Supplier selection based on multi-criterial AHP method

Martina Hudymáčová[1], Marta Benková, Jana Pócsová, Tomáš Škovránek

This paper describes a case-study of supplier selection based on multi-criterial Analytic Hierarchy Process (AHP) method. It is demonstrated that using adequate mathematical method can bring us "unprejudiced" conclusion, even if the alternatives (supplier companies) are very similar in given selection-criteria. The result is the best possible supplier company from the viewpoint of chosen criteria and the price of the product.

Keywords: *AHP, multi-criterial decision making, supplier selection*

Introduction

Supplier selection belongs to most important operations in every company. A huge accent is given on the quality of inputs, as it is a necessary condition for company to produce high-quality products. Each company uses own procedure for the evaluation and selection of suppliers. It can be based on reliability, quality, previous experience with the supplier, etc. The most "objective" selection can be achieved if adequate criteria (for better detailed selection sub-criteria as well) of the selection are given, and after-that alternatives (supplier companies) are chosen based on previous analysis. The conclusion should be obtained using an appropriate method.

The AHP method was first mentioned in Saaty (1980), and later elaborated (e. g. Saaty (2004), Saaty (2008)). Since then it has been used in many applications and in different variants. Multi-criterial AHP method belongs to Multiple Criteria Decision Making tools (MCDM).

Supplier selection procedure

At the beginning of every decision-problem it is necessary to define the goal to be solved, in this case the goal is to find the best possible supplier from given alternatives. Next criteria (and sub-criteria if necessary) adequate to the problem have to be chosen. Based on the complexity of the problem, an appropriate method able to solve it is selected and used. Multi-criterial AHP method is used for solving decision - problem in this paper, and the procedure can be described as follows Hudymáčová (2009):

1. Definition of the goal.
2. Analysis of the situation and decision conditions.
3. Definition of supplier selection criteria.
4. Realization of chosen (selected) method for supplier selection.

Further, we will follow these four steps.

Definition of the goal

First step by solving a decision problem is to define the goal to be achieved. The goal of this case-study is to select a supplier (from three alternatives) of a component part (grub-screw M10x37) for company Ehlebracht Slowakei s.r.o. Michalovce (ES).

Analysis of the situation and decision conditions

Each problem can be reformulated as decision-problem with the purpose to select the best possible alternative. If the problem to be solved is important and complex, and wrong decision can be "expensive", it is necessary to use several criteria and sub-criteria, respectively. This kind of decision-making is denoted as multi-criterial.

[1] *Ing. Martina Hudymáčová, doc. Ing. Marta Benková, CSc., RNDr. Jana Pócsová, PhD., Ing. Tomáš Škovránek, PhD.,* Technical University of Košice, Faculty of BERG,, Košice, Slovak Republic e-mail: {martina.hudymacova; marta.benkova; jana.pocsova; tomas.skovranek}@tuke.sk.
(Review and revised version 14. 12. 2010)

Multi-criterial decision-making is a process, where finding the best possible alternative is based on several criteria. If a decision should be made, one has to know the goal, criteria, sub-criteria, alternative possibilities, and privies.

Process of decision-making, for which a lot of information is needed, uses mathematical methods for evaluation of alternative decisions.

Based on previous analysis the purchaser company ES has decided for these three suppliers:

- Proving s.r.o., Snina,
- Locker s.r.o., Michalovce,
- NOBtec GmbH, Deutschland.

Definition of supplier - selection criteria

To produce an attractive easy-to-sell product, it is necessary to meet the quality required by customer, sell it for appropriate price, and deliver it in agreed deadlines. For these reasons criteria and sub-criteria were chosen partly based on references, but mostly based on personal consultations in different companies. Proposed criteria are shown in Table 1, where each criterion is divided into sub-criteria, which are explained in third column. This set of criteria and sub-criteria was proposed in Hudymáčová and Benková (2010) in a general way to satisfy a large spectrum of different products, which can be subject of interest, where supplier selection is needed.

Realization of chosen method for supplier selection - Multi-Criterial AHP method

There is a big variety of MCDM methods, but all have the same goal, to estimate the best alternative among several options, based on predefined criteria. These methods can be classified as in Triantaphyllou (2000): according to the type of data they use (deterministic, stochastic, fuzzy), according to the number of decision makers (single, group), etc. In Chen and Hwang (1991) the MCDM methods (deterministic, single decision maker) were classified in a taxonomy given in Figure 1.

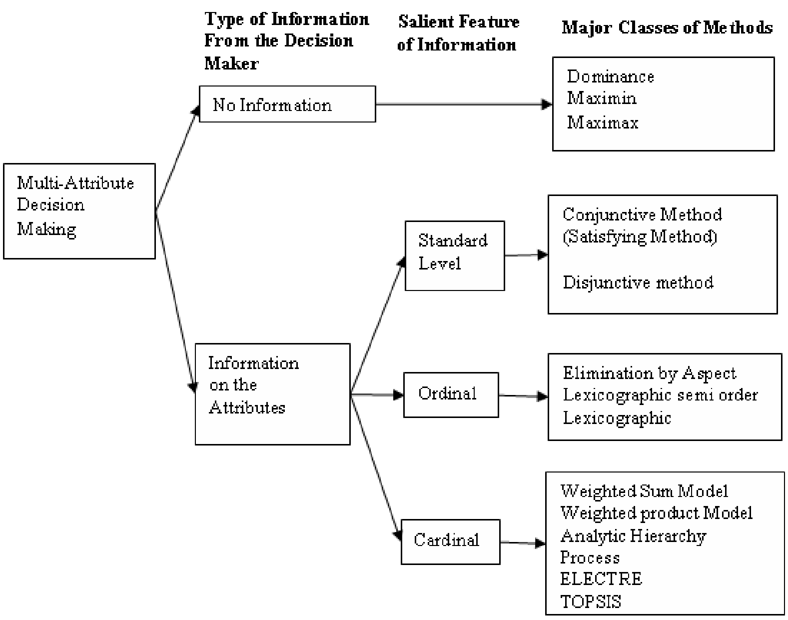

Fig. 1. A Taxonomy of MCDM Methods (Chen and Hwang 1991).

One of possible methods for selection of a supplier is AHP method, which offers a frame of effective tools in complex decision situations, and helps to simplify and speed up natural process of decision making. AHP method is based on breakdown of a complex situation into simple components, where hierarchical system of the problem and pairwise comparisons are made in order to ensure the quantification of qualitative judgments.

After choosing the goal, criteria (and sub-criteria) and an adequate method for solving proposed decision problem, the selection of supplier can be realized. First the hierarchical structure breakdown is drawn (Fig. 2).

First-level criteria were compared between-each-other depending on importance given by ES company (e.g. Quality is twice more important as Costs, etc.). Based on these statements a pairwise reciprocal matrix was created and weights of criteria were calculated as in (1).

$$A = \left|\begin{array}{ccccccc} Qty. & Cos. & Del. & E & F & Doc. & Coop. \\ 1 & 2 & 3 & 4 & 4 & 5 & 6 \\ 1/2 & 1 & 2 & 3 & 3 & 4 & 5 \\ 1/3 & 1/2 & 1 & 2 & 2 & 3 & 4 \\ 1/4 & 1/3 & 1/2 & 1 & 1 & 2 & 3 \\ 1/4 & 1/3 & 1/2 & 1 & 1 & 3 & 4 \\ 1/5 & 1/4 & 1/3 & 1/2 & 1/3 & 1 & 4 \\ 1/6 & 1/5 & 1/4 & 1/3 & 1/4 & 1/4 & 1 \end{array}\right| \begin{array}{c} \\ Quality \\ Cost \\ Delivery \\ Equipment \\ Flexibility \\ Documentation \\ Cooperation \end{array} \qquad (1)$$

The weights (priorities) are obtained as principal eigenvector, i.e. eigenvector corresponding to the greatest real eigenvalue, of the given reciprocal matrix.

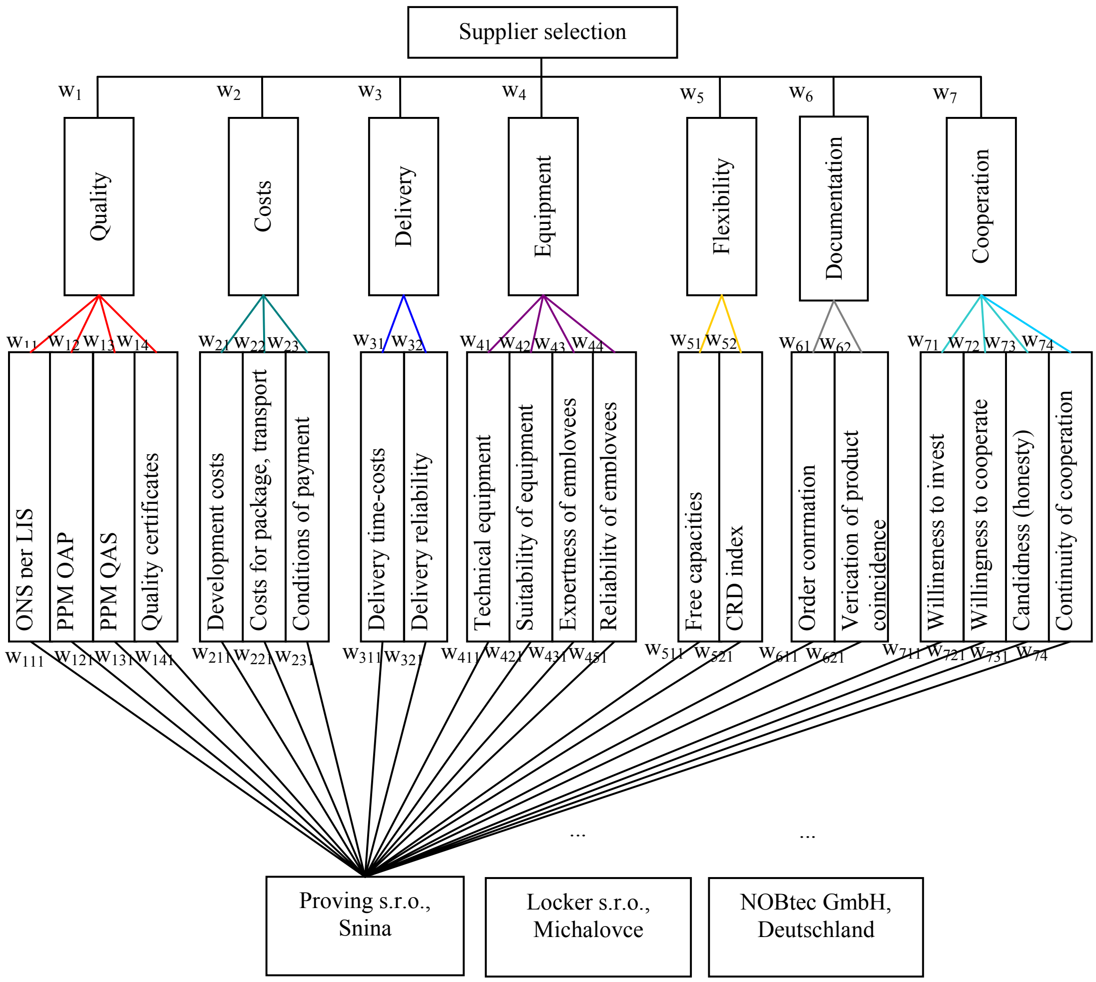

Fig. 2. AHP structure.

Tab. 1. Criteria, sub-criteria and their explanation Hudymáčová (2009).

Criteria	Sub-criteria	Explanation
Quality	QNS per LIS (Quality Notifications per Line Items Shipped)	Number of administrative claims of deliveries from all shipped deliveries.
	PPM QAP (Parts per Million - Quality as Produced)	Number of anti-coincidences from million parts - quality of produced parts.
	PPM QAS (Parts per Million - Quality as Shipped)	Number of anti-coincidences from million parts - quality of delivered parts.
	Quality certificates	Number of quality certificates.
Costs	Development costs	Willingness of supplier to invest into development.
	Costs for package, transport, custom duty	Costs connected with transport (Are these costs included in the price?).
	Conditions of payment	Date of maturity of the invoice.
Delivery	Delivery time-costs	Total time since order to delivery.
	Delivery reliability	% deliveries shipped in time.
Equipment	Technical equipment	Adequacy of suppliers' machines and instruments.
	Suitability of equipment	Suitability of suppliers' equipment for producing of ordered products.
	Expertness of employees	Qualification of suppliers' employees for accomplishment of the work.
	Reliability of employees	Ability of suppliers' employees to produce high-class products.
Flexibility	Free capacities	Ability of the supplier to adapt in case of a request to change the volume of ordered products.
	CRD index (Customer Requested Date index)	Percentile representation of the ability to deliver in time.
Documentation	Order confirmation	Time in which the supplier is able to confirm the order.
	Verification of product coincidence	Availability of the document of product coincidence anytime.
Cooperation	Willingness to invest	Willingness of the supplier to invest, e.g. in modernization of mechanical and technical equipment.
	Willingness to cooperate	Willingness of the supplier to support the partner in terms of according sources (e.g. information, knowledge, experience, technologies, processes, training, etc.).
	Candidness (honesty)	Willingness of the supplier to share information.
	Continuity of cooperation	Lasting of the previous cooperation.

Based on the paper Saaty (1986) principal eigenvector corresponding to a non-consistent matrix can be calculated as:

$$w_i = \lim_{k \to \infty} \frac{\sum_{h=1}^{n} a_{ih}^{(k)}}{\sum_{i=1}^{n} \sum_{h=1}^{n} a_{ih}^{(k)}}, \ i = 1,2,..,n, \tag{2}$$

where w_i are coordinates of the eigenvector and $a_{ih}^{(k)}$ are components of matrix A powered by k.

As we have chosen "four decimal places" precision we looked for smallest power ($k \in N$) of matrix A, where coordinates of principal eigenvector of the matrix A^{k-1} and A^k would be identical on four decimal places. In this case it is sufficient to use $k = 5$.

Coordinates of the principal eigenvector calculated from matrix A^5 using formula (2) without limiting step, are in Table 2.

Tab. 2. First-level criteria.

Quality	0.3418
Costs	0.2284
Delivery	0.1462
Equipment	0.0883
Flexibility	0.1012
Documentation	0.0610
Cooperation	0.0331

Let us introduce the matrix *B* used for calculating of the weights of sub-criteria of the criterion Quality. Matrix *B* was obtained based on priorities formulated by company ES on concrete sub-criteria. Similarly we have obtained matrices for evaluation of weights of all other sub-criteria. Totally there are seven matrices (for each criterion one), for illustration we have displayed only the first-one (3).

$$B = \left| \begin{array}{cccc} Q.p..L. & P.QAP & P.QAS & Q.C. \\ 1 & 2 & 2 & 5 \\ 1/2 & 1 & 1 & 4 \\ 1/2 & 1 & 1 & 4 \\ 1/5 & 1/4 & 1/4 & 1 \end{array} \right| \begin{array}{c} \\ QNS\,per\,LIS \\ PPM\,QAP \\ PPM\,QAS \\ Qty.certificates \end{array} \qquad (3)$$

Tab. 3. Second-level criteria (sub-criteria).

QNS per LIS	0.4393
PPM QAP	0.2456
PPM QAS	0.2456
Quality certificates	0.0696

Table 3 shows resulting weights of the sub-criteria under the criterion Quality (again B^5 was needed for declared precision).

Next step is to calculate the rank of all supplier companies according to selected sub-criterion. In (4) matrix *C* shows pairwise comparison of all suppliers from the point of view of the sub-criterion QNS per LIS.

$$C = \left| \begin{array}{ccc} \mathrm{Pr}\,oving & Loc\,\mathrm{ker} & NOBtec \\ 1 & 2 & 3 \\ 1/2 & 1 & 2 \\ 1/3 & 1/2 & 1 \end{array} \right| \begin{array}{c} \\ \mathrm{Pr}\,oving \\ Loc\,\mathrm{ker} \\ NOBtec \end{array} \qquad (4)$$

The weights of sub-criteria (second-level criteria) are obtained the same way as in case of first-level criteria and are listed in Table 6. Next all suppliers are compared with each other from the viewpoint of each sub-criterion, where necessary data concerning the outputs (performance) of supplier companies were obtained by personal consultations, previous experience, analysis, etc. The resulting weights are listed also in Table 6.

From the resulting evaluation of suppliers shown in Table 4 follows that the best possible choice is the supplier Proving s.r.o., as he has obtained the highest performance. These results were obtained from the relationship:

$$s_l = \sum_{i=1}^{7} w_i . \sum_{j=1}^{k_i} w_{i,j} . w_{i,j,l} \ , \qquad (5)$$

where s_l is the weight of each supplier.

Each criterion was numbered (from 1 to 7) and divided into k_i sub-criteria (numbered from 1 to k_i). So the $w_{i,j}$ is the weight of j-th sub-criterion related to i-th criterion, and similarly $w_{i,j,l}$ is weight of l-th supplier-company from the view-point of j-th sub-criterion related to i-th criterion (Figure 2).

Tab. 4. Weights of suppliers.

Proving s.r.o.	0.4285
Locker s.r.o.	0.3369
NOBtec GmbH	0.2346

Company ES has provided as well the prices offered by supplier companies, so it was possible to make the final calculation which is based on the ratio performance/price (see Table 5). Based on these results one can see that from the viewpoint performance/price the rank of supplier companies was not changed so the best possibility is Proving s.r.o.

Tab. 5. Rank of suppliers.

	Price	Normalized price	Performance/price
Proving s.r.o.	30	0.4110	1.0426
Locker s.r.o.	24	0.3287	1.0249
NOBtec GmbH 1	19	0.2603	0.9012
SUM	73	1	

Conclusion

This case study shows, that although supplier selection is one of the most important activities in a company, it does not mean it has to be complicated and cause problems for the company. It is also demonstrated, that the selection should not be made based on subjective judgments, using suitable mathematical method can assure good and objective results.

Algorithm suitable for any decision process is here described in four steps. This algorithm was used for supplier selection. From results one can see, that it is necessary to evaluate all suppliers not only from the viewpoint of performance, but also from the viewpoint performance/price where the rank shows that the best supplier company is Proving s.r.o.

Tab. 6. Criteria, sub-criteria and their weights.

Criteria (weights)	Sub-criteria (weights)	Proving s.r.o.	Locker s.r.o.	NOBtec G.m.b.H.
Quality 0.3418	QNS per LIS: 0.4393	0.5396	0.2970	0.1634
	PPM QAP: 0.2456	0.5396	0.2970	0.1634
	PPM QAS: 0.2456	0.5396	0.2970	0.1634
	Quality certificates: 0.0696	0.7778	0.1111	0.1111
Costs 0.2284	Development costs: 0.4836	0.4000	0.4000	0.2000
	Costs for package, transport, custom duty: 0.1677	0.2970	0.5396	0.1634
	Conditions of payment: 0.3487	0.1634	0.2970	0.5396
Delivery 0.1462	Delivery time-costs: 0.6667	0.5396	0.2970	0.1634
	Delivery reliability: 0.3333	0.5472	0.2631	0.1897
Equipment 0.0883	Technical equipment: 0.2491	0.3333	0.3333	0.3333
	Suitability of equipment: 0.3380	0.5000	0.2500	0.2500
	Expertness of employees: 0.3151	0.3333	0.3333	0.3333
	Reliability of employees: 0.0978	0.4000	0.2000	0.4000
Flexibility 0.1012	Free capacities: 0.1667	0.2970	0.5396	0.1634
	CRD index: 0.8333	0.2970	0.5396	0.1634
Documentation 0.0610	Order confirmation: 0.7500	0.2500	0.2500	0.5000
	Verification of product Coincidence: 0.2500	0.4286	0.4286	0.1429
Cooperation 0.0331	Willingness to invest: 0.1653	0.4000	0.2000	0.4000
	Willingness to cooperate: 0.4091	0.1634	0.2970	0.5396
	Candidness (honesty): 0.1038	0.2970	0.5396	0.1634
	Continuity of cooperation: 0.3219	0.2000	0.4000	0.4000

Acknowledgements: *This work was partially supported by grants APVV VV-0040-07, VEGA 1/0390/10, 1/0746/11, 1/0497/11.*

References

Chen, S.J., Hwang, C.L. (1991). *Fuzzy Multiple Attribute Decision Making: Methods and Applications*, Springer, Berlin

Hudymáčová, M. (2009). *Vytváranie partnerstiev s dodávateľmi, ich vplyv na zvyšovanie výkonnosti podniku a spokojnosti zákazníkov*. Písomná práca k dizertačnej skúške. Košice: F BERG TU v Košiciach.

Hudymáčová, M., Benková, M. (2010). Návrh kritérií pre použitie multikriteriálnych rozhodovacích metód. In: *Q Magazín - Internetový časopis o jakosti*, No. 6.

Saaty, T.L. (1980). *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*, 281 pp., McGraw-Hill International Book Company, New York.

Saaty, T.L. (1986). Axiomatic foundation of the analytic hierarchy process, In: *Managmennt science*, Vol. 32, No.7.

Saaty, T.L. (2004). Decision making – the analytic hierarchy and network processes (AHP/ANP), In: *Journal of systems science and systems engineering*, Vol. 13, No. 1.

Saaty, T.L. (2008). Decision making with the analytic hierarchy process. In: *J.Services Sciences*, Vol. 1, No. 1.

Triantaphyllou, E. (2000). Multi-Criteria Decision Making Methods: A Comparative Study. *Series: Applied Optimization*, Vol. 44, 324 p.