
- Rayburn, J. M., & Rayburn, L. G. (1991). Contingency theory and the impact of new accounting technology in uncertain hospital environments. *Accounting, Auditing & Accountability Journal*, 4(2), 0–0.
- Razali, A. R., & Tahir, I. M. (2011). Review of the literature on enterprise risk management. *Business Management Dynamics*, 1(5), 8.
- Reason, J. (1990). *Human Error*. Cambridge University Press.
- Reason, J., Parker, D., & Lawton, R. (1998). Organizational controls and safety: The varieties of rule-related behaviour. *Journal of Occupational and Organizational Psychology*, 71(4), 289–304. <https://doi.org/10.1111/j.2044-8325.1998.tb00678.x>
- Reid, G. C., & Smith, J. A. (2000). The impact of contingencies on management accounting system development. *Management Accounting Research*, 11(4), 427–450.
- Rockness, H. O., & Shields, M. D. (1984). Organizational control systems in research and development. *Accounting, Organizations and Society*, 9(2), 165–177.
- Saffold III, G. S. (1988). Culture traits, strength, and organizational performance: Moving beyond “strong” culture. *Academy of Management Review*, 13(4), 546–558.
- Sandelin, M. (2008). Operation of management control practices as a package—A case study on control system variety in a growth firm context. *Management Accounting Research*, 19(4), 324–343. <https://doi.org/10.1016/j.mar.2008.08.002>
- Scapens, R. W. (2006). 15 Changing times: Management accounting research and practice from a UK perspective. *Contemporary Issues in Management Accounting*, 329.
- Schein, E. H. (2010). *Organizational culture and leadership* (Vol. 2). John Wiley & Sons.
- Scott, W. R. (1981). Developments in organization theory, 1960-1980. *American Behavioral Scientist*, 24(3), 407–422.
- Selto, F. H., Renner, C. J., & Young, S. M. (1995). Assessing the organizational fit of a just-in-time manufacturing system: Testing selection, interaction and systems models of contingency theory. *Accounting, Organizations and Society*, 20(7–8), 665–684.
- Shapira, Z. (1995). *Risk taking: A managerial perspective*. Russell Sage Foundation.
- Shields, M. D. (1995). An empirical analysis of firms’ implementation experiences with activity-based costing. *Journal of Management Accounting Research*, 7(1), 148–165.
- Siggelkow, N. (2007). Persuasion with case studies. *Academy of Management Journal*, 50(1), 20.

- Simons, R. (1995). *Levers of Control: How Managers Use Innovative Control Systems to Drive Strategic Renewal*. Harvard Business Press.
- Simons, R. (2000). *Performance measurement and control systems for implementing strategy*. Prentice Hall, Upper Saddle River, NJ.
- Simons, R. (2013). *Levers of Control: How Managers Use Innovative Control Systems to Drive Strategic Renewal*. Harvard Business Press.
- Sjöblom, L. (2003). Management accounting in the new economy: The rationale for irrational controls. A. Bhimani (Ed.), *Management Accounting in the Digital Economy* (Pp. 185–201). Oxford: Oxford University Press. [http://doi.org/10.1093/0199260389.001, 1](http://doi.org/10.1093/0199260389.001.1).
- Skyttner, L. (1996). *General systems theory: An introduction*. Macmillan International Higher Education.
- Smith, J. A., Morris, J., & Ezzamel, M. (2005). Organisational change, outsourcing and the impact on management accounting. *The British Accounting Review*, 37(4), 415–441. <https://doi.org/10.1016/j.bar.2005.07.004>
- Snow, C. C., Miles, R. E., & Miles, G. (2006). The configurational approach to organization design: Four recommended initiatives. In *Organization Design* (pp. 3–18). Springer.
- Strauss, A., & Corbin, J. (1990). *Basics of qualitative research* (Vol. 15). SAGE. <http://www.li.suu.edu/library/circulation/Stein/Comm%206020ksStraussCorbinBasicsQualitativeFall07.pdf>
- Subramaniam, N., Collier, P., Phang, M., & Burke, G. (2011). The effects of perceived business uncertainty, external consultants and risk management on organisational outcomes. *Journal of Accounting & Organizational Change*, 7(2), 132–157. <https://doi.org/10.1108/18325911111139671>
- Taylor, F. W. (1911). *Shop management*. McGraw-Hill.
- Taylor, S. S., Fisher, D., & Dufresne, R. L. (2002). The aesthetics of management storytelling: A key to organizational learning. *Management Learning*, 33(3), 313–330.
- Thompson, J. D. (1967). *Organizations in action: Social science bases of administrative theory*. Transaction publishers.
- Tomkins, C. (2001). Interdependencies, trust and information in relationships, alliances and networks. *Accounting, Organizations and Society*, 26(2), 161–191. [https://doi.org/10.1016/S0361-3682\(00\)00018-0](https://doi.org/10.1016/S0361-3682(00)00018-0)
- Tuomela, T.-S. (2005). The interplay of different levers of control: A case study of introducing a new performance measurement system. *Management Accounting Research*, 16(3), 293–320.
- Van der Meer-Kooistra, J., & Vosselman, E. G. J. (2000). Management control of interfirm transactional relationships: The case of industrial renovation and maintenance. *Accounting, Organizations and Society*, 25(1), 51–77. [https://doi.org/10.1016/S0361-3682\(99\)00021-5](https://doi.org/10.1016/S0361-3682(99)00021-5)
- Vautier, J.-F. (2018). *La notion de configuration dans des approches systémiques pour appréhender la complexité* (Edition des Techniques de l'ingénieur AG).
- Vautier, J.-F., Dechy, N., Coye de Brunélis, T., Hernandez, G., Launay, R., & Moreno Alarcon, D. P. (2018). Benefits of systems thinking for a human and organizational factors approach to safety management. *Environment Systems and Decisions*, 38(3), 353–366. <https://doi.org/10.1007/s10669-018-9692-7>
- Vélez, M. L., Sánchez, J. M., & Álvarez-Dardet, C. (2008). Management control systems as inter-organizational trust builders in evolving relationships: Evidence from a longitudinal case study. *Accounting, Organizations and Society*, 33(7–8), 968–994. <https://doi.org/10.1016/j.aos.2008.02.006>
- Von Bertalanffy, L. (1968). General system theory—A critical review. *Modern Systems Research for the Behavioral Scientist*. Chicago: Aldine, 11–30.

- Waterhouse, J. H., & Tiessen, P. (1978). A contingency framework for management accounting systems research. *Accounting, Organizations and Society*, 3(1), 65–76.
- Weick, K. E. (1979). *The Social Psychology of Organizing* (2nd ed.). McGraw-Hill.
- Wehrich, H., Cannice, M., & Koontz, H. (2019). *Management: A Global, Innovative and Entrepreneurial Perspective*. McGraw-Hill Education.
- Weinberg, G. M. (1975). *An introduction to general systems thinking* (Vol. 304). Wiley New York.
- Whitley, R. (1999). Firms, institutions and management control: The comparative analysis of coordination and control systems. *Accounting, Organizations and Society*, 24(5–6), 507–524.
- Widener, S. K. (2004). An empirical investigation of the relation between the use of strategic human capital and the design of the management control system. *Accounting, Organizations and Society*, 29(3–4), 377–399.
- Widener, S. K. (2007). An empirical analysis of the levers of control framework. *Accounting, Organizations and Society*, 32(7–8), 757–788.
- Wiener, N. (1948). *Cybernetics: Or Control of Communication in the Animal and the Machine*, Paris: Librairie Herman.
- Wiener, N. (2019). *Cybernetics or Control and Communication in the Animal and the Machine, Reissue of the 1961 second edition*. MIT Press.
- Williamson, O. E. (1971). The Vertical Integration of Production: Market Failure Considerations. *The American Economic Review*, 61(2), 112–123.
- Wilson, R. M., & Chua, W. F. (1993). *Managerial Accounting: Method and Meaning*. Chapman & Hall.
- Wodak, R. (2004). *Critical discourse analysis. Qualitative Research Practice*. Concise Paperback Edition. [http://accept-pluralism.eu/Projects/ACCEPT/Documents/Events/2010-11-2ndMeetingACCEPT/presentations/CRITICALDISCOURSE\(ANALYSIS\)RuthWodakpresentation.pdf](http://accept-pluralism.eu/Projects/ACCEPT/Documents/Events/2010-11-2ndMeetingACCEPT/presentations/CRITICALDISCOURSE(ANALYSIS)RuthWodakpresentation.pdf)
- Woods, D. D. (2009). Escaping failures of foresight. *Safety Science*, 47(4), 498–501. <https://doi.org/10.1016/j.ssci.2008.07.030>
- Zawawi, N. H. M. (2018). Actor-network theory and inter-organizational management control. *International Journal of Business and Society*, 19(S2), 219–234.
- Zouaghi, I., & Spalanzani, A. (2009). *Supply chains: Ago-antagonistic systems through co-opetition game theory lens*. 12.

Appendices

Appendix A: Data collection

Appendix A1. Interviews conducted (37) of 27 participants from both the subcontracting firm and the CEA totalling over 45h of recordings

CEA Site	Date	hh:mm	Code	Role (CEA or subcontractor)	Alias	Interview	N-vivo File
Site 2	2016-03-14	01:54	P01	HOF Site Specialist 1 (CEA)	Fedora	Int 1	2P01Int1
Site 2	2016-03-14	00:40	P01	HOF Site Specialist 1 (CEA)	Fedora	Int 2	2P01Int2
Site 2	2016-03-15	01:07	P01	HOF Site Specialist 1 (CEA)	Fedora	Int 3	2P01Int3
Site 2	2016-03-15	02:21	P02	Subcontracting Project Leader (CEA)	Suor	Int 1	2P02Int1
Site 2	2016-03-16	01:09	P01	HOF Site Specialist 1 (CEA)	Fedora	Int 4	2P01Int4
Site 2	2016-03-17	01:50	P01	HOF Site Specialist 1 (CEA)	Fedora	Int 5	2P01Int5
Site 2	2016-03-17	01:15	P03	RCI of the liquid effluent treatment plant and later the second Facility B Manager (CEA)	Gotterdamm	Int 1	2P03Int1
Site 2	2016-03-17	00:43	P04	RCI of the materials decontamination workshop (CEA)	Dardanus	Int 1	2P04Int1
Site 2	2016-03-17	00:43	P05	First Facility B Manager (CEA)	Boris	Int 1	2P05Int1
Site 1	2016-05-03	01:00	P06	Facility A Occupational Safety Engineer (CEA)	Elektra	Int 1	1P06Int1
Site 1	2016-05-04	03:00	P07	Facility A Manager (CEA)	Edgar	Int 1	1P07Int1
Site 1	2016-05-31	00:28	P08	Facility A Occupational Safety Assistant 1 (subcontractor)	Manon	Int 1	1P08Int1
Site 1	2016-07-06	01:00	P06	Facility A Occupational Safety Engineer (CEA)	Elektra	Int 2	1P06Int2
Site 1	2016-07-06	00:37	P09	Facility A Technical Correspondent (subcontractor)	Nicholas	Int 1	1P09Int1
Site 1	2016-07-07	00:25	P10	Facility A In charge Exploitation Contract (CEA)	Aida	Int 1	1P10Int1
Site 1	2016-07-08	00:42	P11	Facility A Nuclear Safety Engineer (CEA)	Pagliacci	Int 1	1P11Int1
Site 1	2016-07-27	00:52	P12	Facility A Radioprotection Tech. 1 (subcontractor)	Amadis	Int 1	1P12Int1
Site 1	2016-07-28	00:35	P13	Facility A Radio-protection Tech. 2 (subcontractor)	Falstaff	Int 1	1P13Int1
Site 1	2016-07-28	00:43	P14	Facility A Occupational Safety Assistant 2 (subcontractor)	Rigoletto	Int 1	1P14Int1
Site 1	2018-03-15	02:22	P7	First Facility A Manager (CEA)	Edgar	Int 2	1P07Int2
Site 1	2018-03-22	04:30	P7	First Facility A Manager (CEA)	Edgar	Int 3	1P07Int3
Site 2	2018-05-27	01:25	P03/P15	Second Facility B Manager (CEA)	Gotterdamm	Int 1	2P15Int1
Site 2	2018-06-24	02:28	P03/P15	Second Facility B Manager (CEA)	Gotterdamm	Int 2	2P15Int2
Site 2	2018-06-25	01:27	P16	Facility B QSE support (CEA)	Don Carlos	Int 1	2P16Int1
Site 2	2018-08-28	01:17	P17	Facility B Production Manager (Middle Management Subcontractor)	Otello	Int 1	2P17Int1
Site 2	2018-08-29	01:31	P18	Facility B Occupational Safety Animator (Middle Management Subcontractor)	Corsaro	Int 1	2P18Int1
Site 2	2018-08-30	01:08	P19	Facility B Nuclear Safety Engineer (CEA)	Masnadieri	Int 1	2P19Int1
Site 2	2018-08-30	00:38	P20	Facility B Deputy Facility Manager (CEA)	Nabucodonosor	Int 1	2P20Int1
Site 2	2018-08-31	00:50	P21	HOF Site Specialist 2 (CEA)	Giorno di Regno	Int 1	2P21Int1
Site 2	2018-08-31	01:03	P22	HOF Site Specialist 3 (CEA)	Jerusalem	Int 1	2P22Int1
Site 2	2018-08-31	01:33	P23	Facility B Quality Manager (Middle Management Subcontractor)	Attila	Int 1	2P23Int1
Site 2	2018-08-31	01:00	P24	Facility B Quality and Environment Manager (Middle Management Subcontractor)	Douphol	Int 1	2P24Int1
Site 1	2019-01-03	00:31	P25	Second Facility A Manager (CEA)	Trovatore	Int 1	1P25Int1
Site 2	2019-01-14	00:26	P26	Facility E Nuclear Safety Engineer (CEA)	Derk	Int 1	1P26Int1
Site 2	2019-01-15	01:06	P26	Facility E Nuclear Safety Engineer (CEA)	Derk	Int 2	1P26Int2
Site 2	2019-01-15	01:43	P26	Facility E Nuclear Safety Engineer (CEA)	Derk	Int 3	1P26Int3
Site 2	2019-09-25	00:42	P27	Facility E Production Manager (Middle Manager Subcontractor)	Foscari	Int 1	1P27Int1

Appendix A2. Meetings Attended (23)

CEA Site	Date	Title of Meeting	Type of Meeting	Code	N-vivo File Name
Site 1	2016-05-02	First meeting and Occupational Safety welcome	First Meeting	FM-1	1FM-1
Site 1	2016-05-04	Reversibility Meeting with New Outsourcer	Reversibility	REV-1	1REV-1
Site 1	2016-05-04	First Meeting with Director	First Meeting	FM-2	1FM-2
Site 1	2016-05-31	Occupational Safety Culture Presentation by the Director	Presentation	PRES-1	1PRES-1
Site 1	2016-06-02	Presentation Session on “Intervention of Facility R”, led by the Account Manager of the New Outsourcer	Presentation	PRES-2	1PRES-2
Site 1	2016-06-03	Reversibility Meeting with Exiting Outsourcers	Reversibility	REV-2	1REV-2
Site 1	2016-06-29	Facility A and R Presentation report of the lasts 5 years by the Exiting Outsourcer	Presentation	PRES-3	1PRES-3
Site 1	2016-06-29	Weekly Reversibility Meeting that postponed by one week	Reversibility	REV-3	1REV-3
Site 1	2016-06-30	Remediation of the Exploitation Multiple Choice Quiz	Feedback	QCM-1	QCM-1
Site 1	2016-06-30	Remediation of the Occupational Safety Multiple Choice Quiz	Feedback	QCM-2	1QCM-2
Site 1	2016-06-30	Reversibility debrief	Reversibility	REV-4	1REV-4
Site 1	2016-07-01	Weekly Co-activity Meeting	Co-activity	COA-1	1COA-1
Site 1	2016-07-01	Weekly Reversibility Meeting that postponed by one week	Reversibility	REV-5	1REV-5
Site 1	2016-07-08	Weekly Co-activity Meeting	Co-activity	COA-2	1COA-2
Site 1	2016-07-08	Laboratory Meeting	Laboratory Meeting	LM-1	1LM-1
Site 1	2016-07-26	End of Contract meeting with the Exiting Outsourcer	Contract Meeting	CM-1	1CM-1
Site 1	2016-07-28	Transport meeting with the New Outsourcer	Transport Meeting	TM-1	1TM-1
Site 1	2016-07-29	Weekly Co-activity Meeting	Co-activity	COA-3	1COA-3
Site 2	2018-08-22	Preparation for the “Plongee/ Dive”	Activity Preparation	APR-1	2APR-1
Site 2	2018-08-24	Daily Co-activity Meeting	Co-activity	COA-4	2COA-4
Site 2	2018-08-27	Daily Co-activity Meeting	Co-activity	COA-5	2COA-5
Site 2	2018-08-30	Daily Co-activity Meeting	Co-activity	COA-6	2COA-6
Site 2	2018-08-31	Daily Co-activity Meeting	Co-activity	COA-7	2COA-7
Site 2	2019-01-14	Bi-weekly Co-activity Meeting	Co-activity	COA-8	2COA-8
Site 2	2019-01-14	Planning of the 2 years with Subcontractors	Presentation	PRES-4	2PRES-4
Site 2	2019-01-15	Finalization of Facility E Tourist Video	Presentation	PRES-5	2-PRES-5

Appendix A3. Observations (21)

CEA Site	Date	Title of the Observation	Type of Observation	Code	N-vivo name	File
Site 1	2016-06-01	Lowering and removal of the Tower	Technical Observation	TO-1	1TO-01	
Site 1	2016-06-01	Contamination Control and use of the Smear Machine	Technical Observation	TO-2	1TO-02	
Site 1	2016-06-02	Placement of the Camera Rod	Technical Observation	TO-3	1TO-03	
Site 1	2016-06-02	Use of the Camera connected to the Bridge	Technical Observation	TO-4	1TO-04	
Site 1	2016-06-03	Use and placement of the foot passage, and the platform to charge and discharge the bins	Technical Observation	TO-5	1TO-05	
Site 1	2016-06-28	Removal and reassembly of the RD39	Technical Observation	TO-6	1TO-06	
Site 1	2016-06-29	Use of the MI bin loading/unloading platform in Gradient Mode or Incident mode.	Technical Observation	TO-7	1TO-07	
Site 1	2016-07-04	Validation of the use of the transport packaging tower MII6T and 17T	Technical Observation	TO-8	1TO-08	
Site 1	2016-07-05	Validation of the loading and unloading platform	Technical Observation	TO-9	1TO-09	
Site 1	2016-07-05	Validation of the use of the transfer tower M1 11T	Technical Observation	TO-10	1TO-10	
Site 1	2016-07-05	Validation of MI bin	Technical Observation	TO-11	1TO-11	
Site 1	2016-07-05	Monthly Radioactive Sources Test	Technical Observation	TO-12	1TO-12	
Site 1	2016-07-25	Disassembly of ETCMI Stud	Technical Observation	TO-13	1TO-13	
Site 1	2016-07-25	1st level (TQRP) and 2nd level (SPR) control of radioactivity on the uniforms	Technical Observation	TO-14	1TO-14	
Site 1	2016-07-28	Monthly Occupational Safety Visit	Technical Observation	TO-15	1TO-15	
Site 1	2016-07-27	Monthly Round	Technical Observation	TO-16	1TO-16	
Site 2	2018-08-22	Projection from afar Meeting	Technical Observation	TO-17	2TO-17	
Site 2	2018-08-22	Command Centre and Fut Production	Technical Observation	TO-18	2TO-18	
Site 2	2018-08-22	Annual transport of the non-compactable 118L canister into the red 223L canister ready to be filled with cement	Technical Observation	TO-19	2TO-19	
Site 2	2018-08-23	Cement filling from the command post	Technical Observation	TO-20	2TO-20	
Site 2	2018-08-28	Transport of 224L fut and concrete containers	Technical Observation	TO-21	2TO-21	

Appendix B: Interview Guide

During the interviews conducted at Facility A, Facility B and Facility E, several themes surrounding risk and control were investigated. Specifically:

- What modalities of control or strategies of management control mechanisms do managers employ when controlling/managing subcontractors and how do these strategies differ according to the level of risk of the activity (high vs. regular risk) and according to the level of control (C0N, C1N, C1.5N)?
- How do these controls compare to Prevention, verification, Behaviour control, output control, and social control?
- How do these strategies differ from an Facility with C1.5N compared to an Facility without this Middle Management Control? (How does the intermediate 1.5 level control impact these strategies?)

All of the interviews were conducted in French (the official language spoken at the CEA), as a result, the interview guide below is in its original format.

Introduction

- Présentation, explication de la thématique abordée, rappelle la confidentialité de l'entretien
- Rappel des objectifs de l'entretien : comprendre les risques de la sous-traitance (pour le CEA) et non les risques aux sous-traitantes.
- Spécifiquement, ma thèse a pour objet d'analyser la maîtrise de l'activité des prestataires dans un contexte de recours à la sous-traitance particulièrement sur le "quotidien" de la relation entre le CEA et les prestataires.

Profil et parcours de l'interlocuteur

- Nom, Fonction actuelle, description de votre activité (niveau d'expérience dans la fonction, dans l'installation)
- Récit de vie : qualifications and parcours professionnel antérieur

Modèles de contrôle existants au CEA

Pouvez-vous m'expliquer le fonctionnement de 3 types d'installations CEA ?

Sur les risques de la sous-traitance

- Quels sont les enjeux de la sous-traitance ?
- Quels sont les risques de la sous-traitance en général ?
- Comment vous gérez la sous-traitance ?
- Comment vous contrôlez (pilotez/manager) les sous-traitantes ?
- Comment se déroulent vos activités ? (C0N, C1N, C1.5N)
- Comment vous vous organisez pour suivre les activités des prestataires ?
- Quelles stratégies vous mettez en place pour adapter le suivi des prestataires selon le niveau de risque de l'activité ?
 - Dans une activité de risque réduit ?
 - Dans une activité de haut risque ?
 - Avec des prestataires qui ont beaucoup d'expérience ?
- Vous pouvez me décrire les pratiques de comment vous surveillez les prestataires ?
- Pouvez-vous me décrire les modalités de surveillance des prestataires ?
- Faites-vous plus des contrôles de pilotage (prévention) ou de vérification (détection des écarts) ?

Un rôle plus préventif ou correctif dans l'installation ?

Je vais me permettre de lire ce que ça veut dire le pilotage et la vérification : (Le cœur de ma thèse)

Le Pilotage : comment on assure la performance du processus d'exploitation. Cette tâche peut ne pas entraîner d'action influençant directement le processus. Ces tâches sont réalisées par des acteurs qui font partie du processus d'exploitation. Ces acteurs sont partis prenantes du processus d'exploitation et sont chargés d'une fonction (Chef d'installation, chargé d'opération du prestataire, etc.).

- Quel pourcentage de pilotage faites-vous dans l'installation ? (Quelles activités ? ce contrôle est réalisé par qui ? quelle fréquence ?)

La Vérification : comment on va détecter les écarts. Ces tâches sont réalisées par des acteurs qui ne font pas partie à ce moment-là du processus d'exploitation. Ces acteurs adoptent un point de vue extérieur au processus d'exploitation afin d'avoir une vue la plus objective possible lorsqu'ils vérifient la présence ou l'absence d'écarts.

- Quel pourcentage de vérification faites-vous dans l'installation ? (Quelles activités ? ce contrôle est réalisé par qui ? quelle fréquence ?)
- Ce ratio change-t-il selon le niveau des contrôles ?
 - Dans le niveau 0 existe-il plus de pilotage ou de vérification ?
 - Dans le niveau 1
 - Dans le niveau 1.5
 - Dans le niveau 2

Sur les risques dans la littérature relative au management

Dans le champ de la sécurité et de la sûreté nucléaire en lien avec la sous-traitance, la littérature relative au management indique que les activités sous-traitées peuvent être sujettes à trois grands risques :

Le risque relationnel : le prestataire n'applique pas ou contourne les règles prescrites par le CEA ou les autorités extérieures (l'idée de non-coopération)

Le risque de non obtention du résultat : le prestataire met en place des moyens (les compétences et ressources) qui ne permettent pas d'atteindre des résultats conformes à ses engagements ; malgré sa coopération et sa volonté de mettre en place des moyens suffisants

Le risque de non application des normes : ne pas utiliser le bon cadre normatif (ne pas utiliser le bon ensemble de règles) ou ne pas mettre en place des moyens adéquats pour atteindre des résultats conformes à ses engagements.

- Existe-t-il des événements ou vous avez vécu ses risques au cours de votre expérience professionnelle en général ? Spécifique à l'Installation ?

Sur la maîtrise des risques de la sous-traitance

- Existe-t-il des outils pour maîtriser ces risques ? Comment vous maîtriser les risques liés à la sous-traitance ?
 - Quels sont ceux donnés par le centre ?
 - Par la cellule ?
 - Développées par vous ?
- Comment vous déterminez l'efficacité de ces outils de maîtrise des risques ?
- Quelles sont les dérives possibles concernant la maîtrise des risques de la sous-traitance en général ?
- Utilisez-vous ces types de contrôles ?

Le contrôle comportemental qui s'assure que les procédures sont bien appliquées. Cela exige de mettre en place des dispositions pour que le prestataire applique bien les règles prescrites par le CEA ou les autorités extérieures.

Le contrôle par les résultats qui s'assure que le prestataire obtient des résultats conformes à ses engagements. Cela exige de mettre en place des dispositions pour que les résultats obtenus par le prestataire soient conformes à ses engagements.

Le contrôle social

*ITEM 1 : S'assurer de la convergence des objectifs ...

**ITEM 2 : S'assurer de la compatibilité des objectifs non-convergents ...

Cela exige de mettre en place des dispositifs pour que les objectifs de sécurité et de sûreté du CEA et du prestataire soient convergents entre eux (*item 1) et pour que les objectifs non convergents se combinent bien entre eux (*item 2).

Clôture d'entretien

Adresse d'email pour le compte rendu :

Pourrais-je vous solliciter de nouveau pour des questions ?

Appendix C: Additional information on the Epistemological Assumptions of the Thesis

As detailed in subsection 1.2 of Chapter 2, this thesis subscribes to a *critical realism* that relies on a *realist ontology* and a *relativist* or anti-positivist *epistemology*. **Critical realism** has evolved over the past years following Roy Bhaskar's (1978) work and exclaims that "*social sciences can be sciences in exactly the same sense as natural ones*" (Bhaskar, 1998a: 17). The term "critical realism" is the merger of two terms: "transcendental realism" and "critical naturalism" (Bhaskar, 1998a). Figure 17 in subsection 1.2 adapted from Burrell and Morgan (1979, p. 3) places critical realism on a philosophical and methodological continuum of two polarized perspectives mentioned above. The purple "X" denotes the position of this research study along each continuum. Each of these four perspectives is viewed from the critical realist perspective and further analyzed below.

- Through its **realist ontology**, it postulates that: "*reality exists independently from human attention. Reality is both intransitive and stratified. Reality is constituted of three overlapping domains [real, actual, empirical]. Generative Mechanisms (GMs) reside in the real domain, observable events occur in the actual domain, and experienced events lie in the empirical domain*" (Avenir and Thomas, 2015, p. 9). According to Danermark et al. (2005), the GMs exist in the real domain, irrespective of whether they produce an event or not. Should the event be produced, then it resides in the actual domain irrespective of whether it is observed or not. When the event is experienced, it yields an empirical fact that exists in the empirical domain. Therefore, in critical realism, the reality studied by scientists exceeds that of the empirical domain (Danermark et al., 2005). In other words, "*reality is assumed to exist but to be only imperfectly apprehendable because of basic flawed human intellectual mechanisms and the fundamental intractable nature of phenomena [...] reality must be subject to the widest possible critical examination to facilitate apprehending reality as closely as possible but never perfectly*" (*Critical Realism Ontology*) (Gabe and Lincoln, 1994, p. 110).
- Through its **relativist epistemology**, it postulates that: "*the real domain is not observable. Events (actual domain) are observable. Experienced events (empirical domain) are knowable*" (Avenir and Thomas, 2015, p. 9). The GMs and structures have emergent power allowing them to produce patterns during the observable events (Bhaskar, 1978, 1998b). The emergent powers appear depending on the contextual conditions and cannot be reduced to their constituent parts (Tsoukas, 1989). Dualism is not possible to maintain and as a result objectivity is considered a regulatory ideal. Enquirors should queri whether "the findings 'fit' with pre-existing knowledge?" and replicated findings are likely true (but subjected to falsification). (*Modified dualist/ Objectivist Epistemology*) (Gabe and Lincoln, 1994).
- Through its **voluntarism human nature**, the causal explanations are not related to the deterministic association of patterns of events but rather to the voluntary activation of causal powers under specific conditions (Tsoukas, 1989). Critical realism aims to "*identify underlying structures and*

GMs that give rise to the flux of phenomena under study”, as well as how the GM are contingently activated (Avenir and Thomas, 2015, p. 8). The identification of generative mechanisms consists of a two-step process, which first inductively identifies patterns and secondly involves the use of abduction to articulate “conjectures” of the probable underlying generative mechanisms and the contingent manner through which they are activated, that may clarify the observed patterns (Bhaskar, 1998c). Thus the researcher first recounts the significant qualities of the events, fathoms possible causes for the generative mechanisms, then by eliminating alternative explanations that do not hold, identifies the generative mechanisms at work (Bhaskar, 1998a; Mingers, 2013), and finally arrives at a theoretical explanation (Avenir and Thomas, 2015, p.8).

- Through its *ideographic methodology* it focuses on individual events, thereby constructing “conjectures” of a specific group of people rather than producing general statements that account for large social patterns as is the case in quantitative monothetic methods. Wynn and Williams (2012) indicate that, from a critical realist angle, the case study is an ideal approach to study the interactions between the events, the actions, the structure and the context so as to identify the causal mechanisms of the phenomenon. Researchers interested in theory building will likely opt for a single abductive case study, while researchers that are interested in theory refinement will opt for a multiple abductive case study. Additionally, Bhaskar (1998b) claims that since social science phenomena only manifest themselves in open systems, the absence of closed systems impedes the prospect of decisive test and prediction (Avenir and Thomas, 2015, p.5). As a result, theory development criteria in social sciences “must be explanatory and non-predictive” (Bhaskar, 1998d, p. 225). The use of qualitative techniques allows the enquirer to falsify hypothesis, “*collect situational information, re-introduce discovery of an element in inquiry [... thereby] soliciting emic viewpoints to assist in determining the meaning and purpose that people ascribe to their actions*” (*Modified Experimental/ Manipulative Methodology*) (Gabe and Lincoln, 1994, p. 110).

Appendix D: Conference Paper 1

Moreno Alarcon, D.P., Vautier, J. F., Hernandez, G., and Guarnieri, F. (2019). Systems Thinking in Risk Management by Preventive and Detective Controls as an Ago-Antagonistic Systems Approach in the French Nuclear Sector. 29th European Safety and Reliability Conference (ESREL2019), Sep 2019, Hannover, Germany.

<http://itekcmonline.com/rps2prod/esrel2019/e-proceedings/html/0243.xml>

Systems Thinking in Risk Management by Preventive & Detective Controls as an Ago-Antagonistic Systems Approach in the French Nuclear Sector

Diana Paola MORENO ALARCON

CRC, MINES ParisTech, PSL- Research University, France. E-mail: diana.moreno@mines-paristech.fr

Jean François VAUTIER

CEA (French Atomic Energy & Alternative Energies Commission), France. E-mail: jean-francois.vautier@cea.fr

Guillaume HERNANDEZ

CEA (French Atomic Energy & Alternative Energies Commission), France. E-mail: guillaume.hernandez@cea.fr

Franck GUARNIERI

CRC, MINES ParisTech, PSL- Research University, France. E-mail: franck.guarnieri@mines-paristech.fr

The French Atomic Energy and Alternative Energies Commission (CEA) employ preventive and detective controls, fundamental elements of risk management in the nuclear facilities of the French nuclear sector. Using an ago-antagonistic systems (AAS) approach, CEA managers balance two ago-antagonistic (AA) forces (preventive and detective controls) that together make an AA couple, to mitigate subcontracting risks. The systemic vision of AAS, underpinned by systems thinking, enables managers to consider the collective impact of adjusting either a single force or both forces, particularly as action(s) on the couple may rebalance the overall system. This paper illustrates how preventive and detective controls meet Bernard-Weil's eight principal characteristics of AAS. The temporal aspect of preventive and detective controls, at the nucleus of the AA model, and their time-sensitive role in averting and detecting an event are also discussed. Examples are provided of how CEA managers mitigate risk through AA couples by pursuing forces and considering them collectively in terms of "both /and" rather than separately in terms of "either/or".

Keywords: Ago-antagonistic Systems (AAS), Risk Management, Preventive Controls, Detective Controls, Management Controls, Subcontracting, Nuclear Sector, Systems Thinking, Defence in Depth, Temporal aspects

1. Introduction

Over the past 50 years, the concept of **defence in depth** has been imperative in nuclear safety and has influenced the design and operation of nuclear facilities, thereby providing an approach to both prevent postulated accidents and mitigate their consequences (INSAG, 1996, 1999). Specifically, this approach enforces the creation of multiple independent barriers or echelons of protection to compensate for potential human and organizational failures, so not to rely on a single level of defence irrespective of its robustness. France's Decree from February 7, 2012, the general rules for nuclear facilities, details the safety framework to be respected by nuclear operators. It promotes the 5 levels of *defence in depth* through the use of access controls, physical barriers, redundant and diverse key safety functions, and emergency response measures. This paper focuses on the first two levels of *defence in depth*: Level 1 addresses the prevention of incidents and of abnormal operations (hereafter referred to as *L1 preventive*

control), while Level 2 focuses on the detection of incidents and failures (hereafter referred to as *L2 detective control*).

This paper proposes the use of an Ago-antagonistic Systems (AAS) approach to analyze and balance *L1 preventive and L2 detective controls* used by the French Alternative Energies and Atomic Energy Commission (CEA) in the prevention and mitigation of three subcontracting risks: (1) the non-application of the normative framework (*relational risk*), (2) failure to obtain expected results (*performance risk*) which may lead to (3) a non-compliance of regulations yielding adversity with external authorities (*compliance and regulatory risk*) (Anderson et al., 2014; Das & Teng, 2000, 2001). Such risks are exacerbated by the organizational distance between two entities of the contractor-subcontractor relationship, an interaction that represents a mere fraction of the risk management system. Our results come from two nuclear facilities at the CEA.

Scholars (Arnold & Wade, 2015; Tosello, et al., 2012; Vautier et al., 2018a) have proposed

Proceedings of the 29th European Safety and Reliability Conference.

Edited by Michael Beer and Enrico Zio

Copyright © 2019 European Safety and Reliability Association.

Published by Research Publishing, Singapore.

ISBN: 978-981-11-2724-3; doi:10.3850/978-981-11-2724-3_0243-cd

3866

Appendix E: Conference Paper 2

Moreno Alarcon D.P., Vautier J.F., Hernandez G., Guarnieri F. (2020) Applying Safety Leadership and Systems Thinking to the Formal and Informal Controls Approach Used in Safety and Risk Management Within the French Nuclear Sector. In: Kantola J., Nazir S. (eds) Advances in Human Factors, Business Management and Leadership. AHFE 2019. Advances in Intelligent Systems and Computing, vol 961. Springer, Cham.

https://link.springer.com/chapter/10.1007/978-3-030-20154-8_44



Applying Safety Leadership and Systems Thinking to the Formal and Informal Controls Approach Used in Safety and Risk Management Within the French Nuclear Sector

Diana Paola Moreno Alarcon¹(✉), Jean Francois Vautier²,
Guillaume Hernandez², and Franck Guarnieri¹

¹ MINES ParisTech, PSL - Research University, CRC, Sophia-Antipolis, France
{diana.moreno, franck.guarnieri}@mines-paristech.fr

² CEA (French Atomic Energy and Alternative Energies Commission),
Gif-sur-Yvette, France
{jean-francois.vautier, guillaume.hernandez}@cea.fr

Abstract. This paper proposes a new approach to risk and safety management, underpinned by systems thinking, applying safety leadership principles to develop and overcome the limits of Management Control Systems (MCS) used in two nuclear facilities of the French Atomic Energy and Alternative Energies Commission (CEA). These facilities execute similar activities by subcontracting, but have different managerial configurations. Using systemic thinking, 18 MCS common to both facilities were identified and an evolution of how one facility implements several of these MCS was observed; pinpointing dimensions of the Empowerment Leadership Model (EML) as a gearshift to this change. This research illustrates how CEA managers implement safety leadership to re-enforce risk prevention in their management of safety and of human and organizational factors. The implications of these findings are discussed by detailing how they may transform current and future MCS contractor-subcontractor practices, thereby responding to the continually evolving demands of the nuclear industry.

Keywords: Management Control Systems (MCS) · Systems thinking · Risk management · Safety management · Subcontracting · Human and organizational factors (HOF) · Nuclear Power Plants (NPP)

1 Introduction

France's nuclear power plants (NPP) generate 70% of the total electricity by means of the 58 nuclear reactors in operation (13% of the worldwide reactors in operation) [1]. Given the consequences of safety anomalies at any of these French NPPs and its impact on human safety, safety management of NPPs is an international issue. Research demonstrates that safety issues in nuclear plants are rooted in human and organizational

Systems Thinking in Risk Management by Preventive & Detective Controls as an Ago-Antagonistic Systems Approach in the French Nuclear Sector

Diana Paola MORENO ALARCON

CRC, MINES ParisTech, PSL- Research University, France. E-mail: diana.moreno@mines-paristech.fr

Jean François VAUTIER

CEA (French Atomic Energy & Alternative Energies Commission), France. E-mail: jean-francois.vautier@cea.fr

Guillaume HERNANDEZ

CEA (French Atomic Energy & Alternative Energies Commission), France. E-mail: guillaume.hernandez@cea.fr

Franck GUARNIERI

CRC, MINES ParisTech, PSL- Research University, France. E-mail: franck.guarnieri@mines-paristech.fr

The French Atomic Energy and Alternative Energies Commission (CEA) employ preventive and detective controls, fundamental elements of risk management in the nuclear facilities of the French nuclear sector. Using an ago-antagonistic systems (AAS) approach, CEA managers balance two ago-antagonistic (AA) forces (preventive and detective controls) that together make an AA couple, to mitigate subcontracting risks. The systemic vision of AAS, underpinned by systems thinking, enables managers to consider the collective impact of adjusting either a single force or both forces, particularly as action(s) on the couple may rebalance the overall system. This paper illustrates how preventive and detective controls meet Bernard-Weil's eight principal characteristics of AAS. The temporal aspect of preventive and detective controls, at the nucleus of the AA model, and their time-sensitive role in averting and detecting an event are also discussed. Examples are provided of how CEA managers mitigate risk through AA couples by pursuing forces and considering them collectively in terms of "both /and" rather than separately in terms of "either/or".

Keywords: Ago-antagonistic Systems (AAS), Risk Management, Preventive Controls, Detective Controls, Management Controls, Subcontracting, Nuclear Sector, Systems Thinking, Defence in Depth, Temporal aspects

1. Introduction

Over the past 50 years, the concept of **defence in depth** has been imperative in nuclear safety and has influenced the design and operation of nuclear facilities, thereby providing an approach to both prevent postulated accidents and mitigate their consequences (INSAG, 1996, 1999). Specifically, this approach enforces the creation of multiple independent barriers or echelons of protection to compensate for potential human and organizational failures, so not to rely on a single level of defence irrespective of its robustness. France's Decree from February 7, 2012, the general rules for nuclear facilities, details the safety framework to be respected by nuclear operators. It promotes the 5 levels of *defence in depth* through the use of access controls, physical barriers, redundant and diverse key safety functions, and emergency response measures. This paper focuses on the first two levels of *defence in depth*: **Level 1** addresses the prevention of incidents and of abnormal operations (hereafter referred to as *L1 preventive*

control), while **Level 2** focuses on the detection of incidents and failures (hereafter referred to as *L2 detective control*).

This paper proposes the use of an Ago-antagonistic Systems (AAS) approach to analyze and balance *L1 preventive and L2 detective controls* used by the French Alternative Energies and Atomic Energy Commission (CEA) in the prevention and mitigation of three subcontracting risks: (1) the non-application of the normative framework (**relational risk**), (2) failure to obtain expected results (**performance risk**) which may lead to (3) a non-compliance of regulations yielding adversity with external authorities (**compliance and regulatory risk**) (Anderson et al., 2014; Das & Teng, 2000, 2001). Such risks are exacerbated by the organizational distance between two entities of the contractor-subcontractor relationship, an interaction that represents a mere fraction of the risk management system. Our results come from two nuclear facilities at the CEA.

Scholars (Arnold & Wade, 2015; Tosello, et al., 2012; Vautier et al., 2018a) have proposed

Proceedings of the 29th European Safety and Reliability Conference.

Edited by Michael Beer and Enrico Zio

Copyright © 2019 European Safety and Reliability Association.

Published by Research Publishing, Singapore.

ISBN: 978-981-11-2724-3; doi:10.3850/978-981-11-2724-3_0243-cd

the use of systemic tools to allow managers to see the system holistically, taking into account the dynamics of the system by focusing on dialogical couples and their effects. The AAS approach, underpinned by systems thinking, combines concepts that have both **antagonistic** (*opposite*) and **agonistic** (*parallel positive*) effects on the system (Bernard-Weil, 2002; 2003). One such ago-antagonistic (AA) couple includes the managerial tools of **preventive** and **detective nature** used in risk management at the CEA. The contractor employs **detective controls** to ensure subcontractors use adequate rules, policies, and procedures (normative guidelines) and also supervises behaviors and results in order to maximize performance (Anderson et al., 2014; Das & Teng, 2000, 2001; Eisenhardt, 1985; Merchant, 1985; Ouchi, 1979). Additionally, **preventive controls** promote shared social values, beliefs, and goals by reinforcing and rewarding appropriate behaviors amongst members of the two firms, thereby averting potential events of the multiple actor interactions within the system (Das & Teng, 2001; Vautier et al., 2018a).

The following section introduces the research constructs surrounding AAS (systems thinking, AAS model, and characteristics of AAS). The next section details the implication of these AAS on managerial controls (preventive and detective controls, and temporal aspect of averting an unwanted event). Finally, empirical references of AA couples at the CEA are provided.

2. Constructs of Ago-antagonistic Systems

2.1. Systems Thinking

A system is a global unit made up of a “set of elements which interact together in a dynamic manner and are organized to achieve a specific goal” (De Rosnay, 1975, 2014).

Systems thinking is a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviors, and devising modifications to them in order to produce desired effects (Arnold & Wade, 2015). These skills work together and are “methodological supports that link knowledge, expertise, and data from various disciplines relating to the same system” (Garbolino et al., 2019). By connecting the units of a system, systems thinking provides a holistic vision that unifies a group of variables and sheds clarity on the effect of their interactions (De Rosnay, 1975, 2014). The resultant global template permits elements of the system to be acted upon either directly or

indirectly by changing a parameter in parallel to the element.

Durand (2006) characterizes the systemic approach by four characteristics:

- Elements within a system must **interact** with each other, performing actions on certain elements while being subjected to actions from other elements. Elements that do not interact are external to the system (Garbolino et al., 2019).
- Elements have irreducible properties (cannot be reduced to the sum of their parts) that transform depending on the degree of agreeability between these elements and on their hierarchy within the system (Garbolino et al., 2019). Durand, (2006) referred to this as **comprehensiveness**.
- The **organization** of the system takes into account the structure of the system and its operations in attaining a common goal.
- The system’s **complexity** can be witnessed by its sensitivity to changes in conditions and by its adaptability constraints (Garbolino et al., 2019). This complexity impedes the ability to predict the dynamics and evolution of the system (Donnadieu & Karsky, 2002).

These four characteristics of the systemic approach highlight the importance of using systemic modeling tools such as an AAS in risk management; particularly as traditional causal analysis tools model events and causal factors linearly. As a result, such traditional tools are not designed to analyze complex interactions between actors, the temporal and spatial gaps between these actors or their consequences (Goh et al., 2010). Given the importance of the interactions between actors (subcontractor-contractor) and the temporal aspects of *L1 preventive* and *L2 detective controls*, a systems thinking approach is extremely pertinent.

2.2 Ago-antagonistic Systems Model

The French endocrinologist E. Bernard-Weil formalized AAS during his work on adrenal-post-pituitary interactions and later applied this model to successfully solve other endocrine disorders (Nunez, 1997). To date, this model proposes a more abstract and theoretical application to numerous scientific fields (Bernard-Weil et al., 1975; Corbel et al., 2007; Martinet & Payaud, 2006; Zouaghi & Spalanzani, 2009). The term “ago-antagonistic” (AA) is composed of two terms: **antagonistic** meaning “*opposite effects*”; and **agonistic** meaning “*parallel positive effects*” (Bernard-Weil, 2002; 2003). The AA approach consists of

analyzing couples whose forces have both “opposite, **antagonistic effects** on certain receivers of these actions” and “parallel positive, **agonistic effects** on other parts of the same receiver”, thereby “taking into account the unity to which both sides belong” (Bernard-Weil, 2002; 2003).

Our AA model, illustrated in Figure 1, contains four components: two forces (x - preventive controls, y -detection controls), a regulator (CEA) and a receiver (subcontracting risks). This systemic vision enables the regulator to consider the collective impact of adjusting either a single force (x or y) or both forces (x and y), particularly as action(s) on the couple may rebalance the overall system (Bernard-Weil, 1999, 2003).

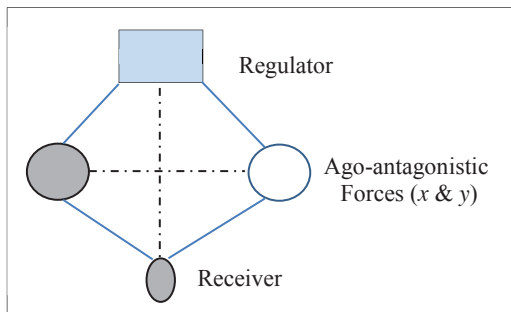


Fig. 1. Ago-antagonistic Model of risk management at the CEA.

2.3. Characteristics of Ago-antagonistic Systems

AAS can be identified by eight (8) principal characteristics (Bernard-Weil, 1975; 1999; 2003; Zouaghi & Spalanzani, 2009): *The first* defines an AA couple, whose poles have opposing actions on one part of the receiver and actions in the same direction on another part of the receiver (see Figure 1). *The second* denotes AAS as a dissipative system, a thermodynamically open system defined by Nobel Lauriat Prigogine, which describes equilibrium against a standard or a reproducible ready state. Mathematically AAS has two equilibrium states: a physiological equilibrium (if the standards are respected) and a pathological equilibrium (run on poor standards). As a result, equilibrium will oscillate around the equilibrium point known as equilibrium constant. *The third* describes an AA network made up of a combination of AA elementary couples. This network is organized into competing pressures of hierarchy and autonomy, explaining how an action on one part of the network can rebalance

the entire network. *The fourth* is the concept of constituent division whereby one force acts in its own interest and simultaneously for the common interest of the system. *The fifth* explains that AAS integrates dichotomies, a series of properties typically opposing compatibility with each other (external-internal; dangers-safety; contractor-subcontractor). *The sixth* proposes that AAS have states comparable to pathological homeostasis or autonomy, thereby resulting in unusual strategies within these complex systems. *The seventh* highlights false AA couples such as imbalance and balance, good and evil, which are not AA despite their semantic opposition. *The eighth characteristic* indicates that all models irrespective of their “universality” require a meta-model. However, the meta-model of the AA model is yet to be created or identified.

3. Implications of Ago-antagonistic Systems on managerial controls

3.1. Preventive and detective controls

Controls are tools that avert and mitigate errors and anomalies. When used correctly, *L1 preventive controls* are very effective as they anticipate and preclude undesirable behaviors. These behaviors can also be identified and corrected (but not averted) by *L2 detective controls*. The sequential presence of *L1 preventive* and *L2 detective controls* is dependent on numerous parameters described below (see Table 1).

L1 Preventive controls minimize goal discrepancies between the receptor (subcontractor) and the regulator (contractor) by establishing common culture and values. They can be defined as *a task that aims to ensure the performance of the operating process. This task may not result in action directly influencing the process and are performed by actors who are part of the operating process. These actors, such as the facility chief or safety officer, are stakeholders in the operating process and are entrusted with responsibilities.* *L1 preventive controls* take place *before and during the task.* A directory of verbs used to describe *L1 preventive controls* includes: to ensure, to follow, to organize, to dispense, to review, to program, and to authorize.

L2 detective controls enforce rules, policies, and procedures by monitoring the behavior of the receptor (subcontractor) and by rewarding performance. They can be defined as *a task that aims to detect deviations. This task is performed by actors who are not part of the operating process at this point in time, but rather these actors take an external view of the exploitation process in order to have the most objective view possible when they check for the presence or absence of deviations* during and after the task. A directory of verbs used to describe detective controls includes: to verify, to check, to execute, to effectuate, and to perform.

Table 1. Characteristics of L1 preventive controls and L2 detective controls

	Preventive Control	Detective Control
<u>Aim:</u>	Performance of the operating process	Detect deviations
<u>Task:</u>	May not result in action directly influencing the process	Performed by actors not part of the operating process
<u>Actors:</u>	Internal view (part of the process) Entrusted with responsibilities	External view (objective) when checking for deviations
<u>Temporality:</u>	Prior to & during task	During & after task

3.2. The temporal aspect of averting an event

Events frequently occur either during or after the completion of an activity, as a result of the dysfunction that took place during the activity. Therefore, the most effective time to control and avoid potential events is either prior to the task (*L1 preventive control*) or during the task (*L1 preventive control and/or L2 detective control*). In contrast, a control that is carried out after the task such as an *L2 detective control* serves to verify results but is futile to prevent potential events given that such controls often take place after the event, therefore are unable to detect and correct the actions that set the event in motion. Nonetheless, once the event is in motion, such *L2 detective controls* are effective in detecting the event (see figure 2 below).

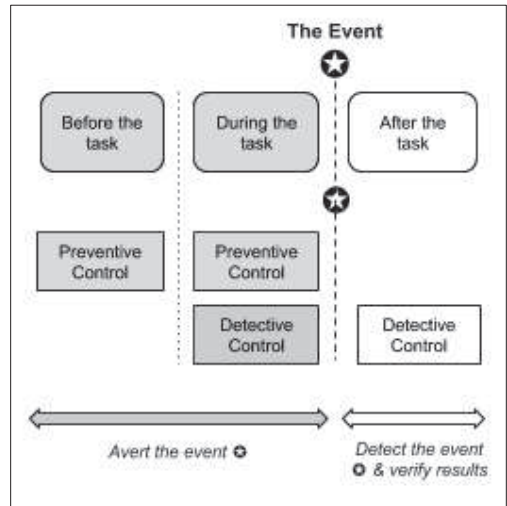


Fig. 2. The temporal aspect of management controls used in the prevention of an event

The temporal aspect of risk management and the additional parameters of *L1 preventive* and *L2 detective controls*, detailed above, are the nucleus of this AA model. Specifically, *L1 preventive* and *L2 detective controls* act from an **antagonistic point of view** (*crossed actions in opposite directions*) with regards to when the controls take place (before/after the activity) and with regards to the actor’s position (internal and part of the operating process/ external and not part of the operating process). These managerial controls also act from an **agonistic point of view** (*parallel actions in the same direction*) with regards to the common regulator (contractor) and receptor of the forces (subcontractor) as well as their joint aim in safety management of decreasing risks, events.

When analyzing risk management using AAS, it is possible to extrapolate many of the characteristics presented in section 2.3 and apply them to management controls. *The first* characteristic allows us to identify preventive and detective control as an AA couple. *The second* reinforces our intuition that risk management is a dissipative system (not static) with a set of oscillating equilibrium constants (ideal balances between preventive and detection control). *The third* can also be applied to risk management, which consists of a network of management controls whose actions on one couple (by way of preventive and detective

controls) may rebalance the network thus preventing potential events. *The fourth* highlights the heterogeneity and constituent division of the *preventive-detective control* dynamics. On one hand, *preventive controls* act in their own interest (as an independent barrier) to avert potential events and focus on an internal view of the operating task, while simultaneously providing a protection layer to compensate for human and organizational failures. On the other hand, *detective controls* offer their own independent external and objective view of the operating process and come into force at the failure of prevention controls, while concurrently working in unison as a protection system to maintain safe operations should an event occur. *The fifth* integrates dichotomies present in risk management via incompatible elements such as subcontractors who may act in their own interest (the basis of non-cooperation in relational risk); while concurrently conforming to converging safety objectives (preventive social control). Similarly, the *co-operation* between subcontracting firms when one firm trains another while at the same time *competing* for knowledge acquisition and performance. *The sixth* highlights the pathological homeostasis or autonomic state of risk management, which yields alternative strategies such as multi-layered safety barriers that, may seem incompatible with traditional business practices that focus on benefit-cost ratios. *The seventh* emphasizes false ago-antagonists couples, which are not prevalent in risk management. *The final characteristic* describes the need to identify the meta-model of risk management. This model would offer a tool to analyze both unwanted (conceived) situations as well as unimagined events. Therefore, after careful study of the eight characteristics of AAS, risk management through *L1 preventive and L2 detective controls* is a type of AAS.

4. Preventive and Detective Controls: An Ago-antagonistic System - Empirical references of Ago-antagonistic Couples at the CEA

For any single task, multiple types of control can be used depending on the type of risk one aims to mitigate. Certain tasks such as those surrounding Safety & Occupational Safety require both actions of prevention & of detection. The following provides several

empirical references of the use of *L1 preventive* and *L2 detective controls* at two CEA nuclear facilities:

4.1 Example 1

In order to ensure Health and Occupational Safety (H&OS) objectives are being met, the CEA carries out three controls: A safety brief called "**Safety Minute**" to prevent potential **relational risk and compliance and regulation risks** that is used before the task (*L1 preventive control*); A safety inspection (*L2 detective controls*) to verify the application of H&OS procedures during the task; and once again re-applies a *L1 preventive control* in the form of a "Safety Minute", until the next task; thereby, reinforcing the *L1 preventive controls* at the beginning and at the end of each task.

4.2 Example 2

According to the literature (Anderson et al., 2014; Eisenhardt, 1985; Hopwood, 1976; Merchant, 1985; Ouchi, 1979) **results** are often controlled after the task using *L2 detective controls* to "*ensure the subcontractor obtains results that comply with their commitments*" (Moreno Alarcon et al., 2019; 2020), thereby mitigating **performance risk and compliance and regulatory risks**. However, the CEA prefers to mitigate such risks by using also an *L1 preventive control* during the task to "*ensure the procedures are performed according to the pre-determined specifications*" (Moreno Alarcon et al., 2019; 2020). These examples indicate a transition in the ratio of controls used, moving towards a new balance of risk prevention by augmenting Level 1 controls.

4.3 Example 3

The **co-activity meeting** is a type of *L1 preventive control* that takes place before any activity, to discuss the day's tasks, elements of concern, previous experiences and points to consider while performing these tasks. Additionally, prior to each (high-risk) activity, **operational preparation** occurs in the form of a detailed **pre-job briefing** meeting, an *L1 preventive control* that details the order of procedures to be performed and the presence of "**stop points**". A stop point is a clearly

designated “pause moment” during which the activity is halted, and the contractor (CEA) is called upon to verify the activity and to sign a document validating the task (*L2 detective control*); once authorized the subcontractor can continue with the activity. During the stop points, the contractor is not part of the initial operating process and therefore has an external objective view while inspecting the activity for the presence or absence of deviations.

At the end of this activity, a debrief of the subcontractors known as a “**return on experience**” is conducted to: *determine if the results were obtained; discuss issues or concerns during the manoeuvre (completion of the task, procedures and documents, equipment or tools, planning of the activity); determine points that were missed during the pre-job briefing; discuss future predicaments to avoid; and propose suggestions for this activity in the future.* This debriefs serves as an *L2 detective control* from which the results will be taken into account the next time this activity is programmed. The information obtained from the return on experience will also be discussed during future *L1 preventive controls* such as future **pre-job briefings** and other operational preparations **prior to the task**. Specifically, this pre-job briefing discusses *the intended results of the activity; the potential risks; the situations prone to errors; the alternative scenarios; and permits the appropriation of the previous returns on experience.*

Conclusion

Risk management in the French Nuclear Industry can be described as a dynamic system with complex interactions between diverse subsystems including contractor – subcontractor; subcontracting risk-management tools, and preventive – detective controls amongst many others. Using systems thinking to model AA forces present in the risk management system, allows managers to identify and balance *L1 preventive and L2 detective controls* used in risk management practices at the CEA. Therefore, it would be pertinent in future studies to comprehend the balancing mechanisms of the detection and prevention controls observed at the CEA. Such knowledge would be of service in designing an approach that incites managers to

balance AA tensions between *prevention and detective controls* by learning to identify when agonistic-antagonistic unbalances have occurred.

After analyzing several empirical examples of current CEA practices, a hybrid multi-level control (Level 1 & 2) synonymous with *defence in depth* strategy can be identified. The hybrid control that appears to be most efficient begins with an *L1 preventive control prior to the task*, shadowed by an *L1 preventive or an L2 detective control during the task*, and finally followed by a *L1 preventive control that will take place between the end of this activity and the next time the same activity is carried out*; thereby preventing future events.

In this way, preventive controls serve as both the alpha and the omega of risk prevention, thereby enforcing the classic safety approach that focuses on prevention of barriers and reducing the probability of event occurrence. Such procedures exist to prevent potential & imaginable accidents but overlook inconceivable accidents. Therefore, the development of a template/tool or meta-model to compare accidents would allow a better understanding of accidents that occur either because the prevention barriers did not function (though the event was conceived) or because the prevention barriers did not exist (because the accident was unimagined and unexpected).

References

- Anderson, S. W., Christ, M. H., Dekker, H. C., & Sedatole, K. L. (2014). The Use of Management Controls to Mitigate Risk in Strategic Alliances: Field and Survey Evidence. *Journal of Management Accounting Research*, 26(1), 1–32.
- Arnold, R. D., & Wade, J. P. (2015). A Definition of Systems Thinking: A Systems Approach. *Procedia Computer Science*, 44, 669–678.
- Arrêté du 7 février, 2012. Arrêté du 7 février 2012 fixant les règles générales relatives aux installations nucléaires de base.
- Bernard-Weil, E. (1992). Agonistic Antagonistic Systemics: An Introduction To Bilateral — and Paradoxically Unilateral — Strategies. *Kybernetes*, 21(4), 47–66.
- Bernard-Weil, E. (1999). La théorie des systèmes ago-antagonistes. *Le Débat*, 106(4), 106.
- Bernard-Weil, E. (2002). Approche des systèmes ago-antagonistes. *Techniques de l'ingénieur*.

- L'Entreprise Industrielle, (AG1575), AG1575-1.
- Bernard-Weil, E. (2003). Ago-antagonistic systems. In *Quantum mechanics, mathematics, cognition and action* (pp. 325–348). Springer.
- Bernard-Weil, E. (2003). *Theorie et Praxis des Systems Ago-antagonistes*, 11.
- Bernard-Weil, E., Duvelleroy, M., & Droulez, J. (1975). Analogical study of a model for the regulation of ago-antagonistic couples. Application to adrenal-postpituitary interrelationships. *Mathematical Biosciences*, 27(3–4), 333–348.
- Corbel, P., Denis, J.-P., & Payaud, M. A. (2007). Ago-antagonisme positivisme/constructivisme: quelques formes de travail épistémique.
- Corbel, P., & Terziovski, M. (2008). Organizational excellence, knowledge and the theory of the firm: To what extent can we build on the Knowledge-Based View of the firm? *THE THEORIES AND PRACTICES OF ORGANIZATION EXCELLENCE: NEW PERSPECTIVES*, 177.
- Das, T. K., & Teng, B.-S. (2000). A Resource-Based Theory of Strategic Alliances. *Journal of Management*, 26(1), 31–61.
- Das, T. K., & Teng, B.-S. (2001). Trust, Control, and Risk in Strategic Alliances: An Integrated Framework. *Organization Studies*, 22(2), 251–283.
- De Rosnay, J. (1975). *Le macrocosme: vers une vision globale*. Éditions du Seuil.
- De Rosnay, J. (2014). *Le macroscopie. Vers une vision globale*. Le Seuil.
- Donnadieu, G., & Karsky, M. (2002). Systemic: Think and act in complexity. *Liaisons*.
- Durand, D. (2006). *La systémique* (10e éd.). Paris: Presses Universitaires de France (PUF).
- Eisenhardt, K. M. (1985). Control: Organizational and Economic Approaches. *Management Science*, 31(2), 134–149.
- Garbolino, E., Chéry, J.-P., & Guarnieri, F. (2019). The Systemic Approach: Concepts, Method and Tools. In F. Guarnieri & E. Garbolino (Eds.), *Safety Dynamics: Evaluating Risk in Complex Industrial Systems* (pp. 1–30). Cham: Springer International Publishing.
- Goh, Y. M., Brown, H., & Spickett, J. (2010). Applying systems thinking concepts in the analysis of major incidents and safety culture. *Safety Science*, 48(3), 302–309.
- Hopwood, A. G. (1976). *Accounting and human behavior*. Prentice Hall.
- INSAG. (1996). *Defence in depth in nuclear safety* (Safety Reports No. INSAG-10) (p. 33). Vienna: International Atomic Energy Agency.
- INSAG. (1999). *Basic safety principles for nuclear power plants: a report by the International Nuclear Safety Advisory Group* (75th-INSAG-3 Rev. 1 ed.). Vienna: International Atomic Energy Agency.
- Martinet, A. C., & Payaud, M. A. (2006). Absorption d'incertitude, enrichissement des stratégies et cadres intermédiaires: une modélisation ago-antagoniste. *Management International Montréal*, 10(2), 29–14.
- Merchant, K. A. (1985). *Control in business organization*. Financial Times/Prentice Hall.
- Moreno Alarcon, D. P., Vautier, J.-F., Hernandez, G., & Guarnieri, F. (2019, July). Applying Safety Leadership and Systems Thinking to the Formal and Informal Controls Approach Used in Safety and Risk Management Within the French Nuclear Sector. In *International Conference on Applied Human Factors and Ergonomics* (pp. 481-492). Springer, Cham.
- Moreno Alarcon D.P., Vautier J.F., Hernandez G., Guarnieri F. (2020) Applying Safety Leadership and Systems Thinking to the Formal and Informal Controls Approach Used in Safety and Risk Management Within the French Nuclear Sector. In: Kantola J., Nazir S. (eds) *Advances in Human Factors, Business Management and Leadership*. AHFE 2019. *Advances in Intelligent Systems and Computing*, vol 961. Springer, Cham
- Nunez, E. (1997). What are ago-antagonistic couples? Their role in normal and pathological situations. *Therapeutical consequences. Psychoneuroendocrinology*, 22, S95–S101.
- Ouchi, W. G. (1979). A conceptual framework for the design of organizational control mechanisms. In C. Emmanuel, D. Otley, & K. Merchant (Eds.), *Readings in Accounting for Management Control* (pp. 63–82). Springer US.
- Tosello, M., Lévêque, F., Dutillieu, S., Hernandez, G., & Vautier, J.-F. (2012). Conditions for the successful integration of Human and Organizational Factors (HOF) in the nuclear safety analysis. *Work*, 41(Supplement 1), 2656–2660.
- Vautier, J.-F., Dechy, N., Coye de Brunéls, T., Hernandez, G., Launay, R., & Moreno Alarcon, D. P. (2018a). Benefits of systems thinking for a human and organizational factors approach to safety management. *Environment Systems and Decisions*, 38(3), 353–366.

- Vautier, J.-F., Hernandez, G., Sylvestre, C., Barnabé, I., Dutillieu, S., Tosello, M., Moreno Alarcon, D. P. (2018b). Averting Inadequate Formulations During Cause Analysis of Unwanted Events. In S. Bagnara, R. Tartaglia, S. Albolino, T. Alexander, & Y. Fujita (Eds.), *Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018)* (pp. 607–612). Springer International Publishing.
- Zouaghi, I., & Spalanzani, A. (2009). Supply chains: ago-antagonistic systems through co-competition game theory lens, 12.



Applying Safety Leadership and Systems Thinking to the Formal and Informal Controls Approach Used in Safety and Risk Management Within the French Nuclear Sector

Diana Paola Moreno Alarcon¹(✉), Jean Francois Vautier²,
Guillaume Hernandez², and Franck Guarnieri¹

¹ MINES ParisTech, PSL - Research University, CRC, Sophia-Antipolis, France
{diana.moreno, franck.guarnieri}@mines-paristech.fr

² CEA (French Atomic Energy and Alternative Energies Commission),
Gif-sur-Yvette, France
{jean-francois.vautier, guillaume.hernandez}@cea.fr

Abstract. This paper proposes a new approach to risk and safety management, underpinned by systems thinking, applying safety leadership principles to develop and overcome the limits of Management Control Systems (MCS) used in two nuclear facilities of the French Atomic Energy and Alternative Energies Commission (CEA). These facilities execute similar activities by subcontracting, but have different managerial configurations. Using systemic thinking, 18 MCS common to both facilities were identified and an evolution of how one facility implements several of these MCS was observed; pinpointing dimensions of the Empowerment Leadership Model (EML) as a gearshift to this change. This research illustrates how CEA managers implement safety leadership to re-enforce risk prevention in their management of safety and of human and organizational factors. The implications of these findings are discussed by detailing how they may transform current and future MCS contractor-subcontractor practices, thereby responding to the continually evolving demands of the nuclear industry.

Keywords: Management Control Systems (MCS) · Systems thinking · Risk management · Safety management · Subcontracting · Human and organizational factors (HOF) · Nuclear Power Plants (NPP)

1 Introduction

France's nuclear power plants (NPP) generate 70% of the total electricity by means of the 58 nuclear reactors in operation (13% of the worldwide reactors in operation) [1]. Given the consequences of safety anomalies at any of these French NPPs and its impact on human safety, safety management of NPPs is an international issue. Research demonstrates that safety issues in nuclear plants are rooted in human and organizational

factors [2–4], all the more important given that safety barriers are designed and built by humans. These concerns apply also to nuclear research facilities operated by CEA.

The International Atomic Agency Report (IAEA) [5] highlights the importance of human factors in nuclear safety and illustrates the lessons learnt from three NPP accidents. The Three Mile Island accident in 1979 acknowledged the existence of non-technical aspects in nuclear operations [5]. The Chernobyl accident in 1986 highlighted the importance of safety culture, management and organizational factors in nuclear safety [5]. The Fukushima Daiichi accident in 2011 accentuated the need to complement traditional safety approaches with a systemic approach, thereby considering the interactions between human, organizational and technological factors that contribute to safety, as well as the complexity of the interrelationship among them [5, 6].

In recent years, numerous scholars have emphasized the need for system-oriented approaches to technical and organizational safety [7–9]. Recent studies demonstrate that safety performance is influenced by leadership [10–16]. Additionally, the IAEA reports [5, 6] call for effective leaders as leadership is viewed as a “shift lever” for safety culture and as an important precursor to obtaining high levels of safety [5, 6, 12–14] and hence an antecedent to effective safety management. Such statements affirm the importance of applying safety leadership principles underpinned by systems thinking to organizational controls used by the French Atomic Energy and Alternative Energies Commission (CEA) in their safety and risk management practices. These nuclear facilities subcontract a percentage of their work that yields strategic and economic advantages [17], but may expose both parties to a great deal of risk [9, 18] as for example each organization may have different agendas [19]. This risk is exacerbated by the organizational distance between two separate entities of the contractor-subcontractor relationship. However, MCS such as *formal controls* (*rules, policies and procedures for monitoring and rewarding performance*) and *informal controls* (*shared values, beliefs*) contain limits since most are based on the observation and evaluation of the elements declared by the subcontractor as the contractor is not physically present to observe and evaluate all the safety items.

As such, attention is drawn to the empowerment leadership model (ELM) [20] one of the most recent models to emerge in the safety leadership literature surrounding NPPs [12–14] that accounts for task and person focused behaviors. Empowering leadership occurs when the leader shares authority and allocates responsibilities and autonomy to his team members by augmenting the meaningfulness of their work, by conveying confidence in high performance, and by encouraging participation in decision-making [21].

This study identifies several dimensions of the ELM at the source of several changes in the formal and informal controls implemented in safety management practices at one of the nuclear facilities of the CEA. By combining a systems thinking approach to safety leadership with a systems thinking approach to MCS, managers can complement task oriented MCS practices with the more human approach of leadership. The following sections introduce the research constructs (systems approach, MCS, safety leadership) and the leadership model utilized in this study.

1.1 The Systems Approach

Systems approach and systems theory has been progressively recognized within the safety science literature as an essential factor in examining safety within complex socio-technical systems [4, 5, 7, 8, 22] and as an important complement to traditional safety approaches. The systemic approach to safety addresses a complex system of interactions across every level of the organization, by initially identifying interactions between human, organizational and technological factors and then considering the complexity of the interrelationship amongst them [5, 6, 23]. Consequently, the CEA employs a systems thinking approach in their HOF approach to safety that is concerned with “human failure and the unsafe acts carried out by workers, as well as the factors within the system that influence human performance directly or indirectly; viewed from a human and social science perspective” [8] across different levels of the organization.

Safety is viewed as a “control problem” and safety is managed by a control structure embedded in an adaptive socio-technical system [23]. Accidents or incidents are the result of degradation in the safety system’s performance due to the interaction of several causal factors at multiple-levels (component failures, external disturbances, and/or dysfunctional interactions among system components) rather than a single causal factor at a single level [23]. Therefore, preventing accidents requires designing a safety control structure that is large enough to encompass all of the managerial factors that influence the system’s development and its operations [23]. As such, system thinking in combination with organizational tools can provide opportunities for productive dialogues and methods for leaders to create and implement fundamental changes and improvements within the organization leading to sustained superior safety performance.

Safety may be considered as a social activity and management cannot bring about effective safety performance alone [24]. Instead, in a “plural leadership perspective” [25], leadership roles (skills and responsibilities) can be dispersed throughout different levels of the organization over time, permitting multiple actors to adopt leadership roles encourages more widespread implementation and adoption of safety practices; thereby enhancing safety compliance.

1.2 Management Control Systems (MCS)

Management control is the process by which managers influence other members of the organization to implement the organization’s strategies. MCS have been described as a collection of control devices that serve as “*a system of organizational information seeking and gathering, accountability and feedback designed to ensure that the enterprise adapts to changes in its substantive environment and that the work behavior of its employees is measured by reference to a set of operational sub-goals (which conform to overall objectives) so that the discrepancy between the two can be reconciled and corrected for*” [26] (p. 8). Given this definition, MCS are useful in the management of both intra-organizational and inter-organizational actors [27] such as the contractor-subcontractor relationship that due to the distance between firms requires a resourceful management of systems and controls.

The development and implementation of **formal** control mechanisms and **informal** control mechanisms in an organization enables managers to strategically obtain results [28, 29]. An organization has two types of formal controls [22, 30]: behavior and output controls. **Behavior controls** or process controls standardize the work process using prescriptive rules, policies and procedures often measuring the behavior to ensure the process is appropriate and performed according to the pre-determined specifications [18, 29–31]. Behavior controls ensure the subcontractor adheres to safety regulations by applying rules and behavior prescribed by the contractor or the external regulatory authorities. **Output controls** measure the results of this behavior through a feedback control process that contrasts output measures with performance and organizational objectives [18, 29–31].

Output control serves as an accurate assessment of key performance measures, allowing contractors to adjust changes to those measurements thereby ensuring subcontractors implement their skills and resources to obtain results that comply with safety regulations. Finally, **informal** or **social controls** minimize goal discrepancies between the contractor and the subcontractor by establishing common culture, values and beliefs [18, 30, 31], thereby ensuring the convergence of objectives or the compatibility of non-convergent safety objectives.

Given the complexity and the plethora of managerial controls, it is essential to explore the design of MCS using a systems thinking approach, in order to identify the most suitable design components and their interactions at multiple levels of the organization. However, research indicates that the simple reinforcing of rules and procedures is insufficient to foster safe workplace behaviors; therefore, it is essential to complement MCS with other elements to ensure positive safety behavior outcomes.

1.3 Safety Leadership

Leadership is recognized as a key element in safety culture and an integral part of safety management within NPP [5, 6, 12–14]. **Safety leadership** is a “*process of interaction between leaders [managers] and followers [subcontractors], through which leaders could exert their influence on followers to achieve organizational safety goals under the circumstances of organizational and individual factors*” [10]. A central feature of leadership (in contrast to management) is the embodiment of processes through non-coercive influence [12, 32]. Instead, the leader uses his capabilities and competences to persuade individuals and groups to perform activities that they would not have initially carried out had their leadership not been enforced [12, 16, 33].

Empirical studies from a variety of industrial sectors (manufacturing, construction, chemical industries, metal processing and the food industry) have studied well-known leadership approaches such as transformational leadership [16, 32–34] and leader-member exchange (LMX) [35]. Through LMX, employees have a greater propensity to commit themselves to safety and maintain an open communication about safety when they consider the organization supports them and when they sense a high quality relationship with their leaders [35, 36].

Burns [37] proposes two leadership styles: **transactional leadership** that resembles formal MCS as it focuses on compliance of contractual obligations by establishing objectives, monitoring and controlling results [16, 33, 34]; and **transformational**

leadership which parallels informal MCS as it motivates followers to improve performance by transforming followers' attitudes, beliefs and values as opposed to simply training compliance) [16, 33, 34]. Burns [37] believed that transformational leadership and transactional leadership are at opposite ends of a continuum. However, Bass [34, 38] suggested that transformational leadership augments the effects of transactional leadership by encouraging followers to exceed expected performance, yielding follower satisfaction and commitment to the group and organization [34].

Leadership studies on safety performance in the nuclear industry are limited, but have been studied at different managerial levels. At the medium management level, communication and feedback were associated with safety performance [39]. At the senior level, leaders with stimulating, individually considerate and rewarding leadership styles impacted workers' behaviors and obtained better safety results [11]. Another study advocates that the most effective leadership style at all leadership levels in NPP is one characterized by flexibility, the development and implementation of new ideas and the encouragement of new initiatives [40]. All of these studies emphasize the importance of supervision levels in NPPs and the leadership style of those supervisors, as effective safety leadership results from maintaining a balance between caring and controlling [38].

Literature on MCS and leadership complement each other and may improve the understanding and implementation of safety practices in NPP among all levels of the organization [32]. While MCS provide effective, measurable and transparent manners of shaping and controlling human behavior, they may be criticized as lacking concern for human characteristics such as the need for motivation, flexibility and personal development [32]. On the other hand, while safety leadership drives loyalty, safety culture and social dynamics through non-coercive actions, such leadership criteria are difficult to quantify and measure, making it difficult to determine leadership performance [32]. Due to the complementing nature of MCS and safety leadership, successful integration of one into the other's implementation can make a significant impact in the organization's safety management practices.

The present study aims to expand the findings of Safety leadership and Management Contract Systems in the Nuclear Industry in three ways. First, by highlighting the similarities between transactional and transformational leadership styles used in safety management and formal and informal MCS used in the prevention and mitigating nuclear related subcontracting risks. Second, by employing the empowerment leadership model (detailed in the following section) that includes elements of both transactional and transformational leadership, to better comprehend the evolution of certain MCS observed at one of the nuclear facilities. Finally, by illustrating how CEA managers employ an empowerment leadership approach that accounts for human factors (*person-focused*) to reinforce organizational MCS practices (*task-focused*).

1.4 Empowering Leadership (EL)

The ideal type of leadership style instrumental in the highly regulated work context within NPP remains inconclusive, particularly as most leadership theories focus on enhancing effectiveness and efficiency of employee performance neglecting the safety aspect, a core element of NPPs. The empowerment leadership (EL) style has been

suggested to embrace leadership behaviors especially relevant for NPPs [12–14], as empowered leaders in the nuclear sector produce compliance with safety procedures and requirements, enhance safety participation behaviors and reduce risky behavior [14]; making it a potential precursor for safety performance. In fact, EL positively enhanced perceived safety behavior of subordinates by means of safety environment in NPPs with both a strong and a weak safety culture [12].

The Empowerment Leadership Model (ELM) proposed by Arnold [20] claims the main function of a leader is to increase (through his or her behavior) the team's potential for self-management. The ELM distinguishes five dimensions that empowering leaders ought to exhibit and can be applied to strengthen the organization's safety systems and procedures. By **leading by example**, the leader demonstrates their commitment to safety and creates cohesion between what is said and done [13]. **Coaching** encourages subordinates to solve problems thus providing members an opportunity to share and increase their knowledge. Member's well-informed ideas and opinions can be integrated through **participative decision making**, therefore, encouraging other members to express their opinions. Disseminating information, that is **informing** members on a regular basis of safety initiatives and changes in procedures; as well as **showing concern/interacting with employees** opens a dialogue and a positive rapport between leaders and team members [13]. Part of ELM's strength and relevance in NPPs is that it amalgamates both **task-focused behaviors** (*informing*) and **person-focused behaviors** (*showing concern*) thereby, on one hand, facilitating the understanding of task requirements, operating procedures and their compliance [12–14], while on the other hand facilitating behavioral interactions and influencing attitudes essential in effective teamwork. As a result, ELM may enhance safety performance by motivating subcontractors to surpass mere compliance with safety standards (via formal safety systems) to encouraging new safety initiatives (via informal safety discussions) that encourage reporting of near misses and minor events.

1.5 Case Study Analysis

The French Alternative Energies and Atomic Energy Commission (CEA) is a French public agency established in October 1945 by General de Gaulle. With 9 research centers across France, the CEA is a leader in research, development and innovation of nuclear and alternative energies.

The research focuses on two nuclear facilities (Facility A & Facility B) in different CEA research centers (Centre 1 & Centre 2). An exploratory pilot study at Centre 2 allowed an understanding of the organizational context (nuclear and subcontracting risks), the organizational configuration (flow of information, regulations and policies) and how control is exercised in this multi-dimensional organization, as well as the work environment and the operational tasks in nuclear facilities. The exploratory results from the pilot study set the context for the comparative case study of Facility A (Centre 1) and Facility B (Centre 2). Both facilities were chosen because they both perform similar activities and subcontract a significant percentage of their work but vary in size and in managerial configurations. Additionally, Facility B has twice the number of personnel as Facility A and exhibit an additional level of managerial control (hereinafter referred to as "middle management") within the subcontracting firm.

2 Method

The research uses abductive reasoning by constantly moving back and forth between theory and empirical data [41, 42] to make sense of the observations. In addition to a close proximity and interaction with the participants of the study throughout the 8 field immersions, the researcher also had strong intervention over a period of 2.5 years with members of the organization, allowing the development of new constructs and discussion of their testability, in-line with a constructive research approach (CRA) [43].

Field immersions lasted between 3 and 10 days and allowed over 250 h of participant observation (meetings, safety procedures, training sessions, examination sessions, operations). A large quantity of empirical data was collected, including internal documents from the subcontracting firm, the CEA and correspondences with the French Nuclear Safety Authority. 31 semi-directive interviews were held with 23 participants across four managerial levels of the subcontractor-contractor entity of Facility A & B. Each interview was recorded, transcribed and analyzed and coded using n-VIVO qualitative analysis software following each data collection phase; allowing a comparative analysis of Facility A & B.

3 Results

A total of 18 categories of MCS used to prevent and mitigate safety related subcontracting risks, common to both facilities, were identified (see Table 1) across six systems levels (subcontractor, supervisor, middle management, senior CEA management within the facility, internal audit department, external regulating body). Of the MCS identified, 15 (over 80%) occurred in the senior management level and demonstrated a link to at least one influencing factors of leadership. Table 1 below categorizes all MCS into formal (behavior/output) and informal (social) controls. These categories identifying the similarities in the timing of their execution with respect to the operation: social controls (S1–S6) took place prior to operations, behavior control (B1–B8) during operations and output controls (O1–O4) after operations. The number of controls performed within each category and the frequency of those controls differed according to the managerial configuration of the facility, the level of management that executes the control and the type of department who organizes the control. Overall, Facility A employs a greater quantity of social controls indicating a more preventative nature, while Facility B places a greater emphasis on behavior controls, possibly due to its larger size, its greater emphasis of managerial presence “on-site”, and its additional level of control (middle management).

Table 1. Categorization of the 18 MCS identified in both facilities 1 & 2 into formal and informal controls (MCS that evolved in Facility B are shown in bold)

Informal controls	Formal controls	
Social controls	Behavior/process controls	Output controls
Health & safety training (S1)	Authorized access (barrier) (B1)	Performance tracking (O1)
Nuclear safety training (S2)	Authorized access (no barrier) (B2)	Tec. contamination inspection (O2)
Document management (S3)	Health & safety inspection (B3)	Radioprotection Inspection (O3)
Co-activity management (S4)	Nuclear safety inspection (B4)	Mastery of operations (O4)
Deputy roles validation (S5)	Conformity with regulations (B5)	
Health & safety exercises (S6)	Procedure validation (stopping points) (B6)	
	Facility inspection (B7)	
	Facility audit (B8)	

Modifications in the implementation of the following three social controls used in safety management were observed in Facility B, from which leadership motivations were identified as the source of these changes.

Co-activity management (S4) entails the programming of operational activities to diminish possible planning and scheduling conflict (incompatibilities where teams may operate in parallel on the same zone or require the same equipment). Co-activity meetings take place at the end of the week with senior managers and middle management to ensure minimal impediments or temporal constraints on the following week's operations. Facility B implemented a daily co-activity meeting each morning with all staff members across four system levels, in order to include subcontractors and supervisors (not previously included in the weekly co-activity meeting) (*ELM dimension: interaction with employees, participative decision-making*).

Health & safety training (S1) is typically scheduled several times during a safety week, followed by health and safety exercises (S6) carried out without warning by the senior CEA management within the facility. Facility B has formalized this training, led by middle management, in its daily morning routine as a final "safety minute" segment of the co-activity meeting (*ELM dimension: coaching, leads by example*).

Document management (S3) procedures consist of notifying the subcontracting firm (middle management, supervisors, subcontractors) of new documents or updated versions via email and the document platform. Facility B implemented a sequence of meetings between (1) senior and middle management and (2) middle management and their subordinates (subcontractor and supervisor level) to formalize the dissemination of new documents to all members of the organization (*ELM dimension: informing*).

4 Discussion and Conclusion

The results obtained in this study provide support for the importance of applying systems-based methods to the examination of MCS as well as the value of leadership practices in safety management. This comparative study was found to be a suitable method to identify differences in management practices across two nuclear facilities in the French nuclear sector and to demonstrate that managers across all levels of the facility can provide the necessary leadership where safety is a prime strategic objective. All 18 MCS practices were mapped-out across multiple system levels, providing insight into the distance between all elements and their connection to safety leadership.

The evolution in MCS practices in Facility B provided three examples of how senior management (CEA) and middle management (subcontractors) used leadership to reinforce risk prevention in their management of safety and of human and organizational factors. These three modifications to safety management identified across several system levels within the organization suggest a new approach to transform current and future MCS contractor-subcontractor practices. By promoting the five dimensions of empowered leaders (*leading by example, coaching, participative decision-making, informing, and showing concern/interacting with employees*), that combine transactional leadership and transformational leadership, managers can detect inadequate safety behaviors or results (through MCS) and transform them using ELM principles for improved safety results. Specifically, changes in **co-activity management (S4)** (daily meeting with all staff members) *increased interactions with employs* and encouraged subcontractors to voice suggestions for daily operations, discuss contingencies in case of unexpected operational changes, thereby promoting a cohesive subcontractor-contractor entity through *participative decision making*. Such person-focused behaviors encourage new safety suggestions or initiatives and reinforce an environment to report near misses or minor events. Similarly, the formalization of daily **health and safety training (S1)** via “safety minute” led by middle management provided a communication platform to voice safety related concerns, cue safety reminders, and to identify areas that require further *coaching*. Leaders *lead by example* as they demonstrate their commitment to safety thereby re-enforcing organizational safety commitment. Finally, changes in **document management (S3)** at the senior and middle management level made a significant impact in the dissemination of information to subcontractors and supervisors, as the previous system made it virtually untraceable to determine if the documents were read (feedback was optional). By implementing a meeting with all middle management to notify them of new documents or changes to existing documents, it ensures tractability of new procedures. Next, a formal meeting where a middle manager could inform their department subordinates of these changes, ensured the dissemination of crucial safety references, and provided a time-period to voice concerns with new guidelines.

Application of safety leadership to MCS practices encourages the implementation of new ideas and initiatives while enhancing safety participation behaviors and encourages broad adoption and compliance of safety practices across multiple systemic levels of the organization. This is because safety leadership provides managers with a platform to demonstrate their commitment to safety and their concerns for employee

welfare through a more relaxed and recurrent exchange of communication compared to the harsh and less frequent examination of MCS; thereby encouraging subcontractors to adopt safety-related organizational citizenship behaviors, as a united contractor-subcontractor business entity. Overall, the formalization of the aforementioned safety controls (document management, daily health & safety training & inclusive co-activity meetings) encourages middle management to lead these changes and develop into an “ambassador” between the two firms. This additional managerial level (only present in Facility B) provides the first two systemic levels of the subcontracting firm with an initial intra-firm control. Subcontractors and supervisors feel more at ease to first evoke any safety concerns or near misses to managers within their immediate firm. Middle managers can, therefore, serve as an intermediary between subcontractors and senior management to disseminate information, encourage communication and promote safety leadership thereby promoting unity across both organizations. Application of leadership practices may help overcome the limits of MCS that arise when the controllers (senior management in over 80% of these controls identified in this study) are not present to evaluate or confirm results. As a result, a “plural leadership perspective” presents a potential method for achieving effective MCS in the ever-changing demands of the nuclear industry.

References

1. International Atomic Energy Agency: Nuclear Power Reactors in the World, Reference Data Series No. 2. IAEA, Vienna (2018)
2. Carnino, A., Nicolet, J.-L., Wanner, J.-C.: *Man and Risks: Technological and Human Risk Prevention*. Marcel Dekker (1990)
3. Perrow, C.: *Normal Accidents: Living with High Risk Systems* (1984)
4. Reason, J.: *Human Error*. Cambridge University Press, New York (1990)
5. International Atomic Energy Agency: IAEA Report on Human and Organizational Factors in Nuclear Safety in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant. IAEA, Vienna (2014)
6. International Atomic Energy Agency: *Leadership and Management for Safety*, IAEA Safety Standards Series No. GSR Part 2. IAEA, Vienna (2016)
7. Leveson, N., Dulac, N., Marais, K., Carroll, J.: Moving beyond normal accidents and high reliability organizations: a systems approach to safety in complex systems. *Organ. Stud.* **30**, 227–249 (2009)
8. Vautier, J.-F., Dechy, N., Coye de Brunélis, T., Hernandez, G., Launay, R., Moreno Alarcon, D.P.: Benefits of systems thinking for a human and organizational factors approach to safety management. *Environ Syst. Decis.* **38**, 353–366 (2018)
9. Jari Kettunen, T.R.: Safety management challenges and tensions in the European nuclear power industry. *Scand. J. Manag.* **23**, 424–444 (2007)
10. Simard, M., Marchand, A.: A multilevel analysis of organizational factors related to the taking of safety initiatives by work groups. *Saf. Sci.* **21**, 113–129 (1995)
11. Yule, S., Flin, R., Murdy, A.: The role of management and safety climate in preventing risk-taking at work. *Int. J. Risk Assess. Manag.* **7**, 137 (2007)
12. Martínez-Córcoles, M., Gracia, F., Tomás, I., Peiró, J.M.: Leadership and employees’ perceived safety behaviours in a nuclear power plant: a structural equation model. *Saf. Sci.* **49**, 1118–1129 (2011)

13. Martínez-Córcoles, M., Schöbel, M., Gracia, F.J., Tomás, I., Peiró, J.M.: Linking empowering leadership to safety participation in nuclear power plants: a structural equation model. *J. Saf. Res.* **43**, 215–221 (2012)
14. Martínez-Córcoles, M., Gracia, F.J., Tomás, I., Peiró, J.M., Schöbel, M.: Empowering team leadership and safety performance in nuclear power plants: a multilevel approach. *Saf. Sci.* **51**, 293–301 (2013)
15. Martínez-Córcoles, M.: High reliability leadership: a conceptual framework. *J. Contingencies Crisis Manag.* **26**, 237–246 (2018)
16. Flin, R.: Leadership for safety: industrial experience. *Qual. Saf. Health Care.* **13**, ii45–ii51 (2004)
17. Smith, J.A., Morris, J., Ezzamel, M.: Organisational change, outsourcing and the impact on management accounting. *Br. Account. Rev.* **37**, 415–441 (2005)
18. Das, T.K., Teng, B.-S.: Trust, control, and risk in strategic alliances: an integrated framework. *Organ. Stud.* **22**, 251–283 (2001)
19. Langfield-Smith, K., Smith, D.: Management control systems and trust in outsourcing relationships. *Manag. Account. Res.* **14**, 281–307 (2003)
20. Arnold, J.A., Arad, S., Rhoades, J.A., Drasgow, F.: The empowering leadership questionnaire: the construction and validation of a new scale for measuring leader behaviors. *J. Organ. Behav.* **21**, 249–269 (2000)
21. Zhang, X., Bartol, K.M.: Linking empowering leadership and employee creativity: the influence of psychological empowerment, intrinsic motivation, and creative process engagement. *AMJ* **53**, 107–128 (2010)
22. Reason, J., Parker, D., Lawton, R.: Organizational controls and safety: the varieties of rule-related behaviour. *J. Occup. Organ. Psychol.* **71**, 289–304 (1998)
23. Leveson, N.: A new accident model for engineering safer systems. *Saf. Sci.* **42**, 237–270 (2004)
24. Cooper, M., Finley, L.: *Strategic Safety Culture road Map*. BSMS, Franklin (2013)
25. Denis, J.-L., Langley, A., Sergi, V.: Leadership in the plural. *Acad. Manag. Ann.* **6**, 211–283 (2012)
26. Otley, D., Emmanuel, K.: *Accounting for Management Control*. Springer (2013)
27. Dekker, H.C.: Control of inter-organizational relationships: evidence on appropriation concerns and coordination requirements. *Acc. Organ. Soc.* **29**, 27–49 (2004)
28. Caglio, A., Ditillo, A.: A review and discussion of management control in inter-firm relationships: achievements and future directions. *Acc. Organ. Soc.* **33**, 865–898 (2008)
29. Eisenhardt, K.M.: Control: organizational and economic approaches. *Manag. Sci.* **31**, 134–149 (1985)
30. Ouchi, W.G., Maguire, M.A.: Organizational control: two functions. *Adm. Sci. Q.* 559–569 (1975)
31. Anderson, S.W., Christ, M.H., Dekker, H.C., Sedatole, K.L.: The use of management controls to mitigate risk in strategic alliances: field and survey evidence. *J. Manag. Account. Res.* **26**, 1–32 (2014)
32. Morsing, M., Oswald, D.: Sustainable leadership: management control systems and organizational culture in Novo Nordisk A/S. *Corp. Gov. Int. J. Bus. Soc.* **9**, 83–99 (2009)
33. Clarke, S.: Safety leadership: a meta-analytic review of transformational and transactional leadership styles as antecedents of safety behaviours. *J. Occup. Organ. Psychol.* **86**, 22–49 (2013)
34. Bass, B.M.: *Leadership and Performance Beyond Expectations*. Collier Macmillan (1985)
35. Schriesheim, C.A., Castro, S.L., Cogliser, C.C.: Leader-member exchange (LMX) research: a comprehensive review of theory, measurement, and data-analytic practices. *Leadersh. Q.* **10**, 63–113 (1999)

36. Eid, J., Mearns, K., Larsson, G., Laberg, J.C., Johnsen, B.H.: Leadership, psychological capital and safety research: conceptual issues and future research questions. *Saf. Sci.* **50**, 55–61 (2012)
37. Burns, J.M.: *Leadership*. NY (1978)
38. Bass, B.M.: Two decades of research and development in transformational leadership. *Eur. J. Work Organ. Psychol.* **8**, 9–32 (1999)
39. Kivimäki, M., Voutilainen, P., Koskinen, P.: Job enrichment, work motivation, and job satisfaction in hospital wards: testing the job characteristics model. *J. Nurs. Manag.* **3**, 87–91 (1995)
40. Katsva, M., Condrey, S.E.: Motivating personnel at Russian nuclear power plants: a case-study of motivation theory application. *Public Pers. Manag.* **34**, 343–356 (2005)
41. Dubois, A., Gadde, L.-E.: Systematic combining: an abductive approach to case research. *J. Bus. Res.* **55**, 553–560 (2002)
42. Dumez, H.: *Méthodologie de la recherche qualitative: Les questions clés de la démarche compréhensive*. Vuibert (2016)
43. Jönsson, S., Lukka, K.: There and Back Again. Doing Interventionist Research in Management Accounting. *MAR Handbook* (2006)

RÉSUMÉ

Cette thèse fournit une compréhension approfondie de la façon dont le **Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA)** conçoit des **Systèmes de Contrôle de Gestion (SCG)** qui peuvent efficacement éviter et atténuer les risques liés à la sous-traitance en quasi-intégration dans le contexte des caractéristiques spécifiques de ses installations nucléaires. Cette recherche se concentre sur les systèmes de contrôle de gestion (SCG) et plus particulièrement sur les mécanismes de contrôle formels et informels utilisés dans la gestion de la sécurité et des risques liés à la sous-traitance en quasi-intégration au CEA. Cette étude propose une approche systémique de la gestion des risques et de la sécurité qui applique les principes du **Leadership par Responsabilisation** pour renforcer la prévention des risques en dépassant les limites du SCG. Cette approche systémique consiste à intégrer les pratiques de leadership en matière de sécurité à la conception, la mise en œuvre et l'équilibre d'une série de SCG adaptés pour "coïncider" avec les facteurs de contingence spécifiques de chaque installation (Chenhall, 2003 ; Nedaei *et al.*, 2015), créant ainsi un impact significatif sur les pratiques de gestion de la sécurité de l'organisation. Cette recherche utilise une approche qualitative, qui se concentre sur trois installations du CEA, ayant des configurations managériales variables, et ce sur une période de 2,5 ans. Ces installations exécutent des activités similaires, avec une sous-traitance en quasi-intégration, mais elles varient en termes de facteurs de contingence et mettent en œuvre des styles de leadership contrastés ainsi que différents SCG dans leur gestion de la sécurité et des facteurs organisationnels et humains (FOH). La recherche fournit une reconceptualisation de la nature des contrôles qui sont utilisés dans la gestion des risques. Elle définit les **contrôles de prévention et les contrôles de détection** comme des éléments fondamentaux de la gestion des risques en raison de leurs caractères temporels pour éviter et détecter un événement. La mise en œuvre des **Systèmes Ago-antagonistes (SAA)** (Bernard-Weil, 1992 ; 1999, 2003), sous-tendue par la pensée systémique, permet au modèle Ago-antagoniste (AA) d'équilibrer ces précédents contrôles. Cette recherche met en parallèle les **contrôles de prévention** et les **contrôles de détection** qui constituent les deux pôles ago-antagonistes du contrôle, et illustre la façon dont les managers du CEA ajustent les deux pôles pour atténuer les risques de sous-traitance, en tenant compte du fait que l'ajustement d'une seule force ou des deux forces ago-antagonistes peut rééquilibrer le système entier. Un troisième élément - **le Leadership par Responsabilisation** - semble fonctionner comme "un levier de vitesse" permettant de **rééquilibrer les contrôles de prévention et de détection** à la suite de plusieurs événements et quasi-événements dans les installations nucléaires. Cette approche systémique aide les managers à identifier les déséquilibres AA et propose des stratégies pour équilibrer la tension AA. En effet, de petits changements dans le couple AA (Prévention / Détection) en relation avec le **Leadership par Responsabilisation** (via des contrôles interactifs) peuvent avoir un impact et améliorer la sécurité du travail et la sécurité de l'ensemble du système. Par conséquent, cette recherche illustre comment les managers du CEA et les managers dits intermédiaires, c'est-à-dire ceux de l'entreprise sous-traitante, détectent les comportements ou les résultats inadéquats en matière de sécurité par le biais du SCG, puis les transforment en utilisant des pratiques de leadership en matière de sécurité, renforçant ainsi les échanges descendants et ascendants au sein de l'organisation. Les implications de ces résultats sont discutées en détaillant la manière dont ils peuvent transformer les pratiques de SCG actuelles et futures entre des donneurs d'ordres et des sous-traitants, répondant ainsi aux demandes en constante évolution de l'industrie nucléaire. Ces résultats élargissent le **cadre des Leviers de Contrôle (LDC)** de Simons (1995) en illustrant comment les quatre éléments de contrôle s'alignent sur les contrôles de prévention et de détection, s'intègrent dans le cycle de contrôle identifié pour la gestion des risques et peuvent être équilibrés en utilisant une **approche de systèmes ago-antagonistes (SAA)** dans le contexte de l'industrie nucléaire française.

MOTS CLÉS

Systèmes de contrôle de gestion (SCG), Pensée systémique, Gestion du risque, Gestion de la sécurité, Systèmes ago-antagonistes (SAA), Leadership en matière de sécurité, Sous-traitance en quasi-intégration, Facteurs organisationnels et humains (FOH), Centrales nucléaires, Contrôles de prévention, Contrôles de détection.

ABSTRACT

This dissertation provides an in-depth comprehension of how the **French Alternative Energies and Atomic Energy Commission (CEA)** can design efficient and effective **Management Control Systems (MCS)** that fit to the specific characteristics of their Facilities, to avert and mitigate risk associated with quasi-integration subcontracting in the Nuclear Sector. This research focuses on Management Control Systems (MCS) and more specifically the formal and informal control mechanisms used in risk and safety management of quasi-integration subcontracting at the CEA. This study proposes a systemic approach to Risk Management and Safety Management, underpinned by systems thinking through an **Ago-antagonistic (AA) model**, that applies principles of Empowerment Leadership to reinforce risk prevention by overcoming the limits of MCS. This systemic approach consists of integrating safety leadership practices to design, implement and balance a series of MCS adapted to "fit" the specific contingency factors of each Facility (Chenhall, 2003; Nedaei *et al.*, 2015), thus creating a significant impact on the organization's safety management practices. The study employs a qualitative approach, which focuses on three CEA Facilities with varying Managerial configurations over a 2.5 year period. These facilities execute similar activities by quasi-integration subcontracting but vary in contingency factors, implementing contrasting leadership styles and different MCS in their management of Safety and Human Organizational Factors. The study provides a reconceptualization of the nature of controls that are used in Risk Management and defines **Preventive Controls and Detective Controls**, as fundamental elements of risk management due to their time-sensitive role in averting and detecting an event. The implementation of **Ago-Antagonistic Systems (AAS)** (Bernard-Weil, 1992, 1999, 2003), underpinned by Systems Thinking, allowed the model to balance these controls. This study parallels **Preventive Controls** and **Detective Controls** that make up the two ago-antagonistic poles of Control, and illustrates how CEA Managers consider the collective impact of adjusting both poles (as a package) to mitigate subcontracting risks; particularly as adjusting either a single force or both forces, may rebalance the overall system. A third element - **Empowerment Leadership**, appears to be a "gearshift" for several changes to **rebalance Preventive and Detective Controls** following several events and near misses within the nuclear Facilities. This systemic approach supports Managers in identifying when AA imbalances have occurred and proposes strategies to balance the AA tension; as minute changes to the AA couple (Prevention / Detection) in connection with Empowerment Leadership (via interactive controls) can impact and improve the occupational safety and safety of the whole system. As a result, this research illustrates how CEA Managers and Middle Managers detect inadequate safety behaviors or results through MCS and then transform them using safety leadership practices, thus reinforcing descending and ascending exchanges within the organization. The implications of these findings are discussed by detailing how they may transform current and future MCS contractor-subcontractor practices, thereby responding to the continually evolving demands of the nuclear industry. These findings extend Simons' (1995) **Lever of Control (LOC) framework** by illustrating how the four control elements *firstly* align with the preventive and detective controls, *secondly* integrate into the identified Cycle of Control for Risk Management, and *thirdly* can be balanced using an **Ago-antagonistic Systems (AAS) approach** in the context of the French Nuclear Industry.

KEYWORDS

Management Control Systems (MCS), Systems thinking, Risk management, Safety management, Ago-Antagonistic Systems (AAS), Safety Leadership, Quasi-integration Subcontracting, Human and organizational factors (HOF), Nuclear Power Plants (NPP), Preventive Controls, Detective Controls.