



HAL
open science

Applying a descriptive participatory simulation to specific case studies: Adapting the LittoSIM coastal flooding management simulation

Nicolas Becu, Marion Amalric, Brice Anselme, Elise Beck, Anaïs Berry, Xavier Bertin, Benoit Gaudou, Marc Gustave, Ahmed Laatabi, Nicolas Marilleau, et al.

► To cite this version:

Nicolas Becu, Marion Amalric, Brice Anselme, Elise Beck, Anaïs Berry, et al.. Applying a descriptive participatory simulation to specific case studies: Adapting the LittoSIM coastal flooding management simulation. 10th International Congress on Environmental Modelling & Software Society (iEMSs 2020), Vrije Universiteit Brussel, Jul 2020, Brussels, Belgium. halshs-04208497

HAL Id: halshs-04208497

<https://shs.hal.science/halshs-04208497>

Submitted on 15 Sep 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.

Applying a descriptive participatory simulation to specific case studies: Adapting the LittoSIM coastal flooding management simulation

Nicolas Becu,^a Marion Amalric,^b Brice Anselme,^c Elise Beck,^d Anaïs Berry,^a Xavier Bertin,^a Benoit Gaudou,^e Marc Gustave,^f Ahmed Laatabi,^a Nicolas Marilleau,^e Alice Mazeaud,^a Amélie Monfort,^a Cécilia Pignon-Mussaud,^a Guillaume Rieu^a and Frédéric Rousseaux^a

^a CNRS - La Rochelle University, UMR LIENSs, France, nicolas.becu@univ-lr.fr

^b University F. Rabelais de Tours, UMR CITERES, France

^c University Paris 1, UMR PRODIG, France

^d University Grenoble Alpes, UMR Pacte, France

^e IRD-SU, UMI UMMISCO, France

^f La Rochelle University, CEREGE, France

Abstract: Participatory simulation is increasingly being used to raise awareness and support collective action on complex environmental problems. During the design of simulation models, choosing between an abstract (or idealized) model that can be used with a wide range of stakeholders, and a more descriptive (or realistic) model that better fits the expectations of certain stakeholders, is often a dilemma. The LittoSIM-GEN project opts for a descriptive simulation approach, but with the possibility to adapt the content to different geographical conditions, and thus increase its reusability. The LittoSIM participatory simulation aims to reinforce social learning among elected municipal officials and risk managers in relation to prevention measures for coastal flooding management. Participatory simulation workshops were organized with local stakeholders, during which they experienced different prevention strategies and assessed their impact against the results of a flooding simulation calculated by a hydrodynamic model. The software architecture used enables the simulation content (land use map, set of available prevention measures, hydrodynamic conditions, etc.) to be adapted to different geographical configurations (e.g. sandy or cliff coastline, highly urbanized or more rural areas). In addition, the way the project was deployed in the field (e.g. the design of the participatory simulation workshop, the stakeholders and institutions invited) was also adapted from one case study to another. This paper reports on the use of LittoSIM in different case studies carried out in three varying geographic contexts along the French coast: the island of Oléron (Atlantic coast), Camargue (Mediterranean coast) and Dieppe-Criel (Channel coast). The results look at the adaptations to the software, simulation content, and to the field deployment method that were needed in order to meet stakeholders' expectations, fit with how risk was managed locally, and encourage stakeholders' engagement in the participatory process.

Keywords: participatory simulation; genericity; marine submersion; stakeholders; awareness raising.

1. INTRODUCTION

Participatory simulation (PS) is a simulation approach that mixes concepts and methods from participatory modelling, and simulation and gaming (Becu and Crookall 2020). In short, a PS is a simulation/game whose intention is explicitly participative (participants share control over the decisions that affect them). It provides a framework allowing the participants to engage in exchanges about a complex problem and collectively come up with ideas (e.g. strategies, plans) which are beneficial to them.¹ Similarly to other modelling approaches, PS designers face a choice between a descriptive or an abstract representation of the topic at hand. This choice affects the simulation model's genericity, and therefore to what extent it can be reused in other contexts. This paper tackles this problem by

¹ Models used in PS can be either computer models or haptic games. In this paper, we deal only with computer-assisted and/or computer-based PS.

looking at both genericity and case studies using an archetype approach that ensures modularity and reusability. The first part of this paper reflects on the notion of descriptive and abstract models related to PS and what it takes to develop a PS that is generic enough to be applied to different case studies. The second part describes an example of a PS being used to foster social learning in relation to coastal flooding prevention, as well as the methodology chosen to make it more generic so that it can be used in different coastal areas of France. The third part presents the results from three different areas of the participatory process and attempts to increase the programme's genericity. The conclusion sums up the findings and the lessons learned from this experience concerning how to produce a generic PS that is both descriptive and yet can be applied to different case studies.

2. DESCRIPTIVE VERSUS ABSTRACT MODELS IN PARTICIPATORY SIMULATION

Computerized PSs are often based on agent-based models (ABMs; Voinov and Bousquet 2010, Le Page et al. 2011) in which human participants have agent-avatars interacting with other simulation agents. In this section, we first look at abstract and descriptive models in the field of ABMs, before opening the topic up to include PSs.

2.1. Abstract and descriptive models in agent-based models

In the field of modelling, KISS and KIDS are two different approaches to deal with models' levels of simplicity and realism (Edmonds and Moss 2005). KISS advocates building simple models composed of small numbers of elements, but capable of reproducing the complexity of the observed world through its emergent properties. KIDS, on the other hand, recommends maintaining an explanatory approach and tries to make each part of the model structurally similar to the modelled phenomena. Banos and Sanders provide an interesting geographical interpretation of the KISS and KIDS standards used in modelling (Banos and Sanders 2013). They propose two dimensions to visualize and characterize the KISS and KIDS approaches: "reproduction of a stylized/particular fact" and "elaboration of the KISS/KIDS model". Delay built on this concept, describing it in a two-dimensional space: "concept-driven/data-driven" and "simple/descriptive" (Delay 2015).

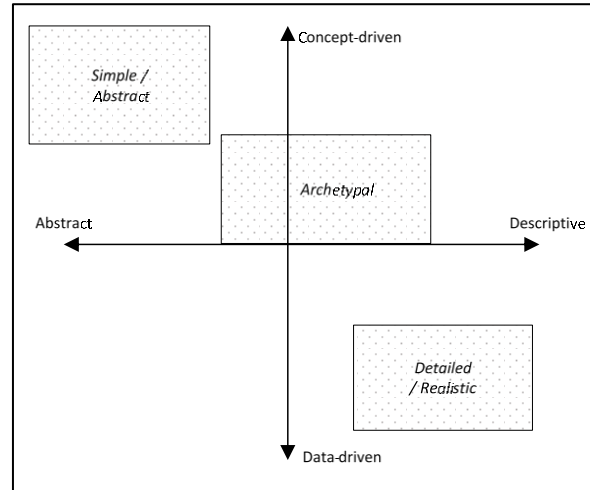


Figure 1: Abstract and descriptive models plotted on the two-dimensional space proposed by Delay (2015)

In Figure 1, we have plotted different types of models in the two-dimensional space proposed by Delay. "Abstract" models are designed models, often with a reduced number of mechanisms. "Realistic" models (quotation marks are used because realism is subjective) aim to describe observed phenomena based on a large amount of data, which often leads to the inclusion of a large number of mechanisms in the artefact. Of course, in between these two extremes are a multitude of configurations, including archetypal models (as opposed to archetypes, which are hypothetical ideal models). With archetypal models, the representation of reality is stylized, and there is an attempt to describe situations that can be found in different places. The design involves incorporating the most noteworthy properties or characteristics of the socio-environmental systems being studied, without getting into too much detail (Le Page et al. 2011). This means, for example, including structures and spatial organizations that are

specific to a region, e.g. the ratios of vegetation strata in a multi-layered Mediterranean forest ecosystem in the case of SylvoPast (Etienne 2003), or the ratio between high-yielding crops and food crops typical of northern Thai watersheds (Becu et al. 2003).

In terms of genericity, descriptive models are problematic. The more an artefact tends to incorporate the observed data from a case study, the more likely it will be accessible only to those who understand the data and know how to interpret it. This can lead to artefacts which can only be used by experts in these data (local actors who are familiar with their areas or experts in a certain field). What's more, the more an artefact tends towards a descriptive representation, the more it will have to include different ways of observing, evaluating and understanding it. This can lead to artefacts that become extremely difficult to comprehend, making it difficult to fully appreciate all the issues at stake without spending too much time on them or without having prior in-depth knowledge of the elements being described. Figure 2 shows schematically the genericity and specificity of abstract and descriptive models.

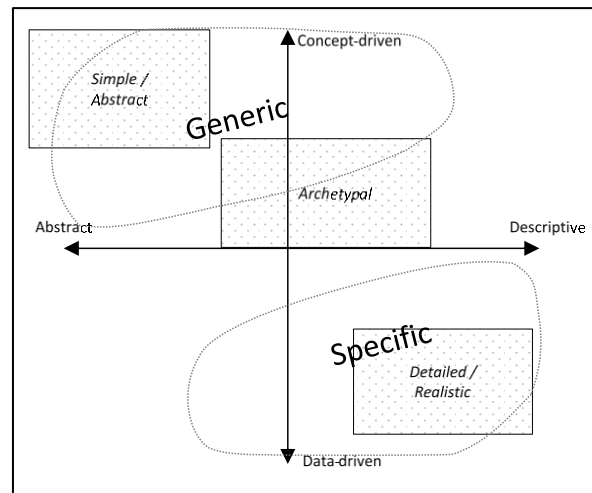


Figure 2: Generic and specific models plotted on the two-dimensional space proposed by Delay (2015)

2.2. Reusability/adaptability of models in participatory simulations

With regard to PS, the “level of realism” of models has been studied by a number of authors (Crookall and Saunders 1989, Ulrich 1997, Crookall 2010, Dormans 2011, Becu et al. 2016, Medema et al. 2016, Amalric et al. 2017, Gourmelon 2017, Le Page 2017). The issue has often been tackled for a pragmatic purpose and aims to answer the question of how a PS can be reused and/or adapted in a different context.

Most practitioners in the domain of companion modelling used to believe that models applied to participatory processes were not meant to be reused since what matters is the modelling process itself and not the resulting model (Etienne 2011). Moreover, it has been argued that spatially explicit and realistic models are not suitable for supporting the exploration of alternative scenarios, as they impose spatial and cognitive boundaries that prevent participants from thinking in a multifunctional manner (Barnaud et al. 2012). This leads many practitioners to prioritize the use of abstract models. The suitability of the spatial representations used depends on the target audience (Gourmelon 2017, Ritschard et al. 2018). In addition, other authors point out that applying a companion modelling process requires prior in-depth knowledge both of the field and local stakeholders (Mathevet et al. 2011). Over the last decade, several studies have proven that the reusability of a PS kit is possible in different contexts, at least for haptic simulation models (Ferrand et al. 2009, d’Aquino and Bah 2014, d’Aquino 2015, Abrami et al. 2016).

The majority of the simulation and gaming community think that the level of realism should be sufficient enough to allow participants to increase their understanding of the interaction system being represented, and therefore meet the objective of fostering systems thinking (Medema et al. 2016). Moreover, practitioners long ago proposed a game-design concept that allows simulations/games to be adapted and reused: the frame-game concept (Thiagarajan and Stolovitch 1979, Stolovitch and Thiagarajan 1980). A frame game is a set of complete game instructions that constitutes a coherent whole and is designed in such a way as to allow the easy integration and replacement of game content relating to a specific case. Thiagarajan has developed and worked with several frame games, which he

uses during facilitation and group coaching workshops, the content of which is continuously adapted to suit the audience (<http://www.thiagi.com/>). During a workshop, he uses several games, whose content he constantly adapts depending on the context and the group's progress. The games he uses are frame games, which have the following characteristics:

- Adaptability and flexibility. The incorporation and replacement of content should allow adaptation to suit the teaching objectives, type of participants and intended use.
- Real-world application. The added content should allow participants to project their reality onto the game and learn skills and concepts applicable to their real work environment.

To succeed in developing a frame game, the authors explain that it is a question of identifying what is content and what is structure in a given game. By separating concept and structure, it is then possible, based on the structure, to describe what constitutes the framework of the game: in other words, the meta-rules and meta-components of the game. From this game framework, new content can be added to create a new game (Figure 3).

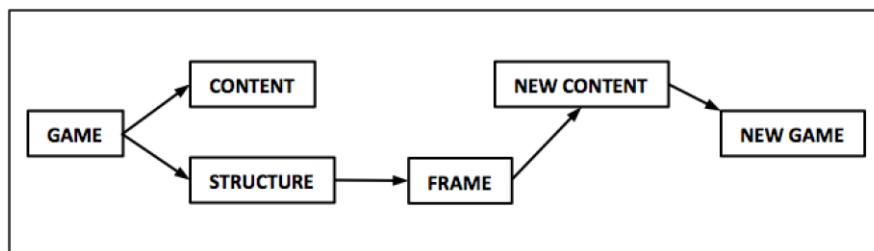


Figure 3: Design of a frame game (source: Thiagarajan and Stolovitch 1979)

A game can then be divided into two parts: the structure (the game framework or frame game) that determines the type of game that can be played, its rules, and the strategies for winning; and the content that provides all the information needed to play the game. Usually the content also includes the game board, which can be constructed from geographical and socio-economic data relating to the application context. Depending on the situation, the learning objectives and skills being developed during a gaming session can result either from the frame game or from the content. Game content can be introduced and replaced in different ways (Thiagarajan and Stolovitch 1979), which generally depend on the type of frame game: game architecture (or kit) or alternative content game. In games with several alternative sets of content, the user can load the content he prefers and often also introduce small adaptations to the available content.

2.3. Reusability/adaptability of participatory mechanisms in participatory simulations

PSs can be used with a range of different end-users (e.g. students, the public, stakeholders). When it comes to using PSs with local stakeholders whose perception of a given issue is influenced by their specific territorial context, it is essential to take the concept of observability into consideration. Klabbers believes that "realism", and by extension the "realism of a model", is too subjective a notion (e.g. Piaget's constructivism theory), and it is therefore more appropriate to ask the question: What are the elements of the simulation that allow users to be able to observe the modelled reference system? (Klabbers 2009). It is to this end that Vinck introduced the notion of the mediating object (Vinck 2009), which is similar to Star and Griesemer's (1989) boundary objects. The idea is to incorporate objects that can speak to the different realities depicted in the simulation artefact. In other words, observability, and therefore subjective realism in the eyes of the participants, depends on elements being incorporated into the artefact which represent the reality perceived by participants. From the model designer's point of view, the following question must be addressed: Can participants project their perception of reality onto the artefact being proposed to them? Depending on the location, this will require an adaptation of the simulation artefact; but this adaptation alone is not enough: it must be able to act as an intermediary between the different subjective realities. From a participatory perspective, choosing between simplicity and realism (abstract vs. descriptive simulations) is not only a matter of learning objectives as described in Crookall (2010); it also depends on how the simulation/game was developed in cooperation with local stakeholders (Amalric et al. 2017). The choice of "realism", and consequently the adaptability of the simulation/game, also depends on the way it is deployed and used in the field. As explained by d'Aquino and Richebourg (2015), in the companion modelling approach, the field deployment of the model, which is a participatory process, is as much about the relationship between local stakeholders as it is about the relationship between those stakeholders and some kind of experts (experts may be physically absent, but their presence is conveyed through the model that is used). The principle of

“endogeneity” (d’Aquino and Seck 2001) considers that the objective of a participatory process should be to support the development of an endogenous territorial dynamic and therefore to create a local environment favourable to the expression and development of local stakeholders’ skills (self-empowerment). It also considers any technical option to involve an ethical and political choice, meaning that territorial planning is above all a political, rather than a technical, act. Consequently, promoting the principle of endogeneity means considering all political means and local skills in order to promote an endogenous process of analysis and collective decision-making, which gradually incorporates long-term issues.

3. AIMING FOR ADAPTABILITY IN A DESCRIPTIVE PARTICIPATORY SIMULATION

LittoSIM-GEN is a research project whose goal is to investigate the potential reusability of a participatory simulation called LittoSIM. LittoSIM aims to promote social learning among elected officials and local risk managers in France in relation to prevention measures for coastal flooding management. The PS was first developed and used on the island of Oléron, on France’s Atlantic coast. The game design was developed in 2016 in partnership with local managers. In 2017, several participatory simulation workshops were organized, during which several groups of participants experienced different prevention strategies and assessed their impact against the results of a flooding simulation calculated by a hydrodynamic model. The PS’s design and its use with stakeholders on Oléron are described in Becu et al. (2017).

Since it was first used, the research team has always taken a territorial approach when using LittoSIM to provide coastal risk management support. As regards the principle of “endogeneity”, this involved trying to cope with, and respond to, end-users’ needs. This strategy has led to a rather descriptive simulation model being chosen, which was an explicit demand from the end-users (local risk managers and elected officials). LittoSIM therefore includes, among other things, topographic and land use maps from national geodatabases, a hydrodynamic coastal flooding model calibrated with field data, and socio-economic data for the case study. It has also led to local partnerships being established in order to adapt the initial simulation model to the unique local characteristics described by partners.

Over the last three years, the research team has worked on applying the LittoSIM approach to other case studies in France, on both the Mediterranean and Channel coasts. The aim is to investigate what it takes to be able to reuse LittoSIM in different geographical contexts (sandy or cliff coastline, highly urbanized or more rural area, etc.). For each new case study, changes were made in the ABM architecture to adapt the model to new requirements, as well as to the participatory deployment method² to cope with local stakeholders’ needs. Beyond this pragmatic aim, the LittoSIM-GEN research project intends to provide answers to the difficult question of the genericity of PSs and, at the same time, of computerized PSs.

The methodology used to work towards the genericity of LittoSIM relies on the frame-game concept, and can be described as follows:

- The different geographical configurations LittoSIM is used on are processed as alternative content for the same frame game. A set of content represents an archetype of a geographical configuration (e.g. rural towns on a sandy coastline exposed to inundation); yet it is first developed based on the data from a specific case study that complies with this geographical configuration.
- When using LittoSIM with a new case study, a new adaptation of the simulation/game is developed and implemented. It can either be based on existing content that corresponds to the case study archetype (in which case, only a few model modifications are required in order to adapt it to local characteristics and requirements), or new content in the form of a new archetype is developed for the platform. The new developments allow the frame-game description to be refined and new game-design configurations and adaptations to be identified.
- Adaptation of the simulation/game’s design and its participatory deployment is partly driven by partnerships with local actors. The goal is to implement LittoSIM with as few adaptations as possible in order to avoid increased complexity.

² The field deployment method involves building a partnership with local partners, setting up a steering committee to decide the adaptations to be made to the simulation/game, and then organizing a series of between two and four PS workshops with participants invited by the local partner.

4. RESULTING GENERICITY AND ADAPTABILITY OF LITTO SIM

The methodology described above has been used in three case studies: the island of Oléron, which was the project’s initial case study; the Camargue delta, located on the Mediterranean coast, which involves the same archetype as Oléron (low sandy coast with small coastal towns); and the Dieppe-Criel area in Normandy, on the Channel coast, which involves a different archetype (high cliff coast, rocky or pebbled, with low-lying urbanized valleys). In addition, adaptations to the model were also made for a fourth case study which has not yet been carried out: the Rochefort estuary on the Atlantic coast, which introduces a new archetype (low-lying estuarine area with a city at the mouth of the estuary). How LittoSIM was applied to each of these case studies is not described here. Instead, we present in this paper the resulting genericity and adaptability of LittoSIM following its use. Since there will be more case, the results presented below might evolve as new case studies are carried out.

4.1. The LittoSIM frame game and its specific content

The first result comes from identifying and processing what belongs to LittoSIM’s frame game, and what is content-specific and can be adapted from one case study to another. To do so, the LittoSIM model and its field deployment method were broken down into different compartments that serve different functions, each linked to one or several devices or components that can be used to fulfil the function. The devices and components that did not require any changes after using the model in four case studies belong to the frame game. The others are content-specific.

The three compartments are the game material required to organize a LittoSIM workshop, the modelling of the system of interactions (the ABM’s software architecture), and the design of the participatory process, which includes the learning objectives, the scenario dealt with during the workshop, and the field deployment method.

COMPARTMENT	FUNCTION	DEVICE / COMPONENT
FRAME GAME		
Material	Individual view for each municipality (one municipality per player)	Touch tablets (one per municipality)
	Collective view for the flooding simulation	Horizontal projection (UST projector)
	Computing power	Powerful computer for submersion numeric computation
Modelling of the interaction system	Coastal defence	Dike management (construction, raising, removal) Alternative coastal defence measures are specific
	Land use management	Action taken on urban land use units (urbanization, densification, flooding adaptation, expropriation) Action taken on natural land use units
	National legislation	Land use and urban planning regulations
	Supra-municipal risk agency	Automatic incentives (bonuses/penalties) Payment/withdrawal of money to a municipality
	Marine submersion hazard	The calibration of the hazard model is content-specific
	Game space	Location of players and risk agency in the room
Design of the participatory process	Learning objectives	Inter-municipality coordination and alternative prevention measures
	Scenario	Mid-game coordination phase between the municipalities
	Workshop participants	Mix participants (elected officials and risk managers) Participants play a municipality different from their own
	Field deployment method	Partnership with local co-project leaders
CONTENT-SPECIFIC		
Material	Explaining game rules	Memo sheet of game actions and briefing
Modelling of the interaction system	Coastal defence	Coastal sand dunes (dune fencing, back dunes, etc.) Pebble ridge (pebble filling)
	Land use management	Actions on agricultural land use units
	Demography	Demographic evolution
	Economic system	Budget of the municipalities based on their population Cost and application delay of measures
	Supra-municipal risk agency	Implementation of an inter-municipality financing plan
	Marine submersion hazard	Calibration of the overflowing model Calibration of damburst probability during flooding events
	Spatial representation of the area	Topography, bathymetry and area description Land use, urban plan (PLU) and coastal defences Administrative borders and reglementary zoning
Design of the participatory process	Scenario	Succession of marine submersions Specific events (e.g. co-occurrence with river submersion)
	Field deployment method	Adaptations to local governance instruments Adaptations to territorial specificities

Table 1: LittoSIM frame game and content-specific components and devices

Table 1 shows that in each compartment, some components and devices are generic, and others are context-specific. What remains generic in the LittoSIM frame game is the design of a simulation/game for coordination between several municipalities on the adoption of alternative flooding prevention measures to the usual use of dikes. This adoption of alternative measures is constrained by national legislation and a supra-municipal risk agency. The marine submersion hazard is part of the frame game, but the calibration of the hazard model is context-specific, as is the succession of submersions in the workshop scenario. Other participatory aspects that are generic include the mechanism to have participants play as a municipality other than the one they belong to, and the establishment of partnership with local bodies.

4.2. Adaptability and modularity of the software architecture

The context-specific content of the LittoSIM simulation model consists mainly of the spatial representation of the area, which comprises a set of georeferenced data, a set of prevention measures specific to the given archetype, the hydrodynamic conditions that determine the calibration of the overflowing model and damburst probability, and the socio-economic data and demographic evolution conditions (see Table 1). To introduce these content-specific aspects to the software architecture, two mechanisms are used. The first mechanism is adaptability. Model input data and model processes are separated, allowing, by means of a simple user input, a whole package of maps and economic and demographic data for a given archetype to be loaded. Output data are also normalized so that they can be automatically processed and analysed. The second mechanism used is the modularity of the software architecture. The ABM's different components can be configured through a settings file: some can be activated/disactivated (e.g. pebble ridge, back dunes), and others are interchangeable to allow a given function to be simulated in different ways (e.g. demographic evolution). A component that can be "plugged in and out" from the core software can be considered an independent module. The details of the software architecture are described in another paper yet to be published.

4.3. Adaptability of the participatory field deployment method

Different types of adaptations to the field deployment method were required. First, the deployment process needed to be adapted to the way risk was managed locally. The local steering committee in the participatory process should be composed of administrations and institutions which will change from one case study to another. The power relations between stakeholder groups will vary as well, and therefore the organization and functioning of the steering committee may also need to be adapted. For example, in Camargue, the influence of environmental groups was greater than in other case studies, and we therefore had to adapt by giving them a more prominent place on the steering committee. Local governance conditions can also affect the composition of the list of workshop participants. For instance, in Normandy national agencies had a particularly large say in determining coastal risk adaptation strategies was particularly important. Therefore, while maintaining a mix of elected officials and managers, representatives from national agencies were also invited to the PS workshops. These different examples show that the participatory process is inextricably linked to existing regional dynamics and thus needs to be flexible and adaptive.

Similarly, existing means of coastal risk management and adaptation should also be considered. For example, in the case of the Rochefort estuary, LittoSIM workshops were intended to be organized alongside other local methods for raising awareness of coastal risk management among elected officials. In Normandy, existing local pilot projects aimed at adapting low-lying urbanized valleys served as an example for incorporating new actions into the simulation/game. Thus, in these kinds of situations, the use of LittoSIM serves to support and strengthen local risk management policy.

An initial knowledge of and relationship with the local area, and the extent to which local actors discuss coastal risk management, are two factors that also influence the field deployment process. On Oléron, LittoSIM benefited from close relations between the research team and local stakeholders, who already had a clear and shared idea of their policy for adapting to coastal risks. In contrast, LittoSIM deployment in Camargue was a more exogenous process, and the establishment of a joint risk management strategy is still at an early stage. In such contexts, implementation requires for those involved to come to understand each other, negotiate and seize opportunities of mutual benefit.

The last type of adaptation involves trying to cope with how the local stakeholders observe the coastal risk management system. For instance, in the Camargue delta, the stakeholders consider their low-

lying sandy coastal area to be a very flat area different from an island, and therefore adaptations had to be made to the initial archetype (based on the island of Oléron) in order for them to be able to recognize the characteristics of their territory (e.g. flat topography, back dunes). Taking observability into account is also a way of reinforcing stakeholders' engagement in the process.

5. CONCLUSION

The research findings presented in this paper provide some answers to the questions of genericity and reusability in computerized participatory simulation. To sum up, the LittoSIM-GEN project made it possible to investigate how a participatory simulation can be positioned between a generic and a specific model design approach. From a conceptual point of view, it has been proven that PS genericity can be achieved by defining a set of game meta-rules and meta-components (the LittoSIM frame game). Based on this generic frame game, more specific content can be loaded. Modularity and adaptability are therefore two mechanisms for increasing the genericity of an archetypal simulation model towards greater description and incorporation of specific data (Figure 4).

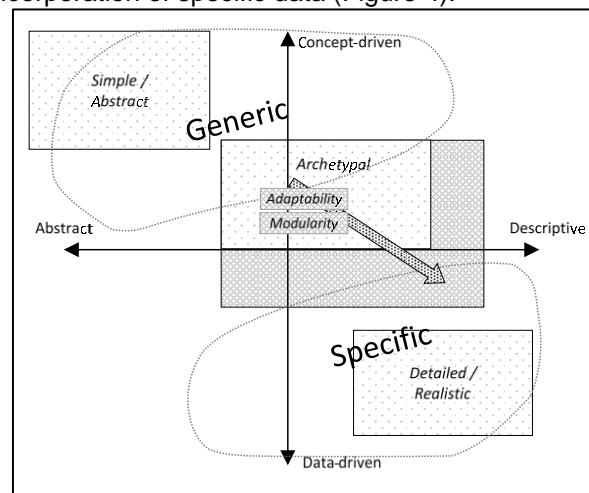


Figure 4: Increasing genericity through adaptability and modularity

Adaptability means incorporating features that allow participants to relate to their own reference context (adapting indicators, adding new game elements, adjusting the game interface and visualization). This ability to relate reflects the concept of observability proposed by Klabbers (2009), and the added features correspond to the notion of mediating objects and their equipment (Vinck 2009). To allow participants to relate the PS artefact with their own reality, the design of the model must incorporate elements that make sense to the different target social audiences. Adapting the artefact to a new context also requires that some features of the simulation model be changed and other new ones introduced. The modularity of the model's structure will then allow practitioners to add or modify features (use cases, calculating dynamics, additional player actions, etc.). Each module must be compatible with both the core structure of the model and with other modules. From an operational perspective, when using computerized PS, the software architecture should be efficient enough to allow the modularity and adaptability to be applied to different components and data sources.

As far as the participatory process is concerned, field deployment was carried out in partnership with local stakeholders. The research findings show that these partnerships were essential to identifying (i) local observability, (ii) who is responsible for managing risk, (iii) and components to be used; and therefore carrying out the consequent adaptations to the deployment method or to the artefact. These partnerships were also necessary in order to understand local expectations and comply with the principle of endogeneity, which aims to support and strengthen local risk management policy. PS deployment therefore needs to be flexible and adaptive. More research is needed in order to evaluate to what extent this necessary flexibility and adaptability of the deployment process is consistent or not with an objective of genericity.

In terms of the continuation of these research findings, the next step is to aim for the transfer and training of the LittoSIM participatory simulation. This objective requires that a consistent kit can be developed, with several alternative sets of content and a sufficiently precise and clear user manual allowing users

to take charge of the organization of a participatory simulation workshop. Assuming that this is possible, the challenge in terms of developing facilitation skills remains considerable. Kriz, as well as other authors, has described this ability to facilitate, its function and the attitude one should have towards participants (Kriz 2010). However, understanding this skill and putting it into practice are two different things. In addition, the transfer and training of a participatory simulation is not only about the ability to facilitate, but also how to convey the participatory intention of the game.

ACKNOWLEDGMENTS

The authors wish to thank their founders, Fondation de France (French Foundation), for the grant concerning the “Future’s Coastline” challenge and the New Aquitaine Region. They also wish to thank all the participants at their workshops, from all the different districts.

REFERENCES

- Abrami, G., Ferrand, N., Ducrot, R., Morardet, S., Hassenforder, E., Garin, P., Robin, P., Aquae-gaudi, W., 2016. Paper and pebbles simulations and modelling for the governance of socio-environmental systems: a review of 8 years of experimenting with the Wat-A-Game toolkit, in: 8th International Congress on Environmental Modelling and Software.
- Amalric, M., Anselme, B., Becu, N., Delay, E., Marilleau, N., Pignon-Mussaud, C., Rousseaux, F., 2017. Sensibiliser au risque de submersion marine par le jeu ou faut-il qu’un jeu soit spatialement réaliste pour être efficace ? *Sci. du jeu* 8, 1–22. <https://doi.org/10.4000/sdj.859>
- Banos, A., Sanders, L., 2013. Modéliser et simuler les systèmes spatiaux en géographie, in: Varenne, F., Silberstein, M. (Eds.), *Modéliser & Simuler: Epistémologies et Pratiques de La Modélisation et de La Simulation*. Paris.
- Barnaud, C., Le Page, C., Dumrongrojwathana, P., Trébuil, G., 2012. Spatial representations are not neutral: Lessons from a participatory agent-based modelling process in a land-use conflict. *Environ. Model. Softw.*
- Becu, N., Amalric, M., Anselme, B., Beck, E., Bertin, X., Delay, E., Long, N., Manson, C., Marilleau, N., Pignon-Mussaud, C., Rousseaux, F., 2016. Participatory simulation of coastal flooding : building social learning on prevention measures with. 8th Int. Congr. Environ. Model. Softw. 98, 1167–1178. <https://doi.org/10.1016/j.envsoft.2017.09.003>
- Becu, N., Amalric, M., Anselme, B., Beck, E., Bertin, X., Delay, E., Long, N., Marilleau, N., Pignon-Mussaud, C., Rousseaux, F., 2017. Participatory simulation to foster social learning on coastal flooding prevention. *Environ. Model. Softw.* 98, 1–11. <https://doi.org/10.1016/j.envsoft.2017.09.003>
- Becu, N., Crookall, D., 2020. Companion modelling and participatory simulation: a glimpse, in: European Geosciences Union Conference. Online.
- Becu, N., Perez, P., Walker, A., Barreteau, O., Le Page, C., 2003. Agent based simulation of a small catchment water management in northern Thailand Description of the CATCHSCAPE model. *Ecol. Modell.* 170, 319–331. [https://doi.org/10.1016/S0304-3800\(03\)00236-9](https://doi.org/10.1016/S0304-3800(03)00236-9)
- Crookall, D., 2010. Serious Games, Debriefing, and Simulation/Gaming as a Discipline. *Simul. Gaming* 41, 898–920. <https://doi.org/10.1177/1046878110390784>
- Crookall, D., Saunders, D., 1989. Communication and simulation.
- d’Aquino, P., 2015. Participatory development of collective rules for natural resource and land management. Lasting effects from the local to the national level. *Perspectives (Montclair)*. 33, 1–4.
- d’Aquino, P., Bah, A., 2014. Multi-level participatory design of land use policies in African drylands: A method to embed adaptability skills of drylands societies in a policy framework. *J. Environ. Manage.* 132, 207–219. <https://doi.org/10.1016/j.jenvman.2013.11.011>
- d’Aquino, P., Richebourg, C., 2015. Participation : le paradoxe d’un dialogue à l’Autre, in: *GIS Démocratie et Participation “Chercheur.e.s et Acteur.e.s de La Participation : Liaisons Dangereuses et Relations Fructueuses.”* Saint-Denis.
- d’Aquino, P., Seck, S. mohammed, 2001. Et si les approches participatives étaient inadaptées à la gestion décentralisée de territoire ? / And if participative approaches were inadaptd to decentralised territorial management ? *Géocarrefour* 76, 233–239. <https://doi.org/10.3406/geoca.2001.2561>
- Delay, E., 2015. Réflexions géographiques sur l’usage des systèmes multi agents dans la compréhension des processus d’évolution des territoires viticoles de fortes pentes : le cas de la Côte Vermeille et du Val di Cembra.
- Dormans, J., 2011. Beyond Iconic Simulation. *Simul. Gaming* 42, 610–631. <https://doi.org/10.1177/1046878111426963>
- Edmonds, B., Moss, S., 2005. From KISS to KIDS- An “anti-simplistic” modelling approach. *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)* 3415 LNAI, 130–144.
- Etienne, M., 2011. Companion modelling - a participatory approach to support sustainable development. Editions Quae.
- Etienne, M., 2003. SYLVOPAST: a multiple target role-playing game to assess negotiation processes in

- ylvopastoral management planning. *J. Artif. Soc. Soc. Simul.* 6.
- Ferrand, N., Farolfi, S., Abrami, G., du Toit, D.R., 2009. WAT-A-GAME: sharing water and policies in your own basin, in: "Learn to Game, Game to Learn", ISAGA 40th Annual Conference.
- Gourmelon, F., 2017. Des formes de simulations multi-agents adaptées à différents contextes sociaux d'apprentissage, in: *Rencontres Jeux et Enjeux*. Université de La Rochelle, La Rochelle.
- Klabbers, J.H.G., 2009. *The magic circle: Principles of gaming & simulation*. Sens publishers, Rotterdam, The Netherlands. https://doi.org/10.1111/j.1467-8535.2007.00725_5.x
- Kriz, W.C., 2010. A systemic-constructivist approach to the facilitation and debriefing of simulations and games. *Simul. Gaming* 41, 663–680. <https://doi.org/10.1177/1046878108319867>
- Le Page, C., 2017. *Simulation multi-agent interactive : engager des populations locales dans la modélisation des socio-écosystèmes pour stimuler l'apprentissage social*. Université Paris 6.
- Le Page, C., Abrami, G., Barreteau, O., Becu, N., Bommel, P., Botta, A., Dray, A., Monteil, C., Souchère, V., 2011. Models for sharing representations, in: Etienne, M. (Ed.), *Companion Modelling. A Participatory Approach to Support Sustainable Development*. Quae, pp. 69–96.
- Mathevet, R., Antona, M., Barnaud, C., Fourage, C., Trébuil, G., Aubert, S., 2011. Contexts and dependencies in the ComMod processes, in: Etienne, M. (Ed.), *Companion Modelling. A Participatory Approach to Support Sustainable Development*. Quae Editions, Versailles, pp. 97–116.
- Medema, W., Furber, A., Adamowski, J., Zhou, Q., Mayer, I.S., 2016. Exploring the potential impact of serious games on social learning and stakeholder collaborations for transboundary watershed management of the St. Lawrence river basin. *Water* 8. <https://doi.org/10.3390/w8050175>
- Ritschard, L., Gourmelon, F., Chlous, F., 2018. Différencier les représentations spatiales selon leurs statuts. *Expérimentation en gestion intégrée des zones côtières. Rev. Int. géomatique* 28, 39–67. <https://doi.org/10.3166/rig.2017.00037>
- Star, S.L., Griesemer, J.R., 1989. Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Soc. Stud. Sci.* 19, 387–420. <https://doi.org/10.1177/030631289019003001>
- Stolovitch, H., Thiagarajan, S., 1980. *Frame games*. Educational Technology Publications, Englewood Cliffs.
- Thiagarajan, S., Stolovitch, H., 1979. *Frame games : an evaluation*. *Simul. Games* 10, 287–312.
- Ulrich, M., 1997. Games/simulations about environmental issues: Existing tools and underlying concepts, in: *Gaming/Simulation for Policy Development and Organizational Change: Proceedings of the 28th Simulation and Gaming Association*. pp. 301–311.
- Vinck, D., 2009. De l'objet intermédiaire à l'objet-frontière : vers la prise en compte du travail d'équipement. *Rev. d'anthropologie des connaissances* 3, 51–72. <https://doi.org/10.3917/rac.006.0051>
- Voinov, A., Bousquet, F., 2010. Modelling with stakeholders. *Environ. Model. Softw.* 25, 1267–1488. <https://doi.org/10.1016/j.envsoft.2010.03.007>