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Using the Analytic Hierarchy Process Method to Select the Best Supplies: A Case Study of a Production Company

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Abstract:

Purpose: *The aim of the article is the practical implementation of the Analytic Hierarchy Process (AHP) method to select the optimal raw-material supplier in a selected company, along with the definition of a set of criteria required to evaluate each of them.*
Design/Methodology/Approach: *The article uses the Analytic Hierarchy Process method, which accounts for both quantitative and quantitative aspects. The source of the data used in the analysis was data provided by the surveyed entity and free-form interviews with the employees.*
Findings: *The research clearly shows which supplier best meets the criteria outlined by the company.*
Practical Implications: *Regardless of industry and company size, selecting using the AHP method to select suppliers allows for making decisions based on several criteria whose correlation is preference-adjusted.*
Originality/Value: *The value of this article is its universality and practical application. The subject of the article is very current and fits in the current trend of seeking suppliers with whom to establish a long-term cooperation and forge a permanent link of the supply chain.*

Keywords: *AHP method, supplier selection.*

JEL codes: *M21, L99, L83, C38.*

Paper type: *Research article.*

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1. Introduction

Production companies, currently operating in a volatile and competitive environment, must constantly improve the efficiency and effectiveness of their logistics processes. Their activity is inherently linked with making the right decisions which help them meet targets and reach goals. The ability to make the right choice in the face of the ever-growing scale of consumption of different goods thus becomes crucial. The process of selecting and evaluating suppliers is currently one of the pivotal aspects of running a business, including in production.

Until recently, many companies used to be guided solely by their intuition and market word-of-mouth where lack of precise evaluation would prompt mistakes in decision-making. An uncertain economic setting is one of the determinants for selecting the right supplier, and as such, it defines a set of criteria for companies that reflects largely on their global performance as well as that of the supply chain at large.

To ensure such decisions are as foolproof as possible, different methods are used that are a mix of mathematics and psychology. They include the analytical hierarchy process (AHP), which makes it easier to make optimal choices in the case of multi-criteria decision problems, supplier selection being clearly one of them.

Accordingly, the aim of this article was to implement the AHP method in practice with a view to selecting the optimal raw-material supplier in a selected company, along with defining a set of criteria required to evaluate each of them.

2. Literature Review of Supplier Selection Methods

In today's volatile environment, procurement logistics plays a very important role in the supply chain, while supplier selection is one of the most important decisions to be made in supply chain management due to its direct impact on competitiveness (Cristea and Cristea, 2017). This is especially true for production companies where choosing supply partners is nothing short of a strategic decision, given that the quality and price of products offered to end-customers depend on the supplier’s capacity and on the quality of the raw materials that they work with.

In particular, this can contribute to savings in logistical costs (Skiba, 2013). In a rapidly changing environment such as ours, this choice is not easy, and any mistakes may trigger losses in the supply chain that will affect performance, all the more visibly in small production companies (Frej *et al.*, 2017). Among the research studies exploring the problem of supplier selection, we find a commonly shared view that modern supply management is about maintaining long-term cooperation with suppliers and working with few but reliable partners (Ho *et al.*, 2010).

And choosing the right supplier sets in motion a multi-criteria decision-making process, to which different analytical approaches and solutions can be found in the literature. The Weighted-Point Method is one of the simplest and most frequently used among them. It is based on the subjective *weighting* of individual criteria by the organization making the selection. The weight of each criterion is then multiplied by the assigned performance score until the points are summed to determine the final score for each supplier.

This method, however, is mainly used for the evaluation of quantitative measurements. The advantages of the Weighted-Point Method lie in its simplicity and the possibility of gauging several factors at once and adjusting their importance based on specific needs. Things become slightly more complicated when qualitative criteria enter the equation (Khaled *et al.,* 2011).

Many researchers have proposed more extensive multi-criteria approaches to decision-making for supplier selection, accounting for both quantitative and qualitative criteria, such as: the Analytical Hierarchy Process (AHP) (Miciuła and Nowakowska-Grunt, 2019), the Analytic Network Process (ANP) (Gencer and Gürpinar, 2007), case-based reasoning (Yu and Zhao, 2011), Data Envelopment Analysis (DEA) (Dutta *et al.,* 2022), fuzzy set theory (Chen *et al.,* 2006), a genetic algorithm (Ben Jouida and Krichen, 2020), mathematical programming (Degraeve and Roodhooft, 2020), the Simple Multi-Attribute Rating Technique (Risawandi and Rahim, 2016).

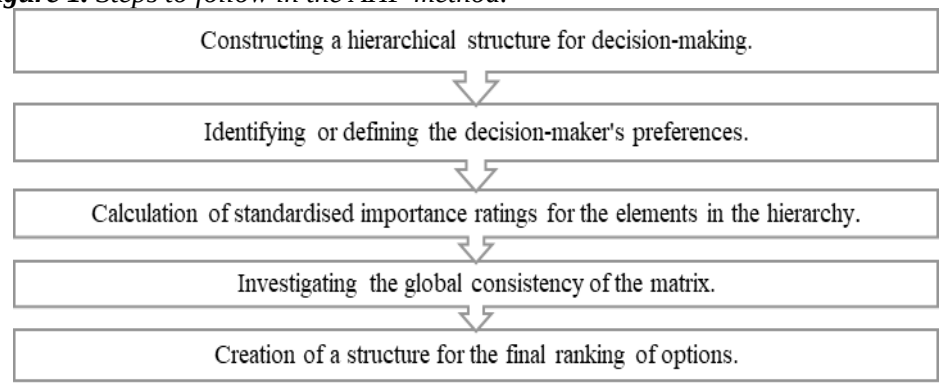
Some researchers have designed hybrid models by combining more than one type of selection method (Tusnial *et al.,* 2020). Each of these methods has its strengths but also limitations. The type of method used in the supplier selection process depends, among other factors, on the conditions in which companies operate and the adopted qualitative and quantitative criteria.

3. Analytic Hierarchy Process (AHP) Methodology

AHP is one of the most widely used multi-attribute decision-making methods out there. But its wide embrace and universality are not the only reasons why companies reach for it so eagerly. A decision-maker's task to benchmark criteria, sub-criteria and variants on a side-by-side basis is relatively simple, as reflected by its broad application in practice.

Developing the reference ranking is not particularly time-consuming either, nor does it require a substantial data input - correlatable preferences will suffice. AHP consists in decomposing a decision problem and ordering a finite set of decision variants. This method can be divided into five stages, or steps, shown in Figure 1.

Figure 1. *Steps to follow in the AHP method.*



Source: *Own elaboration.*

In the first stage, the problem is defined by breaking it down into basics in the form of a hierarchical structure of decision-making (e.g., through a decision tree) where the alternative decision occupies the bottom level of the structure.

In the next stage, the decision-maker at each level of the hierarchy provides preferential input, i.e., the evaluated importance for pairs of criteria and decision variants. The compared elements are then rated on a scale from 1 to 9 where the stronger the preference, the higher the score. Equivalents are rated 1, while 9 is reserved for those particularly strongly preferred over the other. Even-number values (2, 4, 6, 8) denote the "moderate advantage", a compromise between individual advantages. The detailed description was developed by Saaty in 1980 (Table 1).

The compensatory nature of the coefficients means that the value of the element that is less important to the decision-maker is the inverse of the evaluated advantage of the more important element over the comparable one. Values such as 1/3, 1/5 are assigned to elements that are subjectively worse or less important. It is also at this stage that a preference matrix (graph) is designed.

In stage three, the essence is calculating the evaluated importance of individual elements on the basis of the preference matrix for which the eigenvector should be worked out. To this end, the numerical method of determining the vector is used, which consists in squaring the preference matrix. The vector should then be normalized, with this operation repeated until a constant weight vector is obtained. It means that in the next iteration the obtained vector differs from the previous one no more than by the constant $|\varepsilon|$.

Examining the global matrix consistency (stage IV) consists in summing the rows of the matrix. If the result is 1 (assuming the $|\varepsilon|$ error limit), we can proceed to the last stage, which consists in calculating the product of the matrix of the degree of satisfaction by the variants and the criteria-importance ranking matrix for the decision-maker.

Table 1. *The 1-9 Scale in the AHP.*

importance intensity	**definition**	**explanation**
1	equal relevance	equivalence of the two elements being compared
3	moderately more important one over the other	low importance or preference of one element over another
5	definitely more important one over the other	strong preference (importance) of one element over another
7	very definitely more important one over the other	dominant importance or very strong preference of one element over another
9	overwhelmingly more important one over the other	the absolute greater importance (preference) of one element over another
2, 4, 6, 8	for compromise comparisons	if there is a need for numerical interpolation of compromise opinions, as there is no good word to describe them

Source: *Own elaboration base on Saaty, T.L. 1980. The Analytic Hierarchy Process. McGraw-Hill International Book Company, New York.*

4. Application of the AHP Method - Case Study - Selection of a Sawn Timber Supplier for the Analyzed Enterprise

4.1 Research Methodology

The following research methods were used in the study, a case study, the AHP method and free-form interviews with company employees. The former belongs to qualitative scientific research methods and involves empirical inference that deals with a contemporary phenomenon in its natural context. Especially when the boundaries between phenomenon and context are not clearly visible (Yin, 2014).

The aim of this method is, among other things, to confront theory with the empirical world. The AHP method was also used in the study because it is particularly useful in situations that occur in the company under study, i.e., most of the criteria for evaluating the options are not quantitative but qualitative, and much of the evaluation is subjective to the subjectivity of the evaluator (decision-maker) (Chou, *et al.,* 2008).

Sources of data can include observations, interviews, company documents, newspaper articles, supplier reviews, surveys, and databases maintained by various institutions. In this study, the author decided to focus on the problem of selecting a supplier of l sawn timber - a raw material necessary in the production process.

4.2 Production Process in the Analyzed Enterprise

The case study presented in this article refers to a company that manufactures outdoor benches and wooden tables, sourcing the basic raw material - sawn timber - from a sawmill. Other suppliers, i.e., manufacturers of fixing screws, packaging and assembly instructions, were deliberately not included in the analysis. The selection of a suitable sawn timber supplier has been identified as a strategic objective for the company, as it is looking for a co-worker with whom to establish a long-term contract.

The existing supplier, with whom the cooperation lasted about three years, was chosen mainly on the basis of opinions in the timber market. Unfortunately, several irregularities occurred during the contract, which disrupted the company's operations, i.e. the delivery time was supposed to be 36 to 48 h from the moment the order was placed, the staff who brought in the semi-finished product very often delivered an incomplete batch, although the amount of sawn timber ordered was always the same, or the supplier was late, which increased the risk of production stoppages and implied disruptions in sales.

The contract was terminated prematurely by mutual agreement. So this time the AHP method was proposed for supplier selection. The materials needed for the production process are ordered in the quantity required for the order on a just-in-time basis, i.e. after the order is accepted and before production starts.

4.3 Results and Findings

An interview with the company's staff (including the procurement logistics manager and the sales manager) identified a set of criteria needed to assess suppliers:

- quality - the raw material must comply with the PN-EN 1309-1:2002 standard (principles and method of measurement and calculation of the volume of general-purpose and specific-purpose sawn timber in domestic and export trade) and before processing must have a moisture content of no more than 20% and be protected against blue stain in accordance with the guidelines of the PN-83/D-04301 standard,
- price - the sum of the net price after discount (if any) for the materials purchased by the department manager, prices are also compared with the sawn timber exchange,
- timeliness - in a production process based on the 'just in time' system and with limited storage space, it is extremely important to meet the delivery date and even the delivery time,
- location - due to the characteristics of sawn timber, which is a heavy raw material, decision makers want their supplier to be within 200 km, such a distance will allow them to react quickly in case of any changes.

The list of potential sawn timber suppliers included eight participants. From the set created, the decision-maker had to select the 'strongest' candidates. Based on the data, four were selected from the set of suppliers according to the highest volume of unprocessed timber ordered.

The decision-maker considered that a high number of ordered product could indicate not only great technical potential, but also good quality, adequate price and reliability in delivery. The next step in the selection process is to gain knowledge about potential candidates. The decision-maker, in order to obtain information on the pre-selected suppliers, decided to arrange a meeting with a representative from each company. After obtaining the data necessary to evaluate the suppliers, he created a ranking of how well each potential collaborator met the criteria.

Table 2. *Ranking of criterion fulfilment based on information.*

criteria	**quality**	**price**	**punctuality**	**location**
supplier A	0,2	0,1	0,4	0,3
supplier B	0,4	0,15	0,3	0,15
supplier C	0,3	0,1	0,3	0,3
supplier D	0,2	0,3	0,2	0,3

Source: *Own elaboration.*

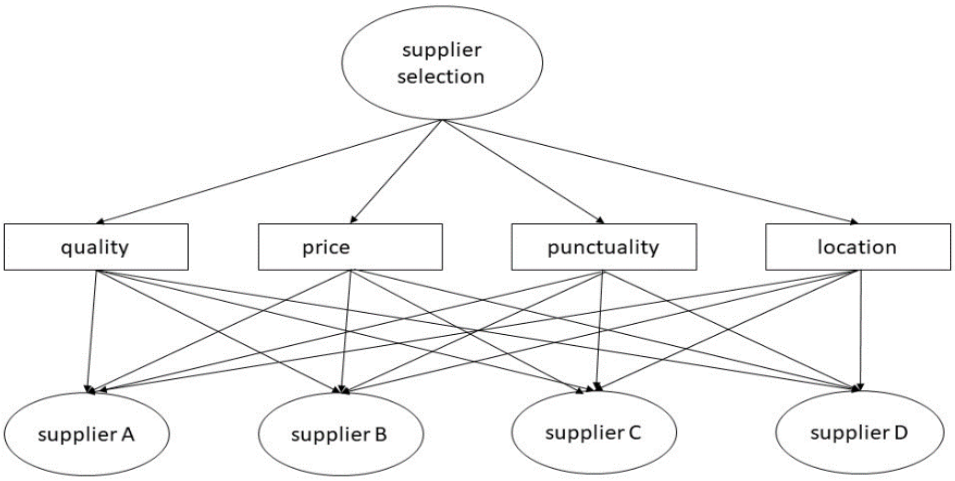
Supplier A was found to be the most timely supplier in relation to the other criteria. However, this does not mean that in terms of these characteristics it is the most on-time supplier of all. Of all the criteria set by the decision-maker, Supplier A satisfies the timeliness criterion to the greatest extent, which influenced the score obtained.

Analysing the situation of supplier B, it can be deduced that, of all the criteria, it met the quality criterion to the greatest extent in relation to the other criteria. The ranking shows that supplier C is equally good at meeting the quality of raw material, timeliness and has a suitable location, but the price in relation to quality is too excessive, as indicated by the lowest score in this criterion. The optimal supplier, according to the ranking, turns out to be supplier D, which meets all criteria at a similar level.

The next step in the supplier selection process is to create a hierarchical evaluation structure in the form of a decision tree (Figure 2). In the case under consideration, it has three levels:

- level 0 - objective - selection of a sawn timber supplier,
- level 1 - the most important criteria for the decision-maker in selecting a supplier,
- level 2 - decision options, i.e., selected suppliers.

Figure 2. *Hierarchical structure of supplier assessment in the company under study - decision tree.*



Source: *Own elaboration.*

The last step that prepares the calculation by means of the AHP method is the creation of a matrix of pairwise comparisons of criteria, which is presented in Table 3.

Table 3. *Matrix of pairwise comparisons of selection criteria*.

criteria	**quality**	**price**	**punctuality**	**location**
quality	1	2	3	7
price	1/2	1	1/5	7
punctuality	1/3	5	1	2
location	1/7	1/7	1/2	1

Source: *Own elaboration.*

In order to find out which criterion is the most relevant, the following calculations should be made for this purpose:

- determine the square of the matrix,
- sum up the values of the elements in each row of the new matrix,
- divide each value in a column of the criteria importance matrix by the value of the sum,
- determine the weight matrix,
- repeat the steps in successive iterations until the sum of the weights is zero.

Table 4 shows the weights obtained in the calculations, their differences and the sums of the differences for each iteration. On the basis of the calculations, the final weights of the individual criteria were determined and are included in the last

columns of Table 4. The timing of the 4th iteration is evidence of the global consistency of the matrix.

Table 4. *Weights and differences in iteration 1-4 for individual criteria.*

	iteration 1		**iteration 2**		**iteration 3**		**iteration 4**	
criteria	weights	difference	weights	difference	weights	difference	weights	difference
quality	0,4155	-	0,4693	0,0538	0,4636	-0,0057	0,4635	-0,0001
price	0,1721	-	0,1744	0,0023	0,1736	-0,0008	0,1735	-0,0001
punctuality	0,3734	-	0,3115	-0,0619	0,3188	0,0073	0,3189	0,0001
location	0,0391	-	0,0447	0,0056	0,0440	-0,0007	0,044	0

Source: *Own elaboration.*

The most important criterion for the procurement logistics manager is quality (0,4635). The final element of the study is to create a final ranking construction of the options. This will provide the decision-maker with an answer as to which supplier to choose. Table 5 presents the ranking of suppliers created by the AHP method based on the decision-maker's preferences.

Table 5. *Ranking of sawn timber suppliers created using the AHP method taking into account the decision-maker's preferences.*

supplier	**weights**
A	0,2508
B	0,3137
C	0,2653
D	0,2218

Source: *Own elaboration.*

Supplier B received the highest score and should be the one to be included in the list of lumber suppliers given the specified selection criteria.

5. Conclusions

Decision-making is an inherent component of any business no matter the industry. For a long time the main drivers for making business decisions were intuition, due to technical limitations. Currently however, many methods are available that can markedly facilitate this process. Any company dealing with tangible goods relies on access to raw materials and energy which are transformed into usables or consumables in the production process.

Stock logistics is the first step paving the way to an outlet market. Using the existing supply options, it coordinates the flow of goods and information to provide companies with the materials used in production.

Production managers must often select the right supplier of key raw materials, with most such decisions being inherently multi-criteria. Particularly significant is whether the decision-maker is able to identify the criteria of most relevance to their company. The method that involves comparing the criteria in pairs (side-by-side) to determine the degree of relevance proves helpful with that.

This article confirms that the application of the AHP method in decision-making makes it easier for companies to select the optimal supplier based on individual user preferences and available data. AHP constitutes a precise method of identifying suppliers for companies regardless of industry focus. Using external indicators as the only benchmark is often counterproductive, whereas AHP-developed rankings streamline identification of the right supplier that best meets the company's individual needs.

In addition, AHP offers a fresh outlook, helps modulate criteria and eliminates the risk of manipulation or bias that could potentially sway the final decision. The analytical percentage of hierarchization makes this method a viable tool for fully functional applications, although adequate caution must be exercised selecting experts and decision-support specialists.

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