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Supplier selection paradigm: An integrated hierarchical QFD methodology under multiple-criteria environment

Arijit Bhattacharya*, John Geraghty, Paul Young

Enterprise Process Research Centre, School of Mechanical & Manufacturing Engineering, Dublin City University, Glasnevin, Dublin, Ireland

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ABSTRACT

A concurrent engineering approach integrating analytic hierarchy process (AHP) with quality function deployment (QFD) in combination with cost factor measure (CFM) has been delineated to rank and subsequently select candidate-suppliers under multiple, conflicting-in-nature criteria environment within a value-chain framework. Engineering requirements and customer requirements governing the selection decision have been identified. The hierarchical QFD methodology allows the decision maker (DM) to rank the candidate-suppliers considering both CFM and the subjective factors. The sensitivity of the proposed methodology is elucidated considering a parameter called objective factor decision weight. The devised methodology has been tested with the dataset adopted from Yahya and Kingsman [89]. Liu and Hai [51] tested their model with the same dataset. A comparative analysis using design of experiment has been elucidated so as to demonstrate the efficacy of the devised hierarchical concurrent engineering approach.

1. Introduction

Supply chain management is a process of planning, implementing, and controlling the operations of the supply-chain network catering to the requirements of customers (purchasers) as efficiently as possible. One of the primary activities of a value chain model [62] is to provide service to the customers thereby adding value to the value-chain network. Further, the goal of any organisation is to maximise the value creation while minimising the costs. Thus, selection of a supplier plays a crucial role in a value chain, or present days' supply-chain network of any organisation as it demands trading off among cardinal and ordinal preferences of the decision makers (DM) in an optimal way. The supplier selection process is the most significant variable in the effective management of modern supply-chain networks as it helps in achieving high quality products and customer satisfaction [33]. Effective supplier selection calls for robust analytical methods and decision support tools [57] that are able to trade off multiple subjective and objective criteria. In an exhaustive review of 76 articles Weber et al. [84] found that 47 address involvement of more than one criterion [84]. Dickson [28] identifies a set of 23 criteria considered by purchasing managers under different supplier selection scenario. A supplier selection decision is inherently a multi-criteria problem and a decision of strategic importance to companies [41]. Thus, the selection decision within a supply-chain framework is a complex process involving multiple criteria. Supplier selection decisions within a supply-chain network are complicated as potential options for such selection decisions are evaluated on more than one criterion [85]. Criteria may vary depending on the type of product being considered and include many qualitative factors in addition to the quantitative criteria [81]. Therefore, supplier selection is a multi-criteria decision-making problem which includes both qualitative and quantitative factors [88,92].

This paper addresses the relationship among the criteria for supplier selection decision-making. Both cardinal and ordinal preferences have been considered for evaluation of candidate-suppliers. In a supply-chain framework such decision-making involves cost factors. Thus, cost factor components have been included and a trade off among all the criteria has been established integrating the quality function deployment (QFD) technique [1] suitably with analytic hierarchy process (AHP) [69,70]. Supplier selection is viewed as a combination of both customer requirements and engineering requirements. Customers are the companies that purchase the technical expertise of the suppliers. Therefore, such a company–supplier relation can be viewed as a 'house of quality' model. The outcome of the integrated methodology presented in this paper is determined with indices trading off all the types of information available within the supply-chain framework.

* Corresponding author. Tel.: +353 1 7006496.
E-mail addresses: arijit.bhattacharya@dcu.ie, arijit.bhattacharya2005@gmail.com (A. Bhattacharya), john.geraghty@dcu.ie (J. Geraghty), paul.young@dcu.ie (P. Young).

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Nomenclature

Symbols

SI	selection index of the *i*th candidate-supplier
SFM	subjective factor measure
OFM	objective factor measure
OFC	objective factor cost
λ_{max}	principal eigenvalue
Q_j	sum of column vector
d_{ij}	element of the decision matrix
n	number of rows/colums in a decision matrix
UV	utility values
CI	consistency index
RI	random consistency index
CR	consistency ratio
w_j	importance weight for the *j*th ER_{eq}
$\bar{w}_j$	normalized importance weight for the *j*th ER_{eq}
R_{ij}	quantified relationship between the *i*th CR_{eq} and the *j*th ER_{eq}
c_i	importance weight of the *i*th CR_{eq}
e_{ij}	utility values of the *j*th alternative on the *i* th technical criteria
S_j	overall score for the *j*th candidate-alternative

The remainder of the paper is organised as follows: Section 2 presents a survey of existing literature in the field of supplier/vendor selection. An attempt has been made in this regard to classify the tools/methodologies used in evaluating the suppliers within the scope of the research. This leads framing of the research objectives in the later part of Section 2. QFD and AHP techniques have been briefed and subsequently the proposed integrated hierarchical methodology for supplier selection is delineated in Section 3. Section 4 is directed towards the development of the case study, interaction of criteria, sub-criteria and cost factor components relevant to the selection decision. The devised methodology has been implemented in a real-world problem adapted from Yahya and Kingsman [89] and Liu and Hai [51] in Section 5. Section 6 provides comparative analyses of the results obtained which are further directed to ascertain the scope for future work. Finally, Section 7 concludes with the criticism of the supplier selection process.

2. Survey of existing literature and research objectives

Literature reveal a vast number of published works in regard to the selection of suppliers within different supply-chain frameworks. Supplier selection as well as evaluation is one of the most critical activities of any firm [8]. The supplier selection literature is rich in terms of conceptual/empirical works and decision support methods [8]. A critical review of the decision methods supporting the supplier selection process is found in [14,75,78]. It has been reported that any real-life supplier selection process is of a multi-objective nature [30].

2.1. AHP, ANP and integrated models for supplier selection

Among the decision support methods, application of the AHP method [6,12,53,61,69,71,77] to the supplier selection problem is not new in the art. It has been reported that AHP provides a framework to cope with multiple-criteria situations involving intuitive, rational, qualitative and quantitative aspects [3]. Due to these advantages of AHP, researchers widely use the AHP framework to integrate with linear programming (LP) [34], data envelopment analysis (DAE) [51,63], goal programming (GP) [26,44], lexicographic goal programming (LGP) [17], multi-objective pre-emptive goal programming (PGP) [60], grey relational analysis [90], rough sets theory and multi-objective mixed integer programming [88].

In the literature the receptivity of decision makers to the use of formal decision tools in terms of formulation of decision criteria, the qualification of suitable candidate-suppliers and recognition of the need for a new supplier have been argued widely [13]. Among such ‘formal decision tools’, Saaty’s analytic network process (ANP) model [72] is found suitable for the supplier evaluation process [32]. On the other hand, claims of some researchers [5,18,41] to integrate the cardinal and ordinal preferences using ANP/AHP for vendor selection decisions are not valid. It is argued that integration of conflicting-in-nature quantitative and qualitative factors is required for an effective supplier selection procedure [55]. The focus of these works leads one to systemise the steps like determination of buyer–supplier relationships and formation of selection criteria, i.e., data collection, but does not consider the voice of the purchaser.

2.2. Fuzzy techniques in supplier selection decisions

In the literature, supplier selection and evaluation studies have been conducted with fuzzy techniques [7,10,36,80] applied to the multi-attribute selection models [64,76]. One such method utilises a fuzzy supplier selection algorithm (FSSA) based on predetermined performance criteria and product-related performance criteria [7]. Adequate argumentations are not present in the literature so as to adopt the FSSA as a ‘realistic approach for supplier selection’ [7]. Though it is much discussed that the decisions based on vague or imprecise data are tackled with fuzzified techniques [10], supportive evidences are lacking in this regard. Moreover, in such cases the voices of the customers are not heard in a well-structured manner.

There are several fuzzy-AHP techniques adopted for evaluation of candidate-suppliers in a supply-chain network [19–22,29,41,48]. Among fuzzy techniques for supplier selection, an integrated AHP-fuzzy LP model has been reported in the art. Sevkli et al. [74] propose a method of supplier selection combining AHP and fuzzy LP. The weights of the supplier selection criteria are calculated using the AHP method and simultaneously those weights are considered as the weights of the fuzzy LP model. In regard to fuzzification, the model looks good for supplier selection. But the statement “more useful than traditional singular multi-criterion methods” has not been justified with evidences. Additionally, the model [74] is not able to hear the voice of customers by integrating qualitative and quantitative criteria.

2.3. Other methods on supplier selection decision

Beside AHP/ANP and fuzzy techniques, studies have been conducted in the arena of multi-attribute utility theory [37], multi-objective programming [26,27,43] and expert systems [4,86]. In these works [4,86] the voices of the purchasers are not the prime issues and, therefore, they are not heard by the DMs. There are examples [23,25] wherein intelligent system, case based reasoning and artificial neural network (ANN) tools have been used to evaluate the supplier selection process. Evolutionary fuzzy systems [58], data-mining-based hybrid approach [39,79], expert systems [46,81,91,93], hybrid intelligent algorithm [56] are much applied in evaluating potential suppliers’ performances for specific tasks. Wang et al. [82] and Jadidi et al. [38] propose a fuzzy hierarchical ‘Technique for Order Preference by Similarity to Ideal Solution’ (TOPSIS) methodology for the supplier selection problem. While applying such soft computing techniques it should be kept in mind that simple decisions, involving merely a few hundred simple criteria/candidate-alternatives, are not always required to be intelligent, unless the decision variables are related in a very complex manner, as intelligent decisions involve huge costs.