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Abstract

This article describes the application of the analytic hierarchy process (AHP) to the supplier selection decision for the strategic development of lean suppliers at a large German industrial company. In a literature survey and from explorative interviews, relevant criteria including supplier improvement potential through buyer involvement, strategic factors of the supplier development program as well as project success factors in supplier development were elaborated. Subsequently a decision model based on the analytic hierarchy process was developed and applied to the supplier selection. All steps of the model development are described in detail and the application of the model is illustrated.

Key words: Supplier Selection, Supplier Development, Analytic Hierarchy Process

Introduction

The markets in which firms compete are increasingly influenced by international competitors, demanding customers, rapid technological change and shorter product life cycles (Krause, Handfield, and Scannell, 1997). As a consequence many firms have decided to concentrate on core competences and to outsource to suppliers. With a supplier value addition share of 50 to 70 percent in many industries (Dyer and Singh, 1998), companies have become very dependent on their suppliers. Excelling in core competences as well as having a pool of qualified and capable suppliers is therefore crucial for competing in today's market environment.

As a means of improving operations many companies have started to adopt Toyota's successful production practices also known as "lean manufacturing". These practices aim for quality and value oriented production that focuses on the customer, often requiring significant changes of traditional production practices as well as changes in the company mindset. In order to maintain a pool of qualified suppliers many companies carefully evaluate and select their suppliers. Additionally some companies have started to strategically improve their supplier's capabilities and thereby their supply base's competitiveness through knowledge transfer or buyer involvement (Krause and Ellram, 1997). In line with the internal operational improvement, implementation of the lean principles at suppliers to improve the supply base can be observed as an advanced approach in strategic supplier development.

However with a large number of suppliers and limited resources in supplier development, not every supplier in the supply base can be improved. Therefore the question emerges of how to select suppliers for a strategic supplier development program. For the supplier selection decision a large number of both quantitative factors such as cost reduction potentials and qualitative factors such as strategic criteria have to be considered. Hence the multi-criteria decision problem is complex in nature and therefore difficult to solve without the help of an appropriate decision support system. Our paper therefore proposes a rational method and relevant criteria for ranking and selecting suppliers for a supplier development program that focuses on the strategic improvement of suppliers.

Literature review

While a lot of literature exists about the selection of suppliers for strategic partnerships little research has been done on how to select suppliers for strategic supplier development. Yahya and Kingsman (1999) apply the analytic hierarchy process to select suppliers for a government-sponsored program to develop the Malaysian furniture industry. However their selection criteria are rather based on the classic vendor selection decision than on strategic needs of developing suppliers. Narasimhan, Talluri and Mendez (2001) evaluate and cluster suppliers using data enveloped analysis but propose to select suppliers in need of development mainly based on the supplier's efficiency. Therefore a broader approach into supplier selection criteria and methods had to be taken.

Supplier selection criteria

Dickson (1966) was the first to provide a comprehensive overview over the selection criteria used by purchasing professionals. Dickson lists 23 selection criteria and ranks them by importance. Weber, Current and Benton (1991) provide a review of the supplier selection literature after Dickson's work in order to provide a comprehensive view of the criteria that academicians and purchasing practitioners felt are important in the supplier selection decision. Their research revealed that all criteria that were used in literature between 1966 and 1991 could also be related to Dickson's list of criteria.

Spekman (1988) gives detailed instructions on how to evaluate suppliers for long-term oriented supplier partnerships. He proposes a two-stage process with threshold criteria to pre-filter the supply base and gives detailed instructions on how to evaluate suppliers for strategic partnerships. Ellram (1990) examines the issue of supplier selection in situations where the firm is considering a partnership type of relationship with suppliers. The argument is made that partnerships are different in nature than traditional buyer-supplier relationships, and thus require the consideration of additional factors in supplier selection that tend to be longer term and more qualitative than factors included in traditional supplier selection models. She proposes further criteria and suggests that these additional factors supplement, rather than replace, the more traditional factors in developing strategic partnerships.

While supplier development has become a well-researched topic, few articles mention relevant criteria for the supplier selection. Based on a literature survey Krause and Ellram (1997) identify elements that appear to be critical to the success of a supplier development effort from the buying firm's perspective. Krause and Handfield (1999) investigate supplier development in terms of its use for buying companies by comparing supplier development efforts across countries and industries. They depict assessment and rationalization of the supply base as first step in supplier development, but do not provide an extensive list of criteria that could be taken into account.

Supplier selection methods

Given the complexity and economic importance of supplier selection, the application of quantitative methods was not well researched for a long time as Weber et al. stated in 1991. In the following years a lot of work in this field was done by a number of researchers who propose systematic models to the selection problem. In an extensive literature review in 2001, de Boer, Labro and Morlacchi group the existing research of the final choice models into five categories. (1) Linear weighting models: linear weighting models are the most commonly used method in supplier selection. All criteria are attributed with weights, with the highest weighted criteria having the highest importance. These criteria weights are then multiplied with a supplier's rating and summed in order to obtain the final rating. In linear weighting the analytic hierarchy process (AHP) and its derivatives are very popular due to their ability to provide criteria weights and performance scores by verbal, qualitative statements or quantitative statements in complex decisions. (2) Total cost of ownership (TCO) models: TCO-based models take into account all costs that incur during the lifecycle of a purchased product and therefore require a quantification of all costs related to the choice of a supplier. (3) Mathematical programming (MP) models: MP-based models formulate the decision problem in a mathematical formula in a given decision setting. The problem needs to be stated as a mathematical objective function that subsequently needs to be optimized. MP-based models are therefore more objective than other scoring methods but take only quantitative criteria into account. (4) Statistical models: Statistical simulation models provide a solution for stochastic uncertainty related to demand situations, however very few publications exist and mainly treat only one criterion at a time. (5) Artificial intelligence (AI) based models: AI-based models are educated by experts and usually enriched with historic data. Non-experts can then consult the database and find assistance for a similar problem situation.

Research approach

Research was performed during a case study at a large German industrial company with several thousand suppliers and production facilities spread around the globe. The company has put a strong focus on the lean philosophy and started a strategic supplier development program for implementing the lean principles at their suppliers several years ago. Much effort is put into the development of a single supplier and actions in a supplier development project include the implementation of lean at a supplier's production line as well as knowledge transfer in extensive workshops about topics such as quality management.

The research approach consisted of four major steps. (1) Literature was surveyed for an appropriate decision model capable of solving the problem, (2) relevant criteria were then evaluated (3) the corresponding model was consequently developed, and (4) finally the decision model was applied to the selection problem. Each step is detailed below.

Choice of method

In the decision for the best model, mathematical programming, total cost of ownership, and statistical models were ruled out due to their inability to take qualitative strategic factors in supplier development into account. Artificial intelligence models were also considered unsuitable, because they would require a larger base of previous projects. Out of the linear weighting models, the analytic hierarchy process was then identified as best meeting the requirements by having the following advantages. (1) Easy decision making in complex environment by systematic problem structuring, (2) the ability to consider both quantitative as well as qualitative criteria, (3) easy quantification of elements by verbal statements, (4) the possibility to incorporate input from differing specialists into decision making, and (5) the successful and well documented applications in many fields.

Elaboration of relevant criteria

In AHP the elaboration of criteria is very important as relevant criteria that are forgotten in the criteria list can lead to changes in the ranking (Saaty, 2008). Therefore existing literature was surveyed for supplier selection criteria and methods. Focus was put on the classic vendor selection, supplier selection for strategic partnerships, international supplier selection, and supplier development literature. Further criteria were gathered through explorative interviews with the manager of the supplier development team, members of the supplier development team and the purchasing department as well as thorough a review of company brochures, internal documents and an evaluation of the supplier management system in place. These additional criteria included targets of the company's supply strategy as well as risk factors encountered in supplier development. One important criterion for the company was the direct benefit in terms of reduced prices or improved quality from a supplier development project. In order to obtain a complete picture of these potential direct benefits, it was evaluated which of Ulaga's (2003) eight value drivers of suppliers from the perspective of the buying company could be improved with a supplier development program. Each of the relevant value drivers was then taken as a criterion for the criteria list.

AHP model development

The analytic hierarchy process is a theory of measurement through pairwise comparisons that relies on the judgments of experts to derive priority scales for criteria. First relevant criteria for the selection decision are grouped in a hierarchy and criteria weight is then derived by pairwise comparison of criteria. For the specific situation, the process for developing the model was slightly modified.

Build a hierarchy of influencing criteria

In several sessions with the manager of the supplier development program, the list of criteria was then discussed in detail. Each criterion was presented to the manager, it was then decided if the criterion was relevant to the decision and if applicable the criterion was classified in the criteria tree. During the discussions of the criteria, a structure with three major branches emerged and best represented the influencing criteria hierarch:

- (1) Direct benefit potential through buyer involvement: describes the potential for direct benefits that results from a lean supplier development project:
- (2) Project success factors describe how favorable the conditions are for a successful supplier development project and
- (3) Strategic importance of the supplier: describes the strategic value of a supplier for a supplier development project

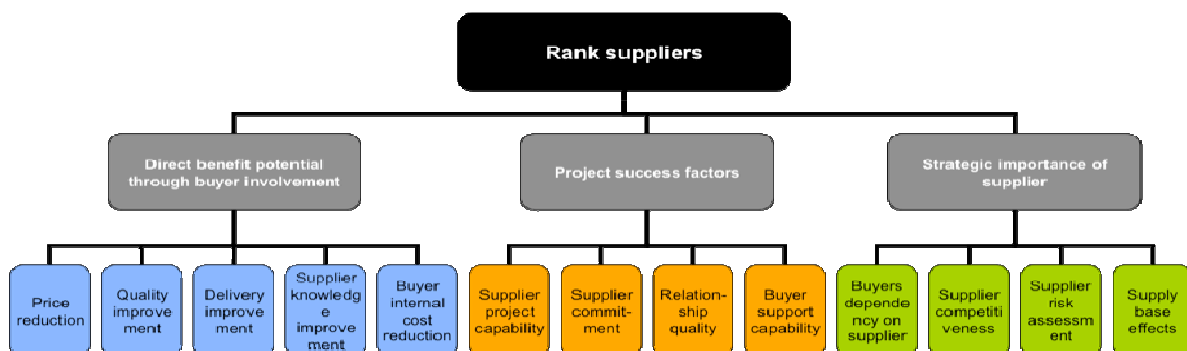


Figure 1: The first two levels of the criteria classification

Table 1: Direct benefit potential through buyer involvement

Price reduction potential	The expected short term and long term purchasing price reduction potential due to improved production costs at the supplier
Quality improvement potential	The product quality improvement potential through introduction of lean manufacturing and systematic implementation of quality management at the supplier
Delivery improvement potential	The supplier's delivery performance and delivery capability improvement potential through introduction of lean manufacturing
Supplier knowledge improvement potential	The improvement potential of the supplier's understanding of customer demands that results from a close collaboration in a supplier development project
Buyer internal cost reduction potential	The buying company's internal costs reduction potential due to lower inventory levels, lower incoming inspection costs, lower scrap rates and further reduction of operational costs

Table 2: Project success factors:

Project relevant supplier capabilities	The supplier's top management capability in supporting the development activities, the mid management's capability in implementing the measures, the workforce capabilities in participating in the project and the company's existing use of standards
Supplier commitment	The owner's / top managements eagerness of supporting a supplier development project and the operating manager's eagerness and openness to implement any proposed changes in production and quality management
Relationship quality	The historic relationship quality including the frequency of conflicts and the level of trust between supplier and buyer
Buyer support capability	The buying company's availability of resources to support the project at the supplier

Table 3: Strategic importance of the supplier

Dependency on supplier	The buying company's dependency on the supplier in terms of current and future volume as well as technical or regional dependency
Competitive capabilities	The supplier's relative competitiveness in terms of cost, quality, delivery and technology
Supplier risk assessment	The evaluation of internal and external risks of the supplier based on risks previously encountered in supplier development projects
Supply base effects	The potential of a supplier development project to support overall purchasing targets such as increasing competitiveness in the market or supporting localization of volumes

Create evaluation questionnaire

Many different actors may be involved in assessing a supplier resulting in potentially differing understanding of factual information and in differing judgment. In order to achieve a high consistency in supplier assessment a standardized questionnaire for evaluation had to be developed. First a clear understanding of the meaning of each criterion needed to be achieved. Therefore a detailed questions was formulated for each criterion.

Table 4: Example questions from the supplier evaluation questionnaire

Long-term price savings potential	How large is the further purchasing cost reduction potential through roll-out of lean principles on other product families, new products or through second sourcing within the next 5 years?
Top management capability	How capable is the plant's top management in supporting and sustaining the supplier development activities?
Localization of volumes	How much would the development of the supplier help for the strategy of localizing volumes?

Once the questions were formulated, an individual rating scale for each question was created based on the possible values. The options on each rating scale depended very much on the availability of information for evaluation of a criterion and the nature of this information. A rating scale with quantitative intervals is used for most cost reduction potentials for example whereas management capability was rather graded in qualitative options.

Table 5: Rating scales from the supplier evaluation questionnaire

Long-term price savings potential	< 1 %, 1 – 2 %, 2 – 3 %, 3 – 5 %, > 5 %
Top management capability	very low, low, satisfactory, high, very high

In order to guarantee a consistent rating of the suppliers even when evaluated by different purchasing agents, a detailed instruction on how to rate the suppliers was created.

Table 6: Rating instruction for the top management capability

very low	low	satisfactory	high	very high
Frequent fluctuation in top management	Stable management but target deployment and delegation not working	Stable management with basic experience in project management, production know how and target deployment	Stable management with good skills in project management, production know how and working target deployment system, top management possesses drive and power to deploy changes	Stable management with very high skills in project management, lean management and production know how, visualized target deployment system, and top management possesses strong power to deploy changes

Finally each rating scale option had to be attributed a value in order to obtain the score of a supplier. One option proposed by Saaty (2006) is to rate each option on a scale from one to hundred according to their value. Scores are then normalized in order to obtain the value of 1.00 for the best option.

Table 7: Score for the rating scale of the top management capability

very low	low	satisfactory	high	very high
0	0.15	0.55	0.75	1.00

Assess criteria importance by pairwise comparison

In AHP criteria weight calculations are based on pairwise comparisons of two criteria. However, not all criteria are compared with each other, but only criteria from the same hierarchy level in the criteria tree. This significantly reduces the total number of comparisons needed for calculating the weights. For the comparison of two criteria, a reference table

created by Saaty is used to allow for easy verbal comparison of two criteria. The possible result for a comparison of two criteria ranges from equal importance of the criteria to absolute preference for one of the two criteria. Each of the five distinguished verbal statements listed in the table is linked to a value from one to nine. If criterion A is absolutely more important than B, a value of 9 is attributed to the comparison. If criterion B is more important than A the reciprocal value is used. For example 1/9 is attributed for absolute importance of criterion B over criterion A. Intermediate values are used as well.

Table 8: Strategic importance of the supplier

Score	Description
9	A is absolutely more important than B
7	A is very much more important than B
5	A is much more important than B
3	A is somewhat more important than B
1	A is equal in importance to B

In two sessions with the manager of the supplier development program each lasting two hours, all criteria from one hierarchy level were compared with each other regarding their importance. The results of the comparison are stored in a matrix where diagonal values are set to one. Only the upper half of the matrix needs to be evaluated since the lower half represents the reciprocal values.

Table 9: Comparison matrix for the strategic factors

	[1]	[2]	[3]	[4]
[1]: Dependency on supplier	1	2	1	1/3
[2]: Competitive capabilities	1/2	1	1	1/2
[3]: Supplier risk assessment	1	1	1	1
[4]: Supply base effects	3	2	1	1

Calculate criteria weight with AHP methodology

AHP follows a special methodology to calculate criteria weights from the comparison matrix. It was proven that the eigenvector of a comparison matrix best represents the relative weight of each criterion. Therefore, in a first step, the eigenvector for each comparison matrix is calculated in order to obtain the relative weights for each criterion. In a second step, the absolute criteria weights are calculated by multiplying in a top-down approach the relative weight of all criteria in the criteria three with the absolute weight of the respective parent criterion.

Model application

Finally 15 suppliers for which projects had already been completed were evaluated to test the model. Questionnaires were filled out by purchasing professionals and supplier development experts, depending on who was best able to answer the questions. The scores of a supplier were then multiplied with the criteria weights to obtain the final score of a supplier.

Preliminary Results

Result of a first supplier assessment

For the preliminary evaluation, a significant difference in score was found ranging from 35 percent to almost 60 percent. The result correlated with the experience from these projects indicating that the assessment of the suppliers in advance will allow better identification of suitable suppliers in the future.

A visualization of the results furthermore allows identifying strengths and weaknesses in the areas of direct benefit potential, projects success factors and strategic importance of the supplier and scores for single criteria can be analyzed and compared.

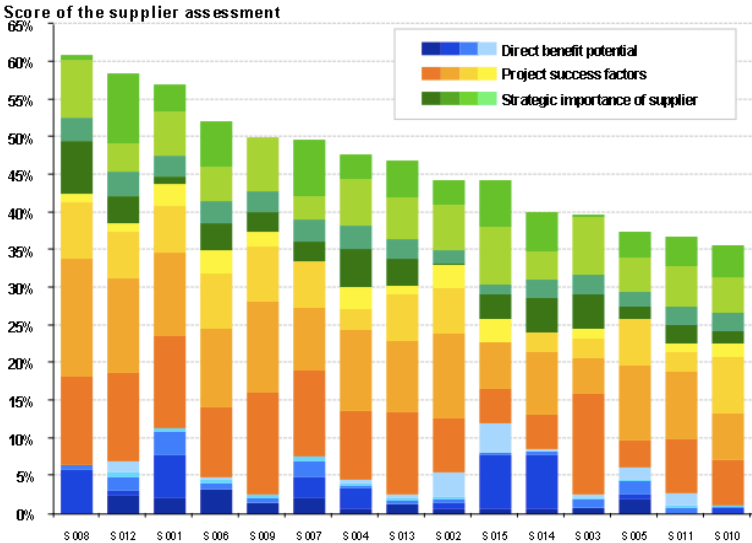


Figure 2: Ranking of suppliers regarding their suitability for strategic supplier development

Criteria importance

The evaluation of the criteria importance revealed, that especially the project success factors are important for the supplier development, followed by the strategic supply base potential and the direct improvement potentials.

Table 10: Order of importance of the criteria

1	Project relevant supplier capabilities	8	Competitive capabilities
2	Supplier commitment	9	Price reduction potential
3	Supply base effects	10	Buyer internal cost reduction potential
4	Relationship quality	11	Delivery improvement potential
5	Dependency on supplier	12	Buyer support capability
6	Supplier risk assessment	13	Supplier knowledge improvement potential
7	Quality improvement potential		

The outcome of the criteria comparison is not surprising, given that the experience from past projects revealed that supplier commitment and capabilities are essential for a successful completion of a supplier development project.

Discussion and conclusion

We developed a model along with relevant criteria for selecting suppliers for supplier development activities that focus on the strategic development of lean suppliers. The model allows for distributed evaluation of suppliers through standardized questionnaires, easy adaptation of criteria weights in case of change in strategic focus or change in business environment. Scores for suppliers can easily be visualized and discussed.

Limitations

The extensive literature research and internal interviews gathered a comprehensive list of criteria, but the decision on the criteria importance was mainly based on recommendations in literature and experience from previous supplier development projects. For the model, the weighting of the criteria was done by the manager of the supplier development program and thus reflects his view on the importance and suitability of the suppliers for supplier development projects.

Future research

A retrospective evaluation of selected suppliers and success of the selection can therefore be used to learn about importance of influencing factors and therefore allow a continuous improvement of the selection process. Furthermore the model was developed for the strategic development of lean suppliers, however the methodology and the logic of creating the criteria can also be used for any strategic supplier development program that targets at improving the supplier through buyer involvement.

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