

Supplier selection in supply chain management using analytical network process for Indonesian cement industry

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Abstract. Supply chain management has increased more significance with the impact of globalization. In the present worldwide market, well-managed supply chain is a standout amongst the most vital requirement to be more competitive in the market. For any organization incorporate cement industry, the most critical decision in initial process of supply chain management is to buy products, materials or services from suppliers. So the role of suppliers is irrefutable important in the global aggressive markets. Appropriate decision of supplier selection can lead to reducing cost in supply chain management. However, it is becoming more complex because of existing various criteria and involving the suitable experts in the company to make valid decision in accordance with its criteria. In this study, the supplier selection of an Indonesia's leading cement company is analyzed by using one of the popular multi-criteria decision making method, Saaty's analytical network process (ANP). It is employed for the selection of the best alternative among three suppliers of pasted bag. Supplier with the highest rank comes from several major steps from building the relationship between various criteria to rating the alternatives with the help of experts from the company. The results show that, Communication capability, Flexible payment terms, Ability to meet delivery quantities are the most important criteria in the pasted bag supplier selection in Indonesian cement industry with 0.155, 0.110 and 0.1 ANP coefficient respectively. And based on the ANP coefficient values in limit supermatrix, the A2 or supplier 2 had the highest score with 64.7% or 0.13 ANP coefficient.

Keywords: ANP, supply chain management, supplier selection, multi criteria decision making

1. Introduction

The implementation of the concept of the Supply Chain Management (SCM) is very important in affecting the performance of the company. Supply Chain Management to become a competitive strategies to bridge the company with suppliers and distributors in interorganizational system [1]. There are three decision levels in supply chain management, which are strategic, tactical and operational. Strategic level decisions involve long-term issues such as demand planning, strategic alliances, outsourcing, supplier selection and pricing [8]. Supplier selection is a critical strategic decision process in the supply chain, which affects the quality of product directly. Supplier selection problem aims to determine the right suppliers for certain product or service. Since some qualitative and quantitative factors are decisive in the selection process, the decision maker has to determine these suitable factors at the first step [9].

Different decision-making methods are designed to solve supplier selection problem, such as the analytical hierarchy process (AHP), data envelopment analysis (DEA), analytic network process (ANP), case-based reasoning (CBR), mathematical programming, and artificial intelligence (AI) techniques. The traditional cost-based solution methodologies are not as efficient and effective as multi-criteria



decision-making approaches since they are not capable of considering qualitative supplier selection criteria such as flexibility, reliability, culture, and service capability [4]. ANP is one of the suitable methods to cope supplier selection problems because it considers the interdependencies between criteria and sub-criteria.

The main goal of the procurement department is to select the proper source to minimize cost and maximize quality, customer satisfaction and market share. However, supplier selection is a multidimensional problem, which is complex to solve because of its intangible and tangible factors [2]. This problem has been considered in many studies for years, and a variety of criteria and solution methods are generated to solve this problem efficiently. In the literature, some of the researchers define some important criteria in the selection process. Dickson (1969) addresses 23 selection criteria as critical factors in the supplier selection problem. So he identifies quality, price and delivery as the most critical factors among these factors. Following to Dickson's work, Weber, Current, & Benton, (1991) review 76 articles published between 1966 and 1991 and they deduce that the net price of the product, quality and delivery time of the product are the most used criteria in the literature shows that a significant change could be observed in the relative importance of various critical success factors with the increasing competition and globalization after 1990's [3]. Furthermore, they state that reliability, flexibility, consistency, and long-term relationship are four new critical criteria considered in the supplier selection process.

The priority is ranked by [4] using supplier selection criteria as follows: quality, delivery, price/cost, manufacturing capability, service, management, technology, research and development, finance, flexibility, reputation, relationship, risk and safety and environment. They point out that quality and delivery time have become more important than price and the traditional evaluation approach, which is a selection of a supplier based on only the lowest price, is not effective in today's competitive supply chain management. Beside the classical supplier evaluation criteria (price, quality and delivery time), there are other critical criteria such as operational performance, service quality, educational status of the personnel, technology, financial capacity, process control capability, after-sales service, and sustainability that may help to select competent suppliers.

Some of the latest studies about supplier selection in cement industry are as follows: Sharma [7] gave an examination of an AHP model for supplier selection in cement industry using addition green activities criteria. Mukherjee [5] developed an integrated model of fuzzy-AHP-VIKOR-MOGA for supplier selection in cement industry in India. Although still rare the study about ANP in this field but Mukherjee in 2016 have a comprehensive study about supplier selection method using MCDM or the integrated model.

In this study, criteria is determined directly by four experts in company with their expertise. Although in the prior interview we put all criteria based on literature review but only 10 criteria we had selected since it is the most significant to the problem based on our experts in company. The criteria seem too small in number if compared with other literatures, but we convinced that it will increasing during the increment of expertise in company.

2. Analytical Network Process (ANP)

ANP is a Multi Criteria Decision Making (MCDM) method which was introduced by Saaty. It is the extension of Analytical Hierarchy Process (AHP) as a MCDM method that describes the interrelationships and feedback between elements and alternatives. The ANP method is able to improve the weakness of the AHP in the form of the ability to accommodate the relation between the criteria or alternative. The ANP is comprise of three major steps such as determined the criteria and the relations between them, made pairwise comparisons and rated alternatives. These steps need the involvement of experts from the company that appropriate to answer the question related to the criteria. The relevance of the ANP method there are 2 types of namely relevance in a set of elements (inner dependence) and the interrelationship between different elements (outer dependence). The relevance is causing the ANP method is more complex than AHP method [6].

The ANP is an approach in the decision making process that provides the general framework in treating decisions without making assumptions about the independency of the elements on a higher level of elements on a lower level and about the independency of the elements in a levels. In fact the ANP network using without having to specify the level as on the hierarchy used in the Analytic Hierarchy Process (AHP), which is the starting point of ANP. The concept of home in the ANP is the influence of 'influence', while the concept of home in AHP is preference 'preferences'. AHP with assumptions dependencies on cluster and the element is a special case of ANP (see Fig.1 below).

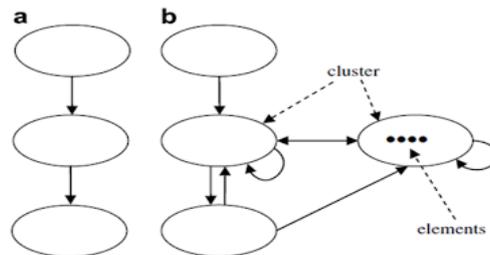


Figure 1. Difference of the structure of the hierarchy and Network [6]

Similar with AHP, every relevance in the network will generate pairwise comparisons and the results of these comparisons form a super matrix. And then the super matrix transforms into a weighted super matrix which sum of the weights in each column is equal to one. The general form of the supermatrix can be described as follows:

$$W = \begin{matrix} & \begin{matrix} C_1 & & C_2 & & & & C_m \end{matrix} \\ \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_m \end{matrix} & \begin{matrix} e_{11} & e_{12} & \dots & e_{1n_1} & e_{21} & e_{22} & \dots & e_{2n_2} & \dots & e_{m1} & e_{m2} & \dots & e_{mn_m} \end{matrix} \\ \begin{matrix} e_{11} \\ e_{12} \\ \vdots \\ e_{1n_1} \\ e_{21} \\ e_{22} \\ \vdots \\ e_{2n_2} \\ \vdots \\ e_{m1} \\ e_{m2} \\ \vdots \\ e_{mn_m} \end{matrix} & \begin{bmatrix} W_{11} & & W_{12} & & \dots & & W_{1m} \\ & & & & & & & & & & & & \\ W_{21} & & W_{22} & & \dots & & W_{2m} \\ \vdots & & \vdots & & \ddots & & \vdots \\ W_{m1} & & W_{m2} & & \dots & & W_{mm} \end{bmatrix} \end{matrix} \tag{1}$$

Where C_m denotes the m cluster, e_{mn} denotes the nth element in the mth cluster and W_{ij} is the principal eigenvector of the influence of the elements compared in jth cluster to the ith cluster. If the jth cluster has no influence on the ith cluster, then $W_{ij} = 0$ [8]. Finally, the weighted super matrix raise to a larger power until generating the limit matrix, the matrix in which the values in each column are equal. The priorities of alternatives can be seen in that limit matrix [9].

In the methodology of the ANP, data that is used is the primary data obtained from the results of the interview (in-depth interview) with experts in company, who have understanding about the issues discussed. Continue with charging the questionnaire on the second meeting with respondents. The data is ready to prepare in the ANP is the variables assessment of the respondents against the problem of the research object in the numerical scale.

3. Result and Discussion

In this study, the supplier selection problem is analyzed in a manufacturing supply chain concept and the proposed model of pasted bag supplier selection is applied in Indonesian leading cement manufacturing (PT ITP). PT ITP is one of the largest cement companies in Indonesia. In 2016 PT ITP using paper bag of pasted bag majority votes in the process of the distribution of cement 5,034,290 units.

PT ITP is supported by some divisions SCM that support the cement production activities to meet the needs of the customer daily. One of the divisions that its existence has an important role in the activities of the distribution of the results of the production of cement, namely is Paper Bag Division that deal with directly creating paper bag of cement. The main function of Paper Bag Division that is concentrated on the production of cement paper bag. The selection pasted bag supplier problem will be analysed in this study. This model were worked with experts professional in the company and defined four criteria and ten sub criteria with 3 suppliers (see Table 1 below).

Table 1. Clusters and Criteria of Supplier Selection Problem in Cement Industry.

Clusters	Nodes
A: Alternatives	A1: Supplier 1 A2: Supplier 2 A3: Supplier 3
B: Technical	B1: ISO certification (9001, etc.) B2: Communication capability (responsiveness) B3: Ability to meet delivery quantities
C: Experience	C1: Working years in this sector \geq 10 years C2: Working years in this sector $<$ 10 years
D: Price-Cost	D1: Net price of the final product (including Transportation) D2: Flexible payment terms D3: Flexible contract conditions
E: Quality	E1: Process control capability E2: Ability to meet delivery due dates

Interviews were performed with the procurement department managers in order to identify weights of the criteria and comparisons. Past experience and the background of the experts are utilized in the determination of the criteria and 4 important criteria (clusters) to be used for supplier selection are established. These 4 clusters are as follows: “Technical” (B), “Experience” (C), “Price-Cost” (D), and “Quality” (E). The list of clusters and nodes of the problem is shown in Table 1 above. These specialists likewise examine the connection between criteria appeared in Figure 2 beneath.

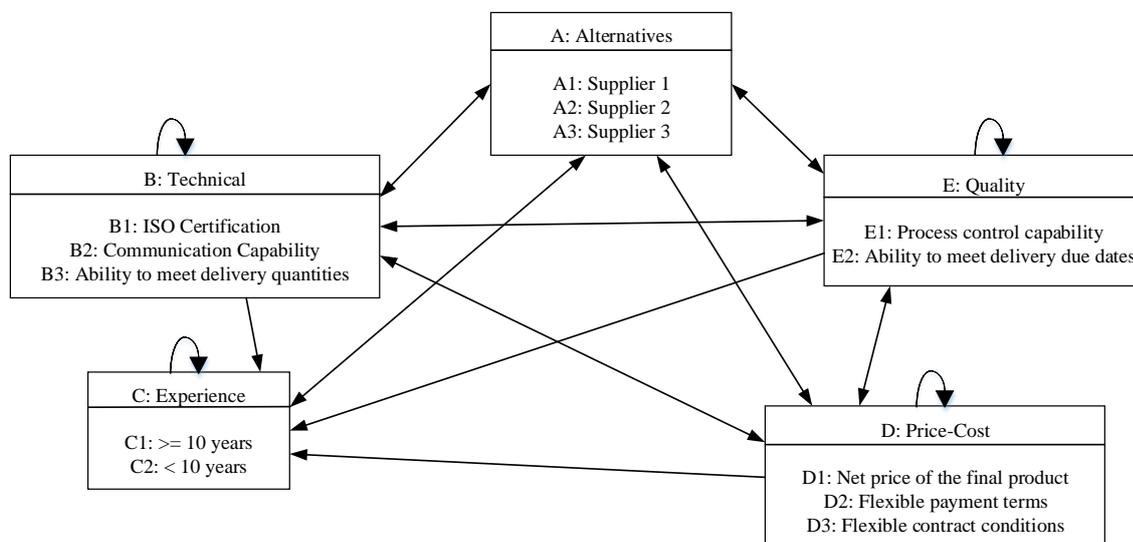


Figure 2. Conceptual ANP Model of Supplier Selection Problem in Cement Industry

This interdependency will generate comparisons between element and those comparisons form the unweighted supermatrix. However the comparisons have to assess the consistency ratio ($CR < 0.1$) before generating the unweighted supermatrix. Unweighted Supermatrix was obtained from eigenvector derived from every paired comparison matrix and then reform as single integrated matrix or supermatrix by inserting the comparisons as sub column of the prior matrix. Some entries can be worth 0 in accordance with the elements/clusters that do not have the influence or impact.

Weighted Supermatrix can be generated by multiplying cells of cluster matrix and each corresponding cells of Unweighted Supermatrix. Weighted Supermatrix is raised to powers for obtaining the Limit Supermatrix. Priorities for all the criteria and alternatives can be read from the Limit Supermatrix. All columns of the Limit Supermatrix have the same value (constant). Therefore the first column is considered as solution with more decimal numbers. Unweighted Supermatrix, Weighted Supermatrix and Limit Supermatrix are all shown in the appendix part of this paper in Appendix A, Appendix B and Appendix C.

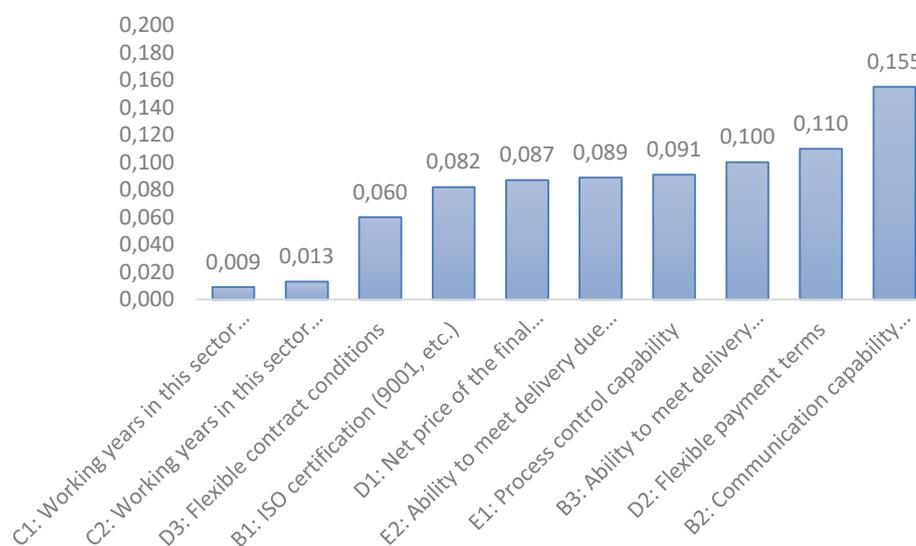


Figure 3. The rank of sub-criteria of supplier selection problem in Cement Industry.

In this study “B2: Communication capability” (0.155), “D2: Flexible payment terms” (0.110), and “B3: Ability to meet delivery quantities” (0.100) are determined as the three most important sub-criteria in the supplier selection problem using ANP. And the 4th to 7th position are so close (the range about 0.8-0.9). Interestingly, experiences criteria (C1 and C2) are the criteria that less important compare to others. It means as long as the suppliers could fulfil the non-experience criteria in a good manner, the chance of being selected is big although the newbie supplier. Consistency ratios of the all pair-wise comparison matrix are calculated less than 0.1. So the weights are shown to be consistent and they are used in the supplier selection process.

Table 2. The Ranking of Suppliers

Rank	Supplier	ANP Coefficient	Score
1	A2: Supplier 2	0.13	64.7%
2	A3: Supplier 3	0.05	26.0%
3	A1: Supplier 1	0.02	9.3%

Relies upon the ANP coefficient values in limit supermatrix (Appendix C), the ranking of the three alternatives from top to bottom order are A2, A3 and A1 as shown in Table 2. Proposed model results

show that A2 is the best supplier alternative with 64.7%. Depends on the analysis the least suitable supplier is A1.

4. Conclusion

A successful supply chain management is a basic factor to gain a competitive advantage in the present worldwide condition. The principle idea of supply chain management is generation of good relationships between individual chain members to serve customers precisely. For sure, definitive operational levels between supply chain members determine the quality of final product or service in a supply chain. In this way, supplier selection process in the supply chain management has a significant impact on competitive advantage. Choosing the appropriate supplier is more than finding the supplier who offers the best price or cost, especially in a leading cement company. Experiences, on-time delivery, the quality of the product, and order accuracy are usually as important as the price.

In the chain relationship, basically long-term relation can be preferable to the short-term savings. In order to gain long-term savings, companies establish a satisfactory relationship with their suppliers. Hence, the supplier selection criteria list may include other factors such as communication and relations, reliability, service quality, financial capability, and sustainability that ensure to develop a long-term supplier relationship. And to manage the risks in this fierce competition multi-suppliers could be the best solution using MCDM like ANP rather single-supplier.

In this study, supplier selection problem is considered as a multi criteria decision problem and a model is produced by utilizing ANP. The assessment criteria are identified according to the company's objectives and the proposed model is applied to a real life case study. Three main supplier evaluation criteria (quality, cost, and delivery) are determined as the main criteria. Additionally to the classical supplier selection criteria, relatively new criteria such as communication and relations and experience are also been considered in this supplier selection problem. The results show that, Communication capability, Flexible payment terms, Ability to meet delivery quantities are the most important criteria with 0.155, 0.110 and 0.1 ANP coefficient respectively, in the pasted bag supplier selection in Indonesian cement industry. (See Fig. 3 above)

Then again, the experience criteria are considered as the minimum essential supplier selection criteria by the procurement division of PT ITP. It exhibits that experience could be the less need satisfied by suppliers. Supplier's consciousness of QCD, quality cost delivery, in supplier selection process should be enhanced later on to pick up a competitive advantage. Also to this, the proposed technique is practicable for assessing potential supplier as far as their exactness as for multiple interdependence criteria.

From three suppliers that ranked based on the ANP coefficient values in limit supermatrix (see Appendix C), the A2 or supplier 2 had the highest score with 64.7% or 0.13 ANP coefficient. Followed by A3 and A1 with 26% or 0.05 ANP coefficient and 9.3% or 0.02 ANP coefficient respectively.

Appendix A. Unweighted Supermatrix for Supplier Selection in Cement Industry.

		B			C		D			E		A		
		B1	B2	B3	C1	C2	D1	D2	D3	E1	E2	A1	A2	A3
B	B1	1	0	0	0	0	0.161	0.162	0.171	0.349	0.455	0.251	0.334	0.226
	B2	0	1	0	0	0	0.38	0.419	0.462	0.438	0.316	0.375	1,043	0.294
	B3	0	0	1	0	0	0.456	0.419	0.354	0.212	0.219	0.375	0.316	0.39
C	C1	0	0	0	1	0	0	0	0	0	0	0.833	0.227	0.599
	C2	0	0	0	0	1	0	0	0	0	0	0.167	0.773	0.401
D	D1	0.476	0.441	0.512	0.469	0.543	1	0	0	0.349	0.455	0.376	0.286	0.354
	D2	0.362	0.384	0.295	0.341	0.276	0	1	0	0.438	0.316	0.448	0.39	0.463
	D3	0.14	0.169	0.171	0.189	0.159	0	0	1	0.212	0.219	0.16	0.313	0.178
E	E1	0.5	0.5	0.5	0.5	0.568	0.5	0.5	0.5	1	0	0.5	0.568	0.432
	E2	0.5	0.5	0.5	0.5	0.432	0.5	0.5	0.5	0	1	0.5	0.432	0.568
A	A1	0.088	0.089	0.104	0.208	0.094	0.087	0.087	0.084	0.092	0.093	1	0	0
	A2	0.671	0.64	0.584	0.472	0.634	0.639	0.667	0.657	0.647	0.615	0	1	0
	A3	0.214	0.238	0.305	0.314	0.261	0.252	0.241	0.252	0.245	0.272	0	0	1

Appendix B. Weighted Supermatrix for Supplier Selection in Cement Industry.

		B			C		D			E		A		
		B1	B2	B3	C1	C2	D1	D2	D3	E1	E2	A1	A2	A3
B	B1	0.342	0	0	0	0	0.038	0.038	0.04	0.099	0.129	0.093	0.124	0.084
	B2	0	0.342	0	0	0	0.089	0.098	0.108	0.124	0.089	0.139	0.388	0.109
	B3	0	0	0.342	0	0	0.107	0.098	0.083	0.06	0.062	0.139	0.118	0.145
C	C1	0	0	0	0.058	0	0	0	0	0	0	0.095	0.026	0.068
	C2	0	0	0	0	0.058	0	0	0	0	0	0.019	0.088	0.046
D	D1	0.108	0.1	0.116	0.125	0.145	0.058	0	0	0.099	0.129	0.11	0.084	0.104
	D2	0.082	0.087	0.067	0.091	0.074	0	0.33	0	0.124	0.089	0.132	0.114	0.136
	D3	0.032	0.038	0.039	0.05	0.042	0	0	0.33	0.06	0.062	0.047	0.092	0.052
E	E1	0.075	0.075	0.075	0.101	0.115	0.089	0.089	0.089	0.175	0	0.097	0.11	0.084
	E2	0.075	0.075	0.075	0.101	0.087	0.089	0.089	0.089	0	0.175	0.097	0.084	0.11
A	A1	0.021	0.022	0.025	0.045	0.02	0.02	0.02	0.02	0.023	0.023	0	0	0
	A2	0.163	0.155	0.142	0.102	0.137	0.149	0.156	0.154	0.16	0.152	0	0	0
	A3	0.052	0.058	0.074	0.068	0.056	0.059	0.056	0.059	0.06	0.067	0	0	0

Appendix C. Limit Supermatrix for Supplier Selection in Cement Industry.

		B			C		D			E		A		
		B1	B2	B3	C1	C2	D1	D2	D3	E1	E2	A1	A2	A3
B	B1	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082
	B2	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
	B3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
C	C1	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
	C2	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
D	D1	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087
	D2	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	D3	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
E	E1	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091
	E2	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089
A	A1	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
	A2	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132	0.132
	A3	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053

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