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An approach for manufacturing strategy development based on fuzzy-QFD

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A B S T R A C T

Today most research related to manufacturing strategy development concentrates on descriptive processes and conceptual models, and therefore lacks the capability of assessing the supportive degree of manufacturing strategy to competitive priorities, and is also difficult to assess the congruence among various decisions of the manufacturing strategy. This paper proposes an approach for manufacturing strategy development based on quality function deployment (QFD). The study starts by analyzing the process of manufacturing strategy development and the features of QFD. Thereafter, a methodology related to manufacturing strategy development based on QFD is developed, which comprises two stages and eleven steps. This approach uses QFD as a transforming device to link competitive factors with manufacturing decision categories such as structural decision categories and infrastructural categories, and uses QFD as a main tool in different stages of manufacturing strategy development process. This paper also integrates fuzzy set theory and house of quality (HOQ) in order to provide a structural tool to capture the inherent imprecision and vagueness of decision-relevant inputs and to facilitate the analysis of decision-relevant QFD information. A case is given to illustrate the utilization of the proposed approach at the end of this paper.

1. Introduction

Manufacturing strategy is part of a manufacturing company's total strategy. It contains the pattern of strategic decisions and actions which set the role, objectives and activities of the manufacturing in a manufacturing company. Just as with any type of strategy, we can consider its content and process separately. The content of manufacturing strategy comprises the specific decisions and actions which set the manufacturing role, objectives and activities. The process of manufacturing strategy refers the procedures which can be used to develop manufacturing strategies (Slack, Chambers, & Johnston, 2004).

Within strategy research, a clear distinction between research on the content of strategy and research on the process of strategy has been presented for a long time (Hallgren & Olhager, 2006). At present, most research focuses on strategy content, however, research on manufacturing strategy development is relatively limited (Dangayach & Deshmukh, 2001).

Manufacturing strategy comprises a series of structural and infrastructural decisions which provide the necessary support for the relevant order winners and qualifiers of the different market segments of a company. From Hill's point of view, manufacturing strategy should be supportive to the achievement of a company's competitive priorities. Hill proposes a five-step procedure to link manufacturing strategy to order winners in order to achieve the congruence between them (Hill, 1995). This procedure is an iterative process, in which the identification of competitive factors is seen as critical. At this stage, any mismatches between the requirements of organization's strategy and the capability of its manufacturing become evident. So far, different analysis models have been developed to describe the congruence between various aspects of manufacturing strategy and competitive priorities. Hayes and Wheelwright provide a tool for the assessment of manufacturing's strategic role, and introduce product/process matrix (Hayes & Wheelwright, 1984). Voss (1990) and Marucheck, Pannesi, and Anderson (1990) have made empirical observation of the strategy formulation and implementation process, and find that the process is essentially hierarchical, which is consistent with Skinner's approach. Skinner's approach have led to a predominant hierarchical process model starting from corporate strategy forming the context for the business strategy which in turn forms the context for each functional strategy including manufacturing (Skinner, 1969). Miltenburg proposes an overall framework with three steps for performing an analysis of a company's manufacturing strategy in terms of congruence with the production system, its products, and its capabilities (Miltenburg, 1995). Safsten and Winroth investigate the usability of Miltenburg's framework in small and medium sized manufacturing companies, and further suggest some changes of the model (Safsten & Winroth, 2002). Lee, Jeong, Park, and Park (2002) propose a framework for a decision-support system to support the formulation of a manufacturing strategy which

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consists of manufacturing system modeling and analyzing performance measures. The proposed decision-support system enables the formulation of manufacturing strategy using what-if analysis against dynamic manufacturing environments. Quezada, Cordova, and O'Brien (2003) develop a methodology for the development of a manufacturing strategy by means of exploiting the concepts of the analytic hierarchy process. In terms of this methodology, a manufacturing strategy can be formulated by creating a five level hierarchy: focus, company objectives, strategic business units, critical success factors and manufacturing decision areas. This methodology also allows a strategic diagnosis of the current manufacturing system and the generation and evaluation of action plans to improve the company competitiveness. Slack et al. give some indications on how to assess the support from the operations function (Slack et al., 2004). Platts and Gregory propose a three-stage procedure of developing manufacturing strategy. The procedure uses profiles of market requirements and achieved performance to show up the gaps which the manufacturing strategy must address (Platts & Gregory, 2004). Karacapilidis, Adamides, and Evangelou (2006) develop a computerized knowledge management system for the collaborative development of manufacturing strategy. The system is used to capture the strategists' rationale and stimulates knowledge elicitation, and it can support the social and knowledge processes of collaborative strategy development by integrating a domain specific modeling formalism.

In summary, the majority research related to manufacturing strategy development has specified and described strategy development process, and as a result, many different methodologies related to strategy development have been suggested. Most literature has proposed many prescriptive processes, and the manufacturing strategy domain has being dominated by conceptual models (Hallgren & Olhager, 2006).

The quality function deployment (QFD) originated in 1972 in Japan as a methodology to be adopted to improve products quality in some Japanese firms (Hauser & Clausing, 1988). QFD methodology has introduced a twofold innovation in traditional product development processes. First, the application of QFD requires the careful consideration of customer during the development process (Akao, 1990). Second, the QFD approach has introduced the collaboration among different business areas as a prerequisite for product design.

Many authors have published papers discussing how to exploit QFD to enhance the quality of product or service design. Karsak, Sozer, and Alptekin (2002) present a systematic decision procedure to be used in QFD product planning. The proposed approach combined analytic network process and 0–1 goal programming approach to incorporate the customer needs and the product technical requirements systematically into the product design phase in QFD. Luo, Tang, and Wang (2008) put forward an optimization method for components selection based on QFD to minimize the difference between the customer's expectation and the selected product. The model is converted into an equivalent linear integer programming model to facilitate the solving approach, and Fuzzy customer requirements are also considered to deal with the uncertainties of human subjective judgment on customer requirements. Chaudhuria and Bhattacharyya (2009) link QFD with Conjoint Analysis through an integer programming based framework to determine the appropriate technical characteristics and consequently the right attribute levels. It is also proposed to measure the elements of the relationship matrix in QFD in a way so that the right levels of the attributes can be generated from the integer programming solution. Chen (2009) integrates QFD with process management techniques to optimize product design investment and process improvement. Process management is used to construct an integrated product and process development model to promote the effectiveness and benefits of applying QFD techniques. Deros, Rahman, Rahman, Ismail, and Said (2009) propose a method based on QFD to measure the service quality performance and identify critical service quality characteristics. In this method, QFD is used as a tool to improve quality in service industry by helping the firms involved to have clearer picture of quality requirements that could improve their customers' satisfaction.

In addition, some authors have also integrated QFD with other methods to improve QFD approach or to propose new approaches based on QFD. Bouchereau and Rowlands (2000) present an approach to incorporated QFD and fuzzy logic, and integrate artificial neural networks and the Taguchi method to produce an intelligent systems approach to QFD. Raharjo, Brombacher, and Xie (2008) propose generic ANP-based network model, which improves the QFD results' accuracy and flexibility. The proposed network model takes into account the crucial factors in new product design simultaneously. Chen and Ngai (2008) propose a novel fuzzy-QFD program modeling approach to complex product planning which integrates fuzzy set theory and QFD framework to optimize the values of engineering characteristics by taking the design uncertainty and financial considerations into account. In the proposed methodology, fuzzy set theory is used to account for design uncertainty, and the method of imprecision is employed to perform multiple-attribute synthesis to generate a family of synthesis strategies. Lee, Sheu, and Tsou (2008) presents an integrative approach by incorporating the Kano model with Fuzzy mode into the matrix of QFD to provide a new way to optimize the product design and enhance customer satisfaction. QFD matrix is used to assure that most critical needs of customers' are translated into the next phases of product development, and Fuzzy mode is used to improve subjective linguistic scale in Kano's two dimensional quality elements. Delice and Zülal (2009) propose a new QFD optimization approach combining mixed integer linear programming model and Kano model to acquire the optimized solution from a limited number of alternative the design requirements. The proposed model can be used to optimize the product development and in other applications of QFD such as quality management, planning, design, engineering and decision-making. Liang (2010) develops an approach of *fuzzy*-QFD to identify service management requirements for customer *quality* needs. This approach provides a method to construct a *fuzzy* relation matrix to link service management requirements and customer *quality* needs based on cross-functional expertise.

Some authors have also conducted categorical analysis about QFD's functional fields, applied industries and methodological development (Carnevalli & Miguel, 2008; Chan & Wu, 2002), and their findings have shown that QFD can be used as a tool to be applied in the development of strategies.

Therefore, QFD is a technique used to convert 'voice of the customer' into design, engineering, manufacturing and production in order to ensure product meeting the needs of the customers. It tries to capture what the customer needs and how it might be achieved through the effort of relevant functional areas. With these characteristics, QFD can be an effective tool to organize and carry out the manufacturing strategy development.

In recent years, the QFD methodology has been applied in the development of business or manufacturing strategies. Jugulum and Sefik (1998) realize that QFD can help organizations develop manufacturing strategies, and it can be incorporated into the classic steps of corporate planning to make strategy more effectively. Crowe and Cheng (1996) propose a methodology by using QFD in manufacturing strategic planning. The methodology comprises four stages called functional strategies, manufacturing priorities, action plans and detail tasks respectively. The proposed methodology provides a systematic tool to facilitate strategy development, and manufacturing strategy and action plans can be realized through the QFD process. Olhager and West (2002) use QFD for