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A Multi-Criteria Decision Model for Construction Material Supplier Selection

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Abstract

Supply chain management (SCM) is a sophisticated concept which contains all material-related activities of construction projects. In the last decade, construction supply chain management (CSCM) has become a new challenge for construction managers in order to procure right quantities of materials to construction site on time, and within the pre-defined budget. Supplier selection as a significant process in SCM is a multi-criteria decision making problem. There is a broad literature on supplier selection that examines selection of supplier evaluation criteria and multi-criteria decision making methods. Individual and integrated multi-criteria decision approaches are studied by many researchers. In this paper, supplier selection analysis for wall, cladding and roofing construction materials are researched. Whilst literature review and expert panel are employed in order to identify criteria, weights of each criterion are determined by an extensive questionnaire survey. Participants are selected from the experts in construction industry, universities and governmental institutions. Analytic Network Process (ANP) is utilized as multi-criteria decision making methodology and weights of criteria are obtained. This study is a section of an on-going doctoral research, in other words, a part of a more comprehensive model. The study is significant due to the development of a new approach on construction material supplier selection and the basis of the model that is able to provide decision support for construction project participants throughout the project life cycle.

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Keywords: CSCM; construction material; supplier selection; multi-criteria decision making; construction industry.

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1. Introduction

In construction projects, material related activities constitute more than half of the total cost and have huge effects on project schedule. Thus a sophisticated management approaches are needed through the life cycle of construction projects. Supply Chain Management (SCM) is a featured management concept which emerged in 1980s, and found a broad scope of application on construction. Consequently, studies of SCM are now increasingly concentrating on the relationships between organizations involved rather than the traditional physical flow of materials and products [1]. Supplier selection problem has become one of the most important issues for establishing an effective supply chain system [2]. Supplier selection and evaluation is the process of finding the appropriate suppliers who are able to provide the buyer with the right quality products and/or services at the right price, in the right quantities and at the right time [3, 4]. Supplier selection is a multiple criteria decision making (MCDM) problem which involves both qualitative and quantitative criteria.

The aim of this paper is establishing a new approach on supplier selection of wall, cladding and roofing materials. Supplier selection criteria are identified based on supplier selection literature and an expert panel. An extensive questionnaire survey is implemented to professionals from construction companies, universities and governmental institutions. Results of the questionnaire survey are analyzed in SPSS software and weights of each criterion are obtained. ANP is implemented for 3 supplier alternatives with respect to 10 main criteria and 19 sub-criteria. This study is significant due to the development of a new approach on construction material supplier selection in Turkey. The study is the basis of the model that is able to provide decision support for construction project participants throughout the project life cycle.

2. Literature Review

Literature on supplier selection can be divided into two major categories; determining and weighting supplier selection criteria, and selecting the best supplier among alternatives by means of MCDM methodology. Early researches indicated that quality, delivery, price and supplier's capacity are the most significant criteria in supplier selection process [5, 6].]. It is stated that technical acceptable material, gross price, discount rate, net price, progress payment, special charges, freight charges, total cost to destination, terms of payment, escalation, acceptance of project terms and conditions, promised delivery date based on award, shipping weight and expiration date of bidder's quotation are featured criteria in supplier selection [7]. In another research, 30 criteria are selected and a questionnaire survey is implemented. According to survey results, most commonly mentioned criteria are cost, quality, delivery performance, capability and culture [8]. Recent studies show that quality is the most popular criterion, followed by delivery, cost and capacity [1, 9]. Service, management, technology, research and development, finance, flexibility, reputation, relationship, risk, and safety and environment are also important criteria for supplier selection. Contrary to popular belief, price obtained the sixth rank in another paper. This means that market is moving toward competition and price is no longer the main factor [10].

MCDM methods are commonly used in order to analyze suppliers and select the optimum alternative. Extensive MCDM approaches have been proposed for supplier selection, such as the analytic hierarchy process (AHP), ANP, case-based reasoning (CBR), data envelopment analysis (DEA), fuzzy set theory, genetic algorithm (GA), mathematical programming, simple multi-attribute rating technique (SMART), and their hybrids [9]. Ma and Yang (2010) stated that supplier evaluation and selection methods are dependent on the type of material purchased [11]. A remarkable research on MCDM methods provide different multi-criteria decision making approaches in order to identify their weaknesses and strengths on comparison each other [4]. Linear weighted method, Categorical method, Fuzzy approach, and AHP are utilized in the study. It is concluded that each methodology has its own advantages and disadvantages depending on the need of the organization. In a systematic literature review, decision making methods are researched under categories of MCDM, mathematical programming and artificial intelligence. Research findings show that most frequently used technique in supplier selection is AHP, followed by linear programming, TOPSIS, ANP, DEA and multi-objective optimization [12]. While supplier evaluation factors influence each other and interdependency between criteria needed to be considered in the evaluation process, ANP is a suitable MSDM method. Sarkis and Talluri (2002) implemented ANP with respect to seven evaluating criteria to select the optimum supplier [3]. An ANP model is proposed to select the best supplier with respect to ten evaluating criteria which were

classified into supplier's performance and capability clusters [13]. Gencer and Gurpinar (2007) developed an ANP model for an electronic company to evaluate and select the most appropriate supplier with respect to several criteria which were classified into business structure, manufacturing capacity and quality system of the supplier [14]. Another study recommended employing ANP method in order to tackle sub-contractor selection problem on construction projects [15].

3. Research Methodology

Research methodology of proposed supplier selection decision model has three major steps that will be introduced in following sections: Criteria Identification, Questionnaire survey study, and MCDM method implementation. Fig. 1 illustrates the structure of the model.

3.1. Criteria identification

Whilst quality, cost, delivery and performance are regarded as most common criteria in supplier selection literature, another criterion such as payment method, material specification, location, supplier company profile must also be considered. Depending on the size of construction industry, bilateral relations between buyer and supplier may become crucial. In the last decade, ecological approach has become a new perspective for construction projects; therefore, ecological characteristics may be taken into consideration. In consequence of expert panel sessions, 10 major and 19 sub-criteria are identified by doctoral thesis juries and professionals (Table 1). Each criterion is identified by also consideration of national construction industry characteristics (e.g. size of the industry, general procurement tendencies etc.).

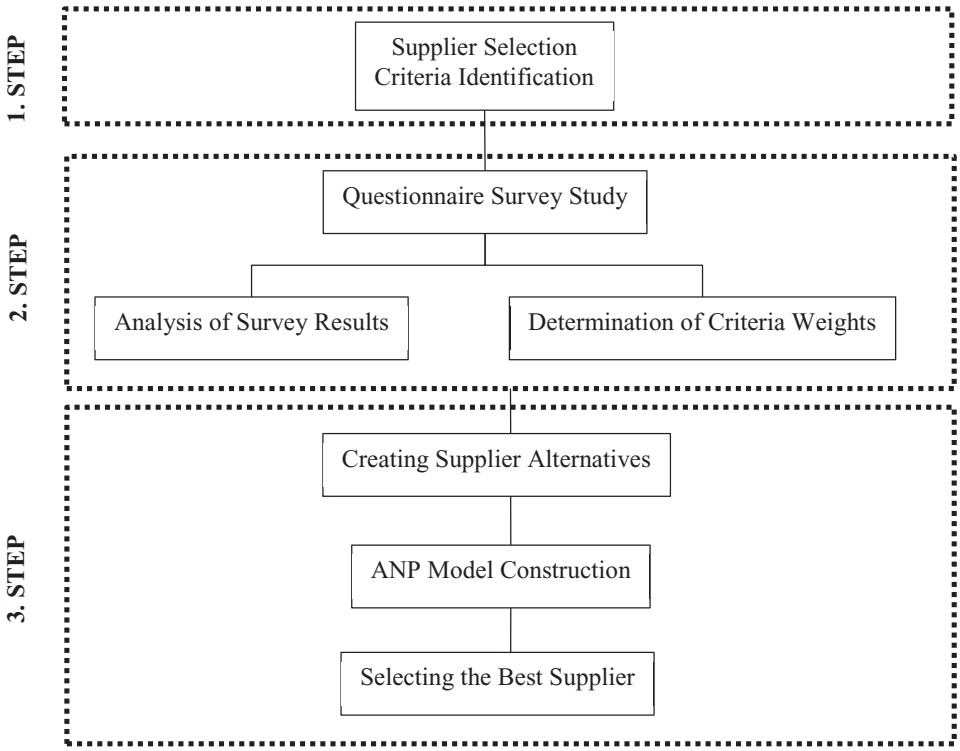

Fig. 1.Structure of proposed supplier selection model

Table 1. Supplier selection main criteria and sub-criteria

Main criteria	Sub-criteria
1. Cost	-
2. Quality	-
3. Delivery	3.1. Length of term
	3.2. Delivery speed
	3.3. Type of delivery
4. Payment method	4.1. Possibility of payment by installments
	4.2. Possibility of payment by barter
	4.3. Refund possibilities
5. Geographical location	-
6. Supplier profile	6.1. Past performance
	6.2. Finance
	6.3. Certificates and references
7. Buyer-supplier relations	7.1. Previous business relations
	7.2. Relatives-friendship relations
8. Ecological characteristics	8.1. Environmental awareness
	8.2. Ecological material possibility and diversity
	8.3. Environment-oriented certification
9. Supplier capacity	9.1. Product range
	9.2. Production / storage capacity
	9.3. Technical competence
	9.4. Technology
	9.5. Postpurchase service
10. Technical acceptable materials	-

3.2. Questionnaire survey

Questionnaire survey is structured including all main criteria and sub-criteria, plus an optional question which is for investigation additional supplier selection criteria. Five point scales of the Likert are used to assess the significant of each criterion. Questionnaire survey is mailed to 250 professionals from construction industry, 142 construction companies, 72 academicians from 39 national and international universities, and 36 professionals from governmental institutions. 500 surveys were mailed in total. Whilst target participants from construction industry are project managers, site managers and purchasing managers, academician participants are professors and lecturers from construction management departments of civil engineering faculties. Professionals from governmental institutions such as Ministry of Transport, Maritime and Communications, Ministry of Justice and Ministry of Environment and Urbanization are also among survey participants. Companies are selected among members of Turkish Contractors Association (TCA) depending on their background, job completion, national and international recognition and reputation. 101 answers are derived, 21 of them are removed because of insufficiency. Information from 80 surveys is evaluated. Distribution of survey participants can be seen from Fig.2.

SPSS Software is employed for validity and reliability analysis. Correlation analysis and coefficient are conducted in order to determine the reliability of the study. SPSS uses Cronbach's alpha value for reliability which ranges between 0 and 1. Reliability value between 0.8 and 1.0 is the indicator of high reliability of a study. Cronbach's alpha value is obtained as 0.849 which means survey in this study is highly reliable. Frequency and

mean value of each criterion are also calculated and criteria weights are obtained. Table 2 shows the questionnaire survey results.

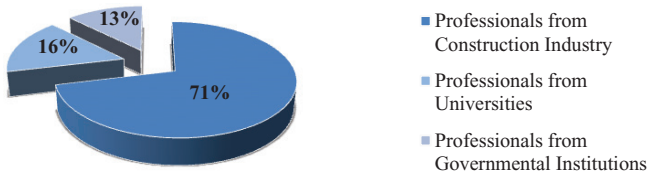

Fig. 2.Distribution of survey participants

Table 2.Questionnaire survey results

No	Criteria and Sub-criteria	Scores	Mean Value	Weights	Overall Weights
1	**Cost**	357	4.463	5.07%	12%
2	**Quality**	343	4.288	4.87%	11%
3	**Delivery**				11%
	Length of term	352	4.400	4.99%	
	Delivery speed	335	4.188	4.75%	
	Type of delivery	304	3.800	4.31%	
4	**Payment method**				10%
	Possibility of payment by installments	338	4.225	4.80%	
	Possibility of payment by barter	252	3.150	3.58%	
	Refund possibilities	303	3.788	4.30%	
5	**Geographical location**	270	3.375	3.83%	9%
6	**Supplier profile**				10%
	Past performance	321	4.013	4.55%	
	Finance	313	3.913	4.44%	
	Certificates and references	301	3.763	4.27%	
7	**Buyer-supplier relations**				8%
	Previous business relations	294	3.675	4.17%	
	Relatives-friendship relations	214	2.675	3.04%	
8	**Ecological characteristics**				9%
	Environmental awareness	268	3.350	3.80%	
	Ecological material possibility and diversity	261	3.263	3.70%	
	Environment-oriented certification	263	3.288	3.73%	
9	**Supplier capacity**				10%
	Product range	325	4.063	4.61%	
	Production / storage capacity	293	3.663	4.16%	
	Technical competence	328	4.100	4.65%	
	Technology	308	3.850	4.37%	
	Postpurchase service	359	4.488	5.09%	
10	**Technical acceptable materials**	346	4.325	4.91%	11%

As can be seen from the analysis results, cost is the most significant criteria for supplier selection, followed by quality, delivery and technical acceptable materials with their equal weight percentages. According to results, buyer-supplier relationship is considered as the less significant criteria, followed by ecological characteristics and geographical location.

3.3. MCDM method implementation

ANP developed by Thomas L. Saaty is a more sophisticated method than AHP. The main difference of ANP from AHP is consideration of dependency among alternatives and criteria. It is a better choice to select ANP rather than other MCDM methods when there are internal relations between criteria. ANP method provides a general framework to deal with decisions without making assumptions about the independence of higher level elements from lower level elements and about the independence of the elements within a level [16]. A decision network involves clusters, elements, and links. A cluster is a collection of relevant elements within a network or sub-network [10, 12]. ANP has two main steps which are creating network including goal, criteria and alternatives, and the pairwise comparisons between all criteria. Fig.3 illustrates the structure of the ANP model.

In this study, supplier selection criteria for wall, cladding and roofing materials are considered interdependent. Thus, ANP method is implemented. Decision model is established with the goal of finding the best supplier, 10 main criteria and 3 supplier alternatives. *Super Decisions* software is employed for decision model analysis. Hypothetical values from 1 to 5 are assigned for each criterion in order to establish pairwise comparisons between supplier alternatives (Table 3). Authors paid attention to assign close values to criteria for each supplier alternative to prevent pre estimation. After pairwise comparisons; unweighted, weighted and limit matrix are obtained as well as the synthesized results. Fig.4 illustrates the synthesized results of decision model analysis. As can be observed from the results, Supplier C is the best supplier. Supplier A follows Supplier C and Supplier B is the less appropriate supplier among the alternatives. It should be noted that this results can differ depending on assigned hypothetical values of criteria.

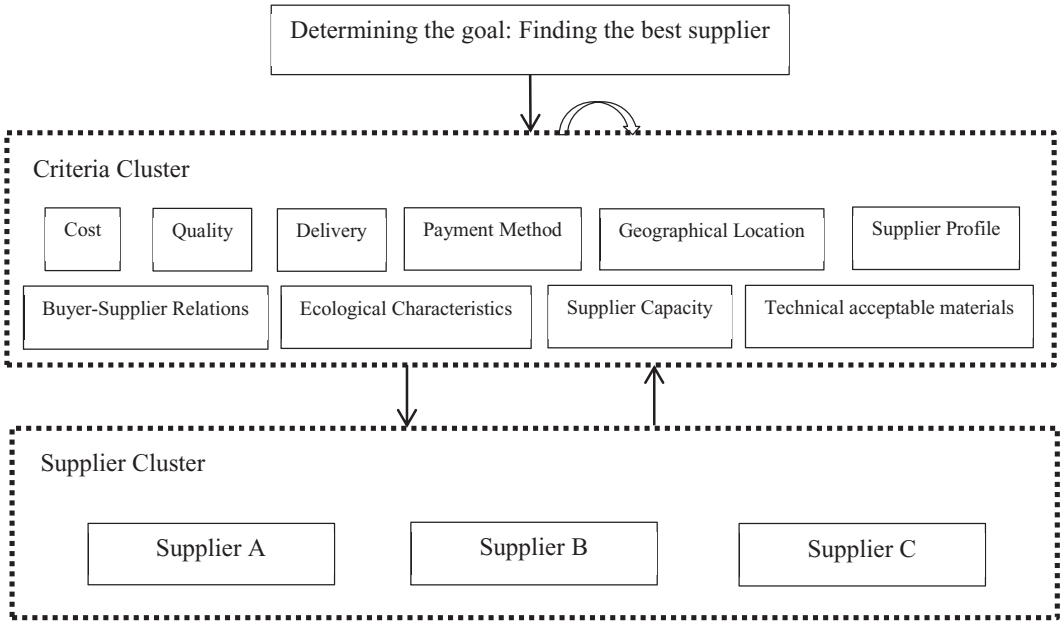

Fig. 3.Structure of the ANP model

Table 3.Hypotetical values of criteria for each supplier alternatives

Main Criteria	Supplier A	Supplier B	Supplier C
Cost	4	5	4
Quality	4	4	4
Delivery	5	3	4
Payment Method	4	4	5
Geographical Location	3	4	4
Supplier Profile	4	4	5
Buyer-Supplier Relations	4	3	5
Ecological Characteristics	3	1	2
Supplier Capacity	4	4	4
Technically accepted materials	5	4	4

Graphic	Alternatives	Total	Normal	Ideal	Ranking
	Supplier A	0.1723	0.3447	0.8970	2
	Supplier B	0.1355	0.2710	0.7053	3
	Supplier C	0.1921	0.3843	1.0000	1

Fig. 4.Supplier alternative rankings of the proposed decision model

4. Conclusion

In this paper, a multi-criteria decision model is proposed for supplier selection of wall, cladding and roofing construction materials. The study is structured on three major steps; criteria identification, questionnaire survey study and MCDM method implementation. Supplier selection literature and expert panel are employed in order to identify criteria. Experts who are professionals from academy and construction industry decided criteria by considering features and needs of construction industry in Turkey. Extensive questionnaire survey is mailed to professionals from construction industry, universities and governmental institutions. 80 survey results are derived from the second expert evaluation, and they are utilized to establish decision making model. ANP is employed as a MCDM method, and implemented on *Super Decisions* software. Decision model has three clusters which are the goal, criteria and alternatives. Hypothetical values from 1 to 5 are assigned for each criterion in order to establish pairwise comparisons between supplier alternatives.

Construction industry in Turkey has highly traditional dynamics. Cost is regarded as the most significant during material purchasing phase. Besides, buyer-supplier relationship may be a prominent criterion. On the other hand, ecological performance is a criterion which should be considered but not being considered yet during supply chain activities in Turkey. Survey results support the popular belief that cost is the most significant supplier selection criterion. It is followed by quality, delivery and technical acceptable materials with their equal percentages. Contrary to the expectations, relationship between buyer and supplier is evaluated as the less significant criterion by survey participants. Ecological characteristics and geographical location are second less significant criteria for supplier selection. It may be interpreted from the result that SCM is not comprehended on application level in Turkish construction industry yet. Results of the study reveal that ANP is an appropriate MCDM method while there is interdependency between criteria in decision model.

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