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APPLICATION OF THE AHP IN EVALUATION AND SELECTION OF SUPPLIERS

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Abstract: *The objective of this paper is to demonstrate the application of the Analytic Hierarchy Process (AHP), a popular multicriteria decision support tool, in assessment and selection of (best) suppliers in an enterprise, namely food wholesalers. Cooperation with suppliers is an important element of quality management. One of the major problems that modern companies have is selection of the best supplier of raw materials, equipment, services, etc. Food sector was selected as particularly sensitive towards potential risks of selection of a wrong supplier. The examples of factors that influence the choice of suppliers include i.e.: price, possibility of discounts, innovativeness. These factors have been organized into hierarchical structure and evaluated by the relevant experts – representatives of food wholesalers in Poland. They indicated, using the 9-point fundamental scale, the relative importance of each factor. Such model can be used as a universal and systematic tool to evaluate suppliers in any company.*

Key words*: AHP, supplier selection, supplier evaluation, food wholesalers*

1. INTRODUCTION

The Analytic Hierarchy Process (AHP) is a popular decision support method developed in the 1970s by American mathematician, Thomas L. Saaty. Since then it has been used in real environment, including business, healthcare, politics and education. There are many organizations that applied this method in making their decisions. For example, IBM used AHP to design the AS/400 computer as part of its quality improvement strategy, and win the Baldridge Quality Award [1]. The Nuclear Regulatory Commission (NRC) of the US applied AHP to allocate money in information technology projects with many competing priorities. The Xerox company also used this method for similar purpose. The AHP was chosen as a decision support tool in many political and military applications, i.e. whether to build or not to build the National Missile Defence system in 2002 [2]. The Saaty's method was also found convenient in the evaluation of suppliers (i.e. [3], [4]). The problem of supplier selection is crucial for contemporary enterprises. A careful selection of a set of suppliers is a strategic decision, which may result in cost reduction and improvement of goods and services. Therefore, it is sensible to use tools, which would support managers in solving such important problems. Apart from the AHP, a number of other tools have been found useful in this respect. They include i.e. DEA (Data Envelopment Analysis), MAUT (Multi-attribute utility theory), TCO (Total cost of ownership) and statistical models [5]. However, the advantage of using the Analytic Hierarchy Process compared with other methods lies in its simplicity, flexibility and dedicated software (i.e. Super Decisions) allowing quick calculation of priorities. The AHP decomposes complex problems into a hierarchy of easily comprehended elements, which can be analysed independently. Experts evaluate the elements of hierarchy by comparing them in pairs using the special 9-point scale, also called "Saaty's fundamental scale". In the

context of decision-making process regarding supplier selection, hierarchical models consisting of different criteria of evaluation of suppliers are constructed. Then, the relative importance of these criteria is analysed and the degree to which they are fulfilled by particular suppliers. It allows choosing the "best supplier", who satisfies – to the highest degree – the most important criteria. The paper aims to present the application of the AHP method in evaluation of suppliers by food wholesalers in Poland. This type of enterprises was considered a good example of reporting supplier selection for several reasons, i.e. sensitivity of the market towards emerging food hazards, influence of food hazards on health and wellbeing of the consumers, and diversity of suppliers in case of food wholesalers. This paper is organized in the following way. First, a short review of literature regarding selection of suppliers is presented, focusing at supplier evaluation criteria and methods. Second, it explains the AHP method and its main stages. Then, the AHP study regarding supplier evaluation by food wholesalers in Poland is reported, followed by conclusions and implications for future research.

2. SUPPLIER EVALUATION CRITERIA AND METHODS

2.1 Supplier evaluation criteria

The evaluation and selection of supplier is one of the most important strategic decisions and major aspect of purchasing policy in all types of enterprises. Selection of the proper suppliers is a multicriteria decision making problem, which determines the quality of the products. The first step of the supplier rating procedure is establishing the criteria of supplier evaluation [6]. Most sources mention criteria such as i.e. price, delivery, quality, customer service, cooperation, organization, innovative approach, quality management systems implemented, financial situation of a supplier, reliability of products and services, quick response, environmental management (e.g. [7], [8], [9], [10]). Many organizations (especially large corporations) establish their own set of the criteria of vendor evaluation. For example, Lear Corporation (who is a leading supplier of Seating and Electrical Power Management Systems to BMW, Audi, Ferrari, Fiat, Maserati, Porsche, Toyota, VW) takes into account the following criteria [11]:

- Competitive pricing;
- Constant, clear and reliable communication as an element of customer service;
- Engineering support taking into account the suppliers' suggestions of new technology or materials;
- On-time delivery;
- High quality products with zero defects;
- Localization opportunities, if a supplier can bring its products closer to Lear;
- Flexibility;
- LSA, that is long-term agreements offering incentives for productivity in exchange for extended contracts;
- SCTO – assistance and proactive participation in searching for cost reduction opportunities.

Another automotive company, General Motors, requires from its vendors to carry out so-called QSB (Quality System Basics) audit. It is based on 11 criteria [12]:

- Fast response – immediate addressing quality failures, clear and precise way of solving quality issues, involvement of all employees in process improvement, identification of causes of the problem (5Why's);
- Control and supervision of nonconforming products, their identification and segregation;
- Verification stations – checking and verification of products during the manufacturing process, solving problems in teamwork; such approach reduces the number of defective parts,

improve quality, and decreases the cost of quality;

- Standardized operations – standardized work, 5S, operator instructions, calibration, monitoring of measuring instruments;
- Standardized training of operators, new employees and documentation of training;
- Error proof verification (Poka Yoke), history of nonconformities with corrective actions;
- Layered process audits – all levels of the organization are involved in the process of audit, reporting of results and determining corrective actions,
- Risk reduction, supporting continuous improvement and problem solving strategies;
- Contamination control – monitoring of possible contamination and cleanliness of products and the environment where products are manufactured, assigning responsibility for contamination reduction;
- Supply chain management – a clearly defined procedures for audits of new and existing suppliers;
- Change management process product specification.

A vast majority of the above listed criteria apply to any supplier, although some of them may vary dependent on a sector in which the company runs its business, production profile, etc. For example, in food industry, suppliers are required to have clean and new trucks and handling equipment and regulatory compliance with food safety standards [13]. Some criteria are further specified i.e. the criterion of technology consists of ability to solve technical problems, machinery, and outlook for the future [14] or technological capacity, product facility, product reliability [15]. There have been many studies attempting to review and classify various papers related to criteria of vendor selection. The most frequently discussed criteria are price (discussed in 80% of the 74 reviewed articles, delivery (59%) and quality (54%) [6].

2.2 Supplier evaluation methods

In the literature, the most popular methods of the supplier evaluation are point method, indicator method and graphical method [16]. In the point method, measurable criteria of supplier evaluation are first set up, then scoring for each criterion is established and weights are calculated for each criterion. Subsequently, sum of the achieved scores or weighted mean is calculated. Indicator method is based on calculation of indexes reflecting quality of supplies, i.e. order realization, delays of delivery, etc. In the graphic method, points (from 1 to 5) reflecting level of fulfilment of particular criterion by the supplier are put into the chart (i.e. radar chart). In this way, the area of fulfilment of the requirements by the supplier is delineated ([17], [18]). A decision which method will be used in supplier evaluation and selection depends on i.e. needs and type of the company, type of provided goods and services, size of production and type of raw materials used. According to [19], the main criterion behind the selection of method of supplier evaluation should be minimization of costs related to purchase and maintanance of stock and creating conditions for undisturbed production and high quality products. Another method of supplier evaluation is Analytic Hierarchy Process (AHP), which allows taking into account the relationships between particular criteria of supplier evaluation [20]. This method (and its generalization ANP – the Analytic Network Process) appears the most utilized methodology of supplier selection [21], particularly in sectors such as automotive industry, white goods and telecommunications. The study presented in this paper uses the AHP method in food industry, specifically food wholesalers. The subsequent section will briefly explain the general rules and steps of the AHP. Then, the results of the AHP research study will be reported.

3. THE ANALYTIC HIERARCHY PROCESS

3.1 Building hierarchical structure (the AHP model)

The Analytic Hierarchy Process (AHP) was developed by Thomas Saaty as a multicriteria decision-making tool, which decomposes a complex problem into a hierarchy consisting of specific elements. A hierarchical decision model consists of a goal (always at the top level of hierarchy), criteria that are evaluated for their importance to the goal, and alternatives that are evaluated for how preferred they are with respect to each criterion. Criteria can be further divided into sub-criteria. A general, four-level hierarchical structure presented in Fig. 1 is a universal schema applicable in most decision problems.

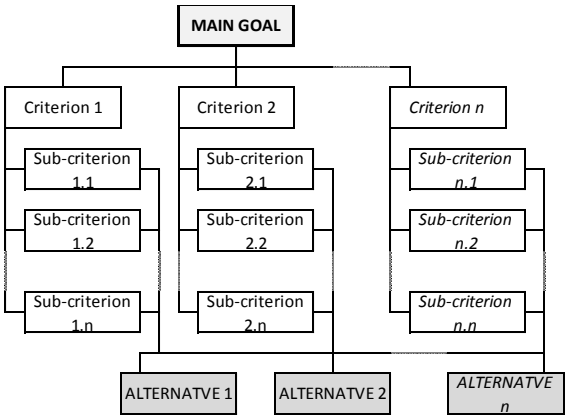

Fig. 1. General four-level representation of hierarchical model

3.2 Pairwise comparison judgments and calculating priorities

Once the hierarchical model has been structured for a decision problem, participating experts make pairwise comparisons for each level of the hierarchy. In fact, the use of pairwise comparisons is one of the major strengths of the AHP to derive ratio scale priorities, as opposed to using traditional approaches of assigning weights. Pairwise comparison is the process of comparing the relative importance, preference, or likelihood of two elements ("children") with respect to an element in the level above ("parent"), in order to obtain priorities for the elements being compared. For example, each criterion is pairwise compared with respect to the goal, and each sub-criterion with respect to the "parent" criterion. Pairwise comparisons are conducted for all the parent/children sets of nodes using a special 9-point scale, called "fundamental scale". The relative importance (preference, likelihood) of one element over another can be indicated as "equal" (=1), "weak" (=3), "strong" (=5), "demonstrated" or "very strong" (=7) and "absolute" (=9). Intermediate values (2, 4, 6, 8) are used if one hesitates in his/her judgment and compromise is needed [22]. The comparisons are based on reciprocal numbers: if element A has "weak" importance over B (A=3B), then B=1/3A. Thus, the scale has in fact not 9, but 17 points. Number of combinations of elements subjected to pairwise comparisons in each node is redundant and follows the following formula (1):

$$\frac{n \times (n-1)}{2} \tag{1}$$

where n is a number of elements compared.

The judgments are placed in a square matrix A (n x n), where n is a number of elements compared [23] (2).

$$\mathbf{A} = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{bmatrix} \tag{2}$$

Such matrices are constructed for all sets of nodes of the AHP model. For each matrix, priority vector is derived as the normalized principal eigenvector. The sum of elements of this vector (priorities, weights) is 1 since it is normalized. They represent relative importance (preference, likelihood) among elements that are compared. The easiest way to calculate priority vector is to use the relevant software, such as Super

Decisions. It can be also done "by hand" or with spreadsheets using three methods: matrix multiplication, arithmetic mean and geometric mean. Matrix multiplication is a difficult way of obtaining priorities but the results are very accurate. The most frequently used "hand" method of priority calculation in the literature is geometric mean. It is, however, not recommended by Saaty if more than 3 elements are compared, since it may generate inaccurate results [23]. It needs to be pointed out that single matrix results in "local priorities" of the children nodes with respect to the parent. "Global priorities" are derived from multiplication by the priority of the criterion with respect to the goal. In a four-level hierarchy, global priorities for sub-criteria are derived as a multiplication of their local priorities by the priority of the relevant criterion. Overall priorities for the alternatives are calculated by adding their global priorities.

3.3 Measuring consistency of pairwise comparisons

The use of pairwise comparisons is one of the major strengths of the AHP method to derive priorities, as opposed to using traditional approaches of assigning weights. However, redundancy of pairwise comparisons generates the problem of inconsistency. Test of consistency is a critical step in the AHP and should be performed for each matrix. When it fails to satisfy the consistency requirement, revisions have to be made by a participating expert. A consistency test developed by Saaty [24] allows a certain level of acceptable deviation (CR<0,1). The consistency test requires calculation of consistency ratio (CR) using the formula (3):

$$CR = \frac{\lambda_{\max} - n}{n-1} / RI \qquad (3)$$

where λ_{max} is the maximum eigenvalue of the pairwise comparison matrix, and *RI* is a random index dependent on *n*. If CR is larger than 0,1 (10%), the respondent is required to revise his judgments until the acceptable level of consistency of CR<10% is obtained. The problem of consistency in the AHP has been widely discussed in the literature (e.g. [25], [26]). One of the general principles of constructing the hierarchy states that no more than 7+/-2 elements (a so called „magical number") should be considered in one group (node), otherwise the inconsistency of judgments could be very high [27, 28]. More details about the AHP method alongside its mathematical foundations are provided in any book by Saaty or other researchers. The literature recommended for further reading includes positions such as (e.g. [23], [29]).

4. RESEARCH METHODOLOGY – THE AHP MODEL

4.1 Building the AHP model of supplier evaluation

As a first step, the goal, criteria and sub-criteria of supplier evaluation for food wholesalers have been identified. The general goal is to select the best supplier. The criteria and sub-criteria have been defined based on the review of literature and following with consultation with the relevant experts. The hierarchical model involves five criteria: Finance (financial conditions of a supplier), Assortment, Logistics, Service, and Quality. Each criterion consists of several sub-criteria, as described below.

Finance:

- Price – prices of products offered by different vendors;
- Price difference – a difference between price for wholesalers and price for retailers; originally this sub-criterion was defined as a Possibility of discount, however, following the pilot study and discussion with wholesalers, it was changed into Price difference which appeared more important for the wholesalers;
- Time limit for payment – longer time limits are desirable.

Assortment:

- Possible changes – the possibility of change (modification) of the components (products) provided; dependent on a component (raw material or intermediate product) specific requirements and possibility of changes are defined;
- Diversity – those vendors who offer broader assortment of products are preferred.

Logistics:

- Buffer stock – a supplier must declare whether or not he is able and willing to keep a certain buffer stock in his premises;
- Flexibility – a supplier is able and willing to change date of delivery;
- Promptness of supply – measured by a time span between making an order and delivery.

Service:

- Innovativeness – ability of a supplier to modernize the assortment;
- Contact – easiness of a contact, including not only traditional means of communication (phone, email), but also time of response to inquiries, existence of communication scheme and whether a supplier delegated a contact person;
- Acceptable procedures – acceptance of the procedures of making orders, whether a supplier accepts and follows the procedures of the company (buyer);
- Customer service – accessibility of a supplier at the local / regional market, i.e. sales offices, logistics points, factory premises, etc.;
- On-line platform – adjusting the IT platform, willingness to cooperate with a buyer within an integrated platform.

Quality:

- The use of SPC – the application of Statistical Process Control by a supplier;
- ISO standards – supplier has the international quality standards implemented;
- Technical support – supplier is able to provide technical support in case of quality problems and to participate in crisis management;
- Reaction on problems – dealing with complaints, readiness to accept the complaint procedures of a buyer.

The complete hierarchical model of supplier evaluation is shown below in Fig. 2.

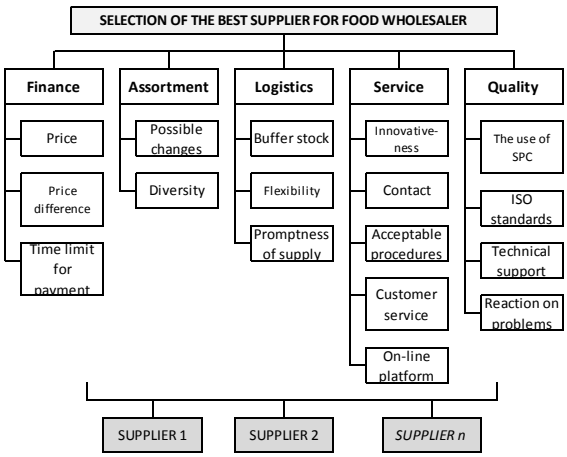

Fig. 2. Hierarchical model of supplier evaluation used by food wholesalers

4.2 Results

The model has been analyzed using a 9-point comparison scale by a group of experts (some were wholesalers). The overall results are presented in Table 1.

Criteria		Sub-criteria	Local	Global
Finance	**0,3859**	Price	0,2344	9,05%
		Price difference	0,6854	26,45%
		Time limit for payments	0,0802	3,09%
Assortment	**0,1906**	Possible changes	0,5	9,53%
		Diversity	0,5	9,53%
Logistics	**0,1075**	Flexibility	0,0909	0,98%
		Buffer stock	0,4545	4,89%
		Promptness of supply	0,4545	4,89%
Service	**0,0692**	Innovativeness	0,1031	0,71%
		Contact	0,3547	2,45%
		Acceptable procedures	0,1309	0,91%
		Customer service	0,2721	1,88%
		On-line platform	0,1392	0,96%
Quality	**0,2469**	Reaction on problems	0,599	14,79%
		ISO standards	0,1128	2,79%
		The use of SPC	0,0606	1,50%
		Technical support	0,2275	5,62%

Table 1. Priorities for criteria and subcriteria

As regards the importance of general criteria of supplier selection (analysis of the criteria with relation to the main goal), Finance received the highest priority

(0,3859), which indicates its highest importance for food wholesalers (it fulfills the main goal in 38,6%). On the other hand, Service received the lowest weight (0,0692). As regards the relative importance of sub-criteria, the so-called "global" priorities (weights) have to be calculated as multiplication of "local" priority of a sub-criterion (its relative importance with respect to the parent criterion) by the priority of that criterion. For example, local priority of the Price is 0,6854 and it indicates its relative meaning with respect to the Finance. Global priority of the Price (0,0905, or 9,05%) was calculated by multiplying 0,6854 by 0,3859 (weight of its parent criterion) and it represents its overall importance with respect to the main goal. Global priorities for all sub-criteria have been illustrated in Fig. 3 from the highest to the lowest values. Price difference between offers for wholesalers and offers for retailers appeared to be the most significant factor in selection of the supplier – its global priority is 26,4%. The bigger the difference, the higher the potential profit of the wholesaler. Reaction on problems such as complaints received the weight of almost 15%, which is the second-best factor of supplier evaluation in respect of importance. The sub-criteria, which received the lowest priorities, include Innovativeness (0,7%), Acceptable procedures (0,9%), On-line platform (1%) and Flexibility (1%). Such numbers indicate their low importance in evaluation and selection of suppliers.

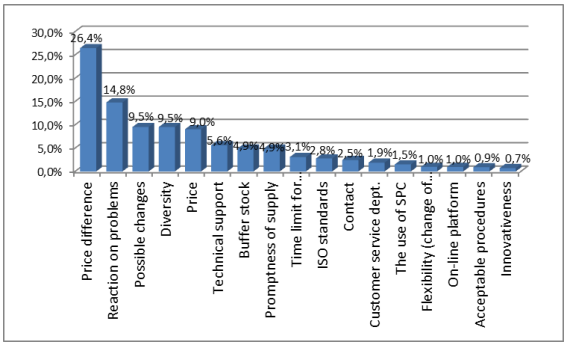

Fig. 3. "Global" priorities for sub-criteria in supplier evaluation model

5. CONCLUSION

The paper demonstrated the application of one of the most popular decision support methods – the Analytic Hierarchy Process – in evaluation and selection of suppliers by wholesalers operating in the food sector. The paper briefly explained rules and steps of the AHP and reviewed the relevant literature concerning criteria and methods of supplier evaluation. In general, four methods are mentioned as frequently used for this purpose, namely point method, indicator method, graphical method and the AHP. The AHP method allows deriving numeric priorities for vendor evaluation criteria, indicating which are the most important and respectively, which should be considered in the first place. It is worthy to note that decision alternatives – the real suppliers – have not been taken into account in this model. The analysis stopped at ranking the importance of the criteria of supplier selection and produced the results applicable to any supplier in this sector. There are two ways of continuing this analysis by assessing a range of suppliers. First, using a "traditional" AHP approach by comparing a degree to which each supplier fulfills the sub-criteria on a 9-point pairwise comparison scale. However, this approach works if no more than 7+/-2 suppliers are involved in the selection process. Second, by applying point analysis (assigning values i.e. 1-5 dependent on the degree to which each factor is fulfilled by a particular vendor). The latter approach allows taking into account more than 9 suppliers without the risk of inconsistency.

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