

Analytical Hierarchy Process in Supplier Evaluation

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Abstract

Supplier Evaluation is of increasing importance for companies and their further business development due to the fact that companies are concentrating on their core competencies. Next to that a distinctive supplier evaluation includes all internal departments and their feedback about supplier's performance to receive a whole picture of supplier's potential. That means that different people are evaluating suppliers due to their responsibility which requires the need of a structured process for supplier evaluation. Exactly this role is captured by AHP which ensures that each single evaluation for a supplier is implicated in the total picture inspection. The practical use of AHP in supplier evaluation and selection is presented with an extended business example of Henkel in Germany enhanced by current business trends like risk management and the advantage to identify best-in-class suppliers out of the supplier portfolio in a comparative approach.

Keywords: Analytical Hierarchy Process (AHP), Supplier Evaluation

1. Introduction

In an increasingly complex world especially in difficult economic situations the right decision regarding supplier management has an important influence for companies and their future business. Since several years companies are outsourcing increasing business, concentrating on their core competencies and reducing their manufacturing share which leads to an increasing success-critical position of suppliers. Therefore companies have to select and identify the best suppliers for their business. That is where Analytical Hierarchy Process (AHP) supports the decision makers to find the decision that best suits their needs and their understanding of the problem. AHP reflects a structured workflow for dealing with complex decisions by offering a rational framework for structuring complex problems. AHP was developed in the eighties by Saaty and intends to support finding the right decisions and minimize expenditure of time [33]. AHP provides a well-founded and comprehensible solution which makes decisions credible especially in teams or groups decision making. A further advantage is that inconsistencies are highlighted at an early stage of the decision process so that negative influences to the projects are avoided. The 'analytical' capability of AHP is created in finding the best solution out of various (different) criteria and their dependencies. The 'process' capability is created by a streamlined workflow how to find the right decision in a structured way and with substantiated and subjective criteria.

Combining AHP with information technologies, organizations can minimize common pitfalls of team decisions, making processes more effective and avoid lack of focus as well as subjective decisions. Identification of high-performing suppliers and managing relationships with them is very important and its importance will increase in future. This concept makes the objective identification of best-in-class suppliers a priority for all companies especially in manufacturing business characterized by an increasing outsourcing quota of tasks. AHP supports and can be used as tool and best-in-class approach to reach this success-critical target

to identify out of the existing supplier portfolio a performance ranking due to company's individual requirements.

This paper presents a framework for criteria selection and prioritization to identify best-in-class suppliers based on both quantitative and qualitative information with multiple dimensions. Analytic hierarchy process is utilized to identify best-in-class suppliers of Henkel AG & Co. KGaA (Henkel).

After a literature review the current supplier evaluation approach of Henkel will be demonstrated. Subsequently supplier evaluation and especially the criteria selection are presented including the trend of risk management in supplier evaluation. Next to this the procedural method of AHP is explained followed by the results of an example and the final conclusions.

2. Literature Review

Supplier evaluation as an integral part of supplier relationship management/supplier lifecycle management aims for selecting the best performing suppliers in regard to business strategy for the company. Supplier evaluation often follows a checklist approach including quantitative as well as qualitative figures. An effective supplier evaluation should have certain characteristics and include the performance categories considered important to the evaluation and selection process. The selection process has to be as objective as possible requiring the use of a standardized process and scoring approach to guarantee transparent and assure the credibility of results [40]. Often named objectives in literature about supplier evaluation are stated as follows:

- Objective analysis about supplier performance,
- Basis for supplier selection or supplier development,
- Identification of supplier's strengths/weaknesses [3].

In contemporary supply chain management, the performance of potential suppliers is evaluated against multiple criteria rather than considering a single factor [30]. An important aspect reflects the matter of fact that AHP assures a structural hierarchy of process, criteria selection and objective handling as well as neutral results for the decision takers in a process where many stakeholders are involved to identify best-performing suppliers. Understanding and evaluating supplier performance is vital to ensure a well-functioning supply network and to keep business running [17]. Doing supplier evaluation in the right way means also to help reducing costs, lower risk as well as improving the companies and suppliers business [50]. One of the main motivation factors for developing new supplier evaluation approaches is directly deduced from practical problems in supplier selection due to the fact that mostly used approaches are based on simple weighted scoring methods primarily relying on subjective judgements and opinions of supply professionals and other involved parties in the evaluation process [41].

Akarte et al. developed a web-based AHP system for casting new suppliers where suppliers are evaluated on an 18 criteria catalogue. First step is the registration of the suppliers and entering their application specifications. For evaluation, the relative importance weightings are determined for the defined criteria based on the casting/application specifications. Last step is the assignment of the performance rating for each criterion using the AHP specific pairwise comparisons [1].

Internal and external factors are considered in the study performed by Hou and Su to meet market requirements in a global changing environment. AHP is used as a decision support system for the supplier selection problem in a mass customization environment [32].

A five-step AHP model with respect to nine evaluation criteria was developed by Muralidharan et al. [42]. Different internal stakeholders such as employees from purchasing or quality department are involved in the selection process [42].

An integrated AHP and linear programming model was developed by Ghodsypour and O'Brien to support companies in considering qualitative as well as quantitative aspects in purchasing activities by a systematic approach [14].

Yahya and Kingsman used AHP to create a new approach for multi-criteria decision problems. The new method overcomes the difficulties associated with the categorical and simple linear weighted average criteria ranking methods. It provides a more systematic way of deriving the weights to be used and for scoring the performance of vendors [52].

Especially under uncertain circumstances of today's business and economic environment, risk management in all functions of business becomes more and more important everyday and buyer-supplier relationship management is not exceptional in this trend. Therefore the potential risk of a buyer-supplier-relationship has to be involved in supplier evaluation practice. Hallikas et al. demonstrate which risks may arise in network collaborations and how the risk management processes operates in network collaboration with suppliers [19]. One of the most important risk factors identified in their research was the supplier ability to follow new trends and to work close to the market which leads also to an added value for the customer. Besides the fact that the supplier is able to manage his cost and pricing and to create reserves for further investments represent further success critical aspects [19].

Today's world business environment is changing continuously and unknown exposures of business partners in the network can affect collaborating companies. Therefore, before selecting suppliers and defining a strategy first it is necessary to understand the sources of uncertainty and adjust it as well as to counteract the level of uncertainty as discussed by Cucchiella and Gastaldi [10].

This research contributes to body of knowledge on both supplier evaluation and AHP implementation. From supplier evaluation perspective, its major contribution is the involvement of risk management factors in an AHP-based framework for supplier evaluation. This framework presents decision criteria and their relative importance for determination of the best-in-class supplier. From an AHP implementation point of view, it supports existing literature on AHP by illustrating a real life case study that provides a realistic and applicable approach for supplier evaluation problems.

3. Industry Review

Henkel AG & Co. KGaA is one of the biggest fast moving consumer goods producer of the world concentrating on the three business units Laundry and Home Care, Beauty and Personal Care as well as Adhesives Sealants and Surface Treatment [27]. Company's head office is located in Düsseldorf (Germany), employs worldwide around 55,000 employees in 125 countries and generates a turnover of 14 billion euro for which a purchasing spend of 9 billion euro was necessary in 2008 [23, 28].

To assure worldwide the following Henkel purchasing guideline: "We best leverage the global supply base and link high performing suppliers to the business need" [22] a standardized concept was developed and implemented concerning supplier lifecycle management/supplier relationship management. Before coming to the three-dimension-approach of supplier evaluation the higher-ranked process flow of supplier lifecycle management is divided in four divisions:

- Supplier on-boarding and qualification
- Supplier evaluation
- Supplier development
- If necessary: Termination of business relationship [36].

Concentrating on the supplier evaluation Henkel pursues a three-dimension-approach to identify high performing suppliers which are motivated to work with a global payer in fast moving consumer goods, act sustainable and are willing to create win-win situations as well as continuous improvements. To reach such targets Henkel developed the following process in supplier evaluation depending of supplier's economical relevance for Henkel [36].

First dimension in supplier evaluation includes the most important raw materials and packaging suppliers (core suppliers) for the company worldwide which are identified on an annual basis according to Figure 1.

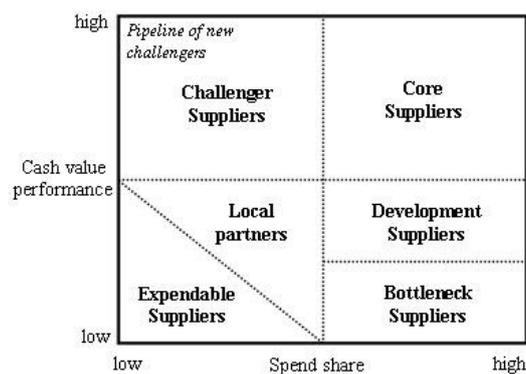


Figure 1: Supplier Classification [24]

These identified most important suppliers are evaluated on hard and soft facts as well as with an agreed target dialog. Hard facts represent quantitative criteria which are measured in an objective way by each delivery whereas soft facts represent qualitative criteria which are mostly measured in a subjective way by the responsible department. The target dialog reflects individual targets which are measured, discussed and reported in so called 'flash reports' on a monthly basis. This approach assures that discrepancies with agreed targets can be identified and tackled short-term. These target dialogues are always individually based on hard and especially soft fact criteria of supplier evaluation which are represented by the 'House of SRM' at Henkel (depicted in Figure 2). Soft facts which are represented by the pillars at the House of SRM are concentrating on cost, risk and innovation aspects which are always included in the corresponding target dialog. Hard facts which are represented by the base of the 'House of SRM' include product quality, on-time delivery, supply security and security and environment. These parameters are weighted in ratio 38%/26%/26%/10% and are measured by each delivery directly in the ERP-System [24].

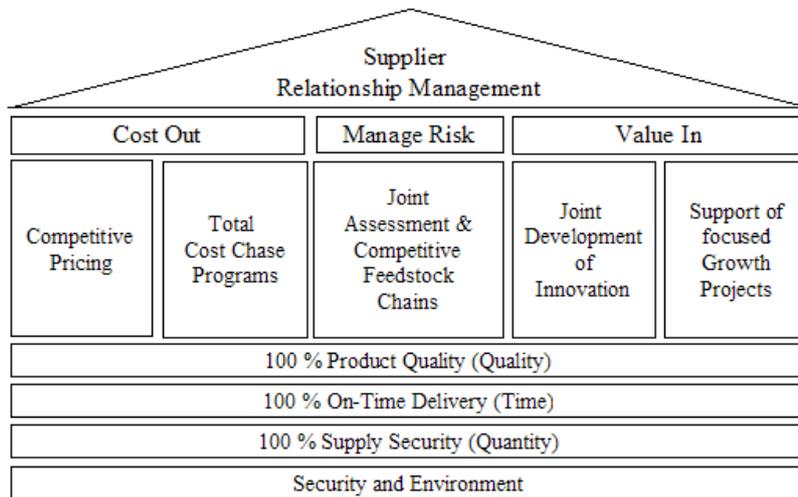


Figure 2: House of SRM [25]

Second dimension of supplier evaluation includes a monthly evaluation by production plant (Western Europe and North America) of all raw materials and packaging suppliers based on the quantitative figures (see base of the House of SRM at Figure 2). This analysis provides important information to purchasing as well as to supply chain colleagues in the relevant plant to manage supplier performance and initiate countermeasures. Dependent of the scoring results suppliers are categorized as A-, B- or C-suppliers. An A-supplier has to reach an overall hard-fact result for the specific plant of >99% of the good receipts he delivered in the referring month whereas a B-supplier fulfil a figure of $\geq 97\%$ and a C-supplier of <97% [36].

Supplier Name	Good Receipts	Quality 38%	Delivery Quantity 26%	Delivery Date 26%	Environmental Aspect 10%	Total Score 100%	Classification
Supplier 1	4	100	100	100	100	100	A
Supplier 2	2	95	100	100	100	98,1	B
Supplier 3	5	100	50	40	100	71,4	C

Table 1: Example Supplier Evaluation Henkel Hard Facts [26]

Third and last dimension of supplier evaluation at Henkel reflects a quarterly analysis of the top 200 raw materials and packaging suppliers in Western Europe and North America which represent a spend volume of nearly two billion euro. In parallel to the second dimension the results are shared with suppliers to identify lever to improve collaboration and organize it more efficiently [36].

Explaining this three-dimension-approach of supplier evaluation the target is always the same. On the one hand Henkel is searching for best-in-class suppliers to bind them long-term to the company and create a win-win situation. On the other hand risk avoidance and this especially due to economic crises has become an important aspect in supplier evaluation wherefore Henkel work close to credit insurance companies like Coface and Creditreform which are delivering information about Henkel’s core suppliers represented in the mentioned ‘House of SRM’ with pillar ‘Manage risk’. Thus risk management is an integrated part of supplier evaluation utilized for strategic business partners.

Up to now Henkel evaluates suppliers on mentioned criteria but suppliers are not ranked in categories or material types they belong to. Besides risk criteria beyond liquidity risk are not

yet taken into account although supplier's customer portfolio or degree of utilization reflect also important risk factors. In addition a ranking of the qualitative criteria such as used for the quantitative aspects is also still not implemented.

4. AHP in Supplier Evaluation

4.1. Criteria Selection

Evaluating suppliers and their performance with a 360° approach requires the standardized feedback collection of different parties in a company which are affected by supplier performance. As the name of this methodology assumes, the 360° approach enlists feedback from a set of observers or various by the supplier performance influenced parties primary used in human resources for employee/manager development [13]. From the organization's perspective this approach leads to:

- Improved feedback from multiple sources;
- Identification of organizational or supplier relating performance development needs;
- Reduced risk for the recipient due to feedback of various parties [7].

A qualified supplier evaluation includes therefore an information collection of all internal stakeholders as described in literature, concentrating on supplier evaluation and supplier performance concepts [2, 9, 11, 12, 15, 20, 31, 34]. Due to the current economical crisis and the increasing dependence between supplier and buyer, risk management becomes more important in supplier evaluation. Quality, quantity and time factors are fundamentals of supplier evaluation but companies are compelled to implement a qualified risk management approach in supplier evaluation to assure sustainable and low-risk business. Such an approach includes additional criteria such as financial health, location risk, supplier's customer and supplier portfolio as well as investment quota and rate of utilization which have to be considered in a up-to-date supplier evaluation [21, 29, 35].

The first step of evaluation is the identification of decision/evaluation criteria which potential supplier will be evaluated upon. Based on the literature on supplier evaluation and interviews with company managers, the attributes of the model are defined as *Purchasing*, *Quality Management*, *Logistics*, *Research and Development (R&D)* and *Risk Management*.

In this study, three cost attributes are considered under *Purchasing* attribute. Analysing and evaluating supplier's cost structure requires an in-depth analysis of supplier's total costs. Detailed information about direct and indirect labor costs as well as manufacturing and process operating costs and general overhead costs are needed. This information is necessary to understand how efficient suppliers work and are able to produce their goods [15, 40]. Cost (or price) performance measure refers to the direct monetary terms associated with suppliers which can be measured in two ways: First by comparison with other suppliers of the same commodity or second by price increase/decrease provided by the supplier [5]. Another strategic aspect is payment terms which are important especially for liquidity of the buyer. The buyer can increase his liquidity by purchasing high value commodities with long-term payment terms in combination with discounts. At the end this often leads also to an improved rating by rating agencies as well as better reputation of shareholders [15].

Next aspect is *Quality* of the delivered goods which could be measured by the product quality of each delivery as well as by the availability of certificates which should assure a certain standard of production process including quality [29]. Quality management departments are able to evaluate the quality of goods by sample tests as well as by quality certificates and plant/production inspections at the supplier to assure the quality guidelines regarding pretended product specifications to the supplier [6].

To run the production as planned, *Logistic* attributes has to be implemented in a supplier evaluation as well. It is an important issue that influences costs, speed to market and value perception by end users and inaccurate, missed or delayed deliveries can disrupt operational efficiency [4]. Additionally, supplier's delivery flexibility to act short-term on extraordinary demands is a criterion which has to be considered if there is uncertainty or variability in customer's demand as well [38].

Innovation input of suppliers is another important criterion in supplier evaluation especially when companies are concentrating on their core competencies and outsourcing production steps. To create an advantage in competition it is vital that suppliers are know-how carriers and that their products are on the latest stage of technology to create an advantage in competition [8].

Influenced by the worldwide economical crises, *Risk Management* became an important aspect for supplier evaluation as well. For the whole company it is important that supply chain controlling uses risk analysis methods and that a classification of risks take place [45]. Supplier's risk assessment not only includes an analysis of the supplier's financial health, but it concentrates also on supplier's customer portfolio and the risk management done by the supplier. The plant risks have to be taken into account according to the location of production plants as well as the potential risks coming from ecological and economical nature [37]. Further risk figures are the capital investment ratio which measures if manufacturing facilities are maintained or substituted according to the technology increase and aligned with this figure what is the average degree of utilization. This criterion offers necessary information for flexibility because a supplier which is producing always at maximum capacity will not be able to act on extraordinary demands and requests which could be a success critical figure for companies.

4.2. Procedural Method

Bringing supplier evaluation and AHP together it represents a symbiosis for the complex decision process of supplier evaluation where different parties are involved. The multi-criteria evaluation process of AHP tends to identify best-in-class suppliers based on the companies defined parameters and their weighting. Main advantages of this approach are: rationalization of subjective criteria so that decisions are not based on good feelings and fragmentation of the overall decision into a number of sub-decisions which minimizes mistakes. Due to its flexibility of selecting and weighting criteria AHP can be modified easily when environmental conditions change.

The name of Analytical Hierarchy Process includes the three main aspects of its theory. First aspect is the analytical component which represents the basic idea of this method to work analytically. Analytical means that AHP supports the decision making in a mathematical way with logical steps [53]. The hierarchical component of AHP describes the way of identifying a decision namely by creating a hierarchy of criteria and sub criteria [44]. A hierarchy in general represents a system whose elements are sorted in different levels where a level could only influence a superior level. Elements or criteria of the same level are not able to influence each other. In AHP these three main levels are considered: goal, criteria (sub criteria), alternatives [53]. The process-related character of AHP indicated that decision-making is created in a structural way which guarantees an objective decision and intends to minimize decision-making workload [53].

Evaluations are done by paired comparisons a_{ij} . These paired comparisons are used to identify to what extend the AHP-user prefers the evaluation object i against the object j based on the one to nine evaluation scale as suggested by Saaty. The index scale and its definition is described in Table 1. Besides the paired comparisons a_{ij} are used to evaluate how the AHP

user scores the relative relevance of two compared criteria i and j with regard to a superior criterion in the one to nine evaluation scale [47].

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Demonstrated importance	An activity is strongly favored and its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals of above nonzeros	If activity i has one of the above nonzero numbers assigned to it when compared with activity j , then j has the reciprocal value when compared with i .	

Table 2: AHP Scale for Pair Comparisons [49]

Pairwise comparisons a_{ij} ($1 \leq i \leq n$, $1 \leq j \leq n$) are then composed in a so called evaluation matrix P which has the structure as depicted in Figure 3 [39].

$$P = \begin{bmatrix} & a_1 & a_2 & a_3 & \dots & a_n \\ a_1 & 1 & & & & \\ a_2 & & 1 & & & a_{ij} \\ a_3 & & & 1 & & \\ \vdots & & & & \ddots & \\ a_n & a_{ji} = \frac{1}{a_{ij}} & & & & 1 \end{bmatrix}$$

Figure 3: Example Evaluation Matrix [39]

This kind of matrix is created for each hierarchy level in regard to the superior level [18]. Then the priorities/weights of the different criteria are deviated out of the evaluation matrix. To compare the different pairwise comparisons a comparable foundation has to be created. Therefore first the sum of each column (c_i) out of the evaluation matrix has to be determined. Afterwards each pairwise comparison result is divided by the sum of the column to get normalized figures. Next step is to create the sum of the normalized matrix (r_i) and to divide this figure by the number of elements to create the weight w for the respective element [39].

	evaluation matrix				normalized matrix				weight	
	a_1	a_2	...	a_n	a_1	a_2	...	a_n	r_i	w
a_1	$a_{11} = 1$	a_{12}	...	a_{1n}	a_{11}/c_1	a_{12}/c_2	...	a_{1n}/c_n	r_1	$w_1 = r_1/n$
a_2	$a_{21} = 1/a_{12}$	1		a_{2n}	a_{21}/c_1	a_{22}/c_2	...	a_{2n}/c_n	r_2	$w_2 = r_2/n$
\vdots	\vdots	\vdots		\vdots	\vdots	\vdots		\vdots	\vdots	\vdots
a_n	$a_{n1} = 1/a_{1n}$	a_{n2}	...	$a_{nn} = 1$	a_{n1}/c_1	a_{n2}/c_2	...	a_{nn}/c_n	r_n	$w_n = r_n/n$
c_i	$c_1 = \sum_{i=1}^n a_{i1}$	$c_2 = \sum_{i=1}^n a_{i2}$...	c_n	1	1	...	1	n	1

Figure 4: Priority Calculation [39]

After the calculation of the different local weights of each hierarchy level the global weights are calculated. Therefore the weight of a sub-hierarchy level is multiplied with the weight of the superior level. The formula of the global weight calculation of a criterion i ($w_{rel}(i)$) for the hierarchy level n is as follows [46]:

$$w_{rel}(i) = w_n * w_{n-1}$$

Due to the fact that pairwise comparisons are done in a subjective way it is important that a consistency check is done. Therefore with the support of the so called Consistency Index (CI) the consistency of pairwise comparisons can be reviewed in an evaluation matrix A . The calculation of the CI includes following equation: In a complete consistency the maximum self-value λ_{max} of an evaluation matrix is equal to its dimension n [43, 48].

$$CI = \frac{\lambda_{max} - n}{1 - n}$$

Transferring the demonstrated AHP theory to the supplier evaluation process the target would be to identify a best-in-class supplier by evaluating potential suppliers by supplier performance effected internal departments like purchasing, quality management, logistics and research & development and the controlling related criterion risk management. Taking the already mentioned criteria into account this leads to an AHP structure in supplier evaluation in the following design by what suppliers are scored and evaluated. Based on daily business experience in supplier evaluation criteria are structured and weighted as depicted in Figure 5.

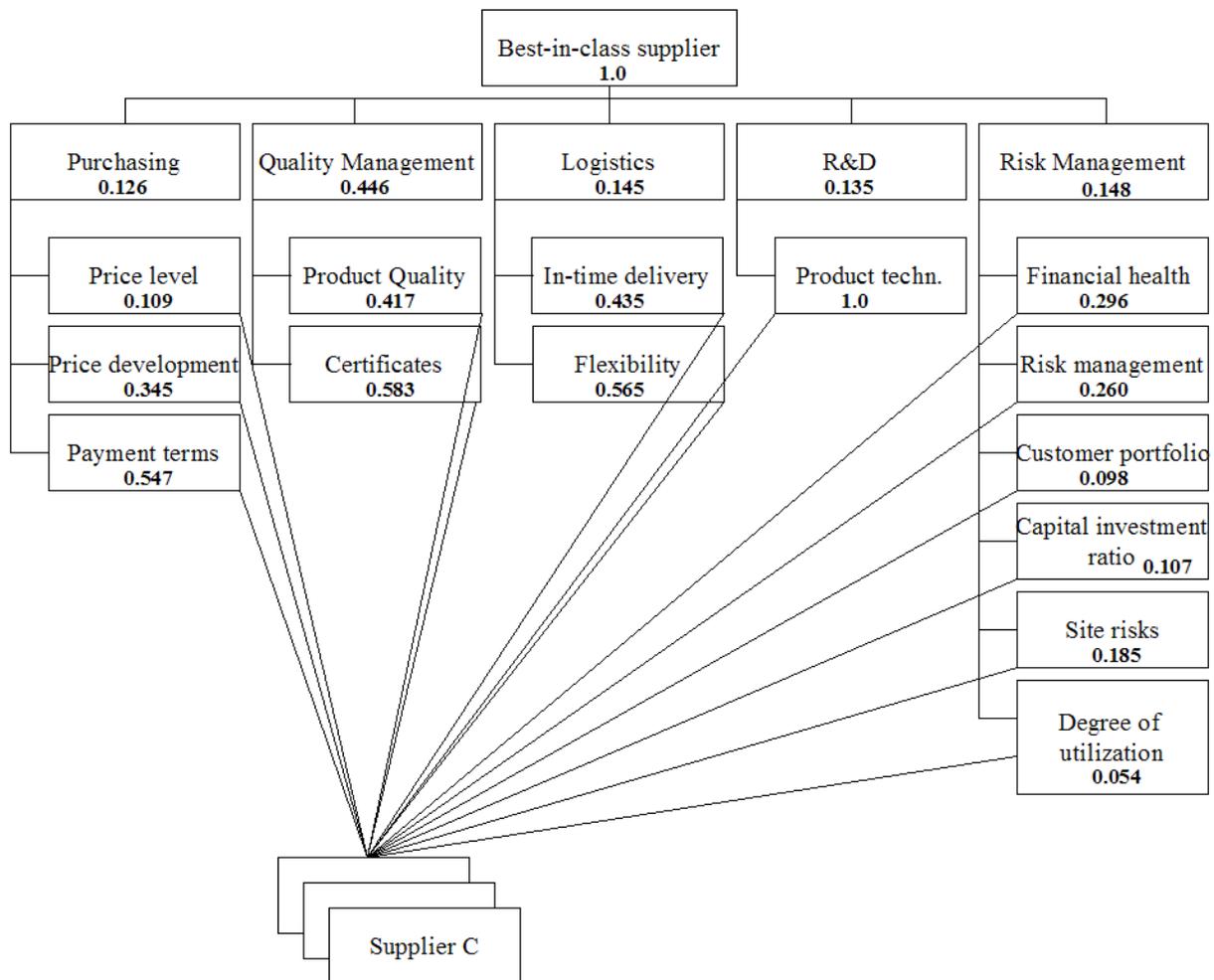


Figure 5: Design of AHP Structure in Supplier Evaluation

Data collection frequency for supplier evaluation depends on the specific criterion. Quantitative criteria like in-time delivery are measured by each delivery whereas qualitative criteria like financial health are evaluated at a prior defined date of time by the responsible department.

After evaluating all suppliers by all defined sub criteria the results can be visualized to identify the required best-in-class supplier by a so called sensitivity graph which is shown in Figure 6 as a performance chart based on the weights mentioned above. Sensitivity analysis investigates in general the impact of a criterion's weight change to the alternative order and in this case to the supplier order [51].

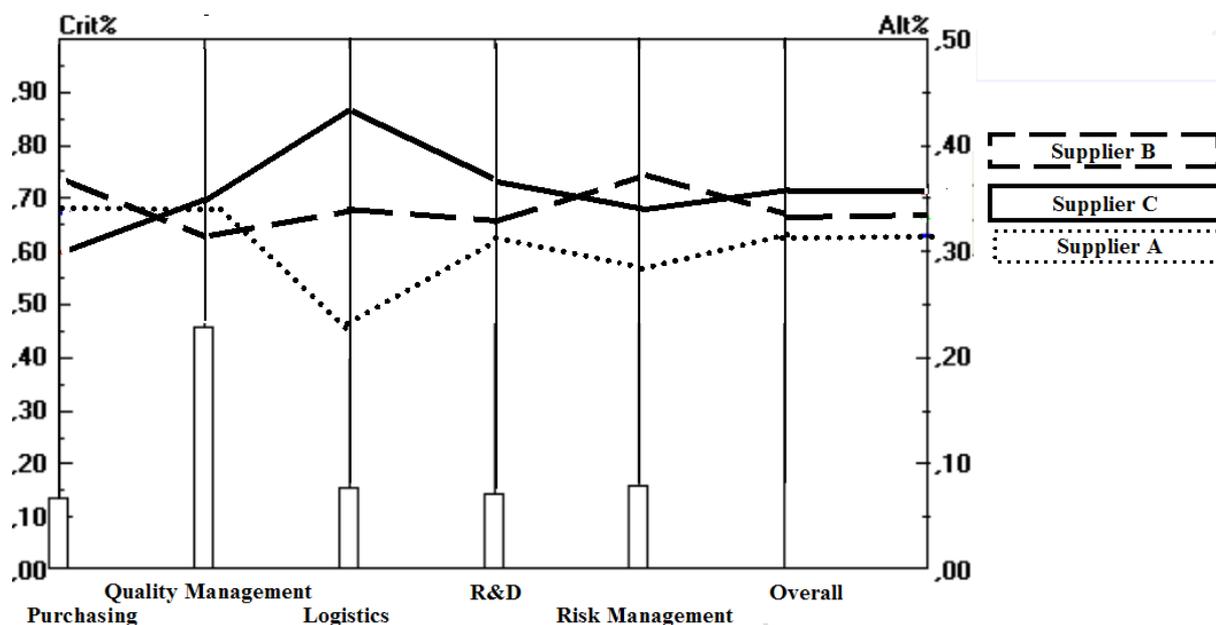


Figure 6: Sensitivity Graph

Based on the presented example supplier B represents the best-in-class supplier followed by supplier C and supplier A. By changing criterion's weight based on an adjustment of priorities another supplier is able to get best-in-class supplier based on the evaluated results. The inconsistency factor of the created model is 0,09.

Compared with the current procedure in supplier evaluation at Henkel the AHP represents a more structural way and allows the (weighted) creation of sub criteria. Besides it has to be considered that the construction of a hierarchy and demonstration and especially the calculation requires professional software like expert choice where results are visualized and can be adjusted easily if companies' priorities change. This also decreases the complexity of the decision process. Furthermore, the supplier performance in AHP is always defined in relation to the other suppliers, which represents a new aspect in comparison to the current approach. AHP's characteristic to create a measurable relation between suppliers can also be used to evaluate suppliers in direct competition and to create a ranking. Following this point, a totally new approach in Henkel would be to create a supplier ranking by purchasing category, material, or material type so that purchasers receive an overview about the best performing suppliers for their area of responsibility at a glance.

5. Conclusions

Evaluation and selection of the right business partner/supplier is very important for companies to create and increase competitive advantages.

This article demonstrates the structured approach of AHP, which can be used as a tool in supplier evaluation to identify best-in-class suppliers and build a ranking out of the defined criterion's weight and the degree of performance. The standardization of team decisions of all involved stakeholders represents the advantage of the proposed method. By establishing a hierarchy and defining criteria, the selection of best-in-class suppliers is switched from a subjective decision of an individual to an objective team decision of all involved parties [16]. AHP in supplier evaluation assures objective results in team decisions, which lead at the end to the selection of the right business partner and minimize in this way the distress of pitfalls in a success-critical decision process such as supplier evaluation. Therefore, AHP represents a compatible process in supplier evaluation to assure a clear, objective, and comprehensible

evaluation. Meanwhile, proposed method has some drawbacks as well. When a new potential supplier is included in the system, the evaluation has to be restarted. Furthermore development and evaluation of pair-wise comparisons and illustration of the results are very time consuming if no AHP software is used [34].

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