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Hybrid MTS/MTO order partitioning framework based upon fuzzy analytic network process

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ABSTRACT

This paper addresses the strategic level of Hybrid Make-To-Stock (MTS)/Make-To-Order (MTO) production contexts using Fuzzy Analytic Network Process (FANP). The decisions which are involved in this level are family formation and order partitioning. First, a family formation procedure is developed; then, a fuzzy analytic network process is proposed to tackle partitioning decision. Since strategic decisions usually deal with the uncertainty and ambiguity of data as well as experts' and managers' linguistic opinions, the proposed model is equipped with fuzzy sets theory. An important attribute of the model is its generality due to diverse decision factors which are both elicited from the literature and developed by the authors themselves. Finally, the model is validated by applying it to a real industrial case study.

1. Introduction

Production planning and control activities of manufacturing firms had been performed mostly upon demand forecasts from 1900s until almost three decades ago. Since then customer satisfaction has played a key role in the competitive market and has been the most important reason to change managers' points of view. One of the outstanding results was production system shift from MTS to MTO system. MTS production system is based upon forecasts of product demands and production is triggered not taking into account customer orders. Hence, considerable holding costs or stock-out costs are inevitable in contexts with highly fluctuating demands. Furthermore, no customization can be performed on MTS-based goods, as orders are received while goods are fully processed and stocked [1]. Some research instances which have studied different issues of MTS are [2,3]. In contrary to MTS, an MTO policy is fully structured with respect to customer orders. In an MTO environment, manufacturing of a specific product is not initiated, unless a specific order is received from a customer. Some researches discussing MTO manufacturing are [4–6].

Hybrid MTS/MTO production context is benefited from both MTS and MTO. In hybrid systems, there are two distinct stages in a common shared production line for each product; common and differentiation stages. During common stage, all products are processed through the same work centers with the same job descriptions and then, semi-finished products are completed in differentiation stage with respect to customer orders and associated customizations. The two above mentioned stages are separated by a stocking point corresponding to each product. Compared with MTS, hybrid MTS/MTO environments yield higher level of customization, less Work-In-Process (WIP) inventories, less backlog or loss-sales costs, less holding cost, higher flexibility etc., while some characteristics, like under load utilization and greater lead times are embedded to this production strategy. A great challenge of hybrid production systems is considering different criteria which are mostly conflicting, because all decisions are made with respect to both MTS and MTO criteria [7]. To tackle the complexity of hybrid systems, Soman et al. [7] proposed a Hierarchical Production Planning (HPP) structure. HPP divides manufacturing structure into several levels each of which deals with different category of issues. In this approach, decision associated with each level is made sequentially and the results obtained from each level enter the next level as parameter, constraint, or some decision criteria. Having HPP applied, the mentioned complex structure is simplified through different levels. Hence, different kinds of data and criteria are considered in these levels. Moreover, by means of HPP, quick responses to changes within manufacturing context are more easily provided, as well as easier implementation, easier to be communicated to the managers and better understood by the production staff. Generally, the attributes used to distinguish these levels are time horizon

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and decision frequency of each level; i.e. time horizons are shorter and frequencies are more as decision moves downward in the HPP. This paper addresses order partitioning of hybrid MTS/MTO production environment, which involves a strategic decision in the above-mentioned hierarchical process. In this regard, order partitioning comprises a decision process in order to determine what production strategy is selected for production of any products. In other words and upon order partitioning, it is decided whether a product is manufactured to stock, to order, or partially to stock and to be completed upon the coming orders. Toward order partitioning, some models have been proposed so far, among which some instances are [8–12]. More seminal research papers developed conceptual frameworks which had focused on basic concepts and definitions involved in the field [8,9]. Other conducted researches are related to developing different models to tackle order partitioning using AHP-based models [10–12]. However, contributions of this paper in order to improve research field of order partitioning are threefold; (a) developing new decision criteria because the problem involves diverse criteria from different viewpoints, (b) proposing a fuzzy ANP model to tackle dependencies among the defined criteria, and (c) proposing family formation structure in order to simplify the proposed decision-making framework. Since order partitioning involves inter-relative qualitative and quantitative criteria, analytic network process is selected to cope with the network structure of the mentioned decision. Additionally, fuzzy sets theory is utilized to model the involved human judgments in partitioning process. Also, a comprehensive list of criteria is developed, explained and utilized in the proposed model because order partitioning requires considering diverse criteria from different angles. In this regard, a family formation procedure is proposed to simplify the decision for families rather than individual products. To do so, remainder of the paper is organized as followings. After a brief review on literature body of hybrid MTS/MTO, Section 3 presents an overview of FANP on which the rest of the paper is based. Proposed model is elaborated in Section 3, while validation of the model is performed in Section 4. Finally, Section 5 provides some concluding remarks and future research directions.

2. Literature review

To tradeoff between MTS and MTO as two extreme production systems, hybrid MTS/MTO systems have attracted practitioners and academicians to adopt this hybrid choice in recent years. Although this approach is one of the best fitted with many manufacturing environments, there are handful research papers dealing with hybrid MTS/MTO. One of the research papers which deal with order partitioning is the one by van Donk [8]. He proposed to locate Order Penetration Point (OPP) for each product upon which its production strategy are determined. The author applied his proposed model in a food-processing industrial center by regarding two categories of factors; product and market characteristics, and process and stock characteristics. Also, factors are evaluated regarding their impact on OPP shifts; i.e. moving OPP downward to pure MTS and upward to pure MTO. Moreover, an OPP determination approach was developed by Olhager [9] in which three major classes of criteria were considered; market, product, and production-related criteria. Moreover, Olhager discusses benefits and drawbacks of shifting OPP downward and upward in the value chain.

However, two other models which are proposed by Zaerpour et al. [10,11] are very generic and applicable to various manufacturing systems and conditions. In their first model [10], they proposed a fuzzy AHP-SWOT methodology in which sixteen criteria were gathered toward partitioning. First drawback of their proposed model is independency assumption of each criterion relative to other factors. Some dependencies amongst the considered factors must be taken into account to be able to model real instances as close as possible. Furthermore, there are some neglected factors among the ones defined by the authors. Another deficiency of Zaerpour et al.'s model is that the model is run for each product to decide on the product's production strategy which increases complexity and computational effort of the proposed structure. In their second paper [11], authors proposed a model with criteria selected by experts' points of view about order partitioning and the partitioning is performed with respect to available capacity of the firm. In other words, orders are first ranked using hybrid fuzzy Analytic Hierarchical Process (AHP) and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) and then, the available production capacity is divided to the ranked orders according their rankings. The drawback of their model is capacity consideration before order partitioning, because they assumed that the capacity allocated to each kind (MTS, MTO, hybrid MTS/MTO) is specified in advance and capacity allocation is logically performed after partitioning [11]. In addition to these instances, a recent research paper has been published by Rafiei and Rabbani [12] which addressed integrated order partitioning and OPP location in hybrid MTS/MTO production environment. In their proposed model [12], three criteria are utilized toward order partitioning; demand volatility, ratio of production to delivery lead-time, and product type. Also, no explicit decision-making structure was developed for order partitioning. In this paper, it is attempted to cope with the drawbacks of the models proposed previously in the literature. To do so, an ANP structure is adopted with a modified network relative to the hierarchy of AHP to conquer dependencies and inter-relations among decision criteria. Additionally, authors propose a comprehensive list of criteria among which some are taken from literature and some newly defined for the first time in this paper. Moreover and in comparison with papers in the body of literature, a product family formation procedure is conducted to form different product families for which partitioning decision is made. This procedure enhances simplicity and applicability of the proposed structure, because the structure is utilized for the product families rather than individual products. Also, human-related judgments involved in partitioning made us to utilize fuzzy sets theory [13] in the proposed model to cope with the uncertainty and ambiguity of the judgments.

3. Fuzzy analytic network process

ANP is one of the most capable multi-criteria decision techniques, which was developed in 1996 by Saaty [14]. He proposed ANP as a general form of the well-known AHP proposed earlier in 1980s [15]. The main characteristic of ANP is its capability to model dependencies among decision criteria upon a network structure. This capability resulted in broad application of this technique in diverse fields of which some are noted: [16] in strategic planning; [17] in quality function deployment; [18] in supply chain management. Moreover, fuzzy sets theory equips ANP with the ability to conquer judgmental pair-wise comparisons to make the desired decision. Since the model proposed in this paper is structured upon FANP which is elaborated in this section. In this regard, it is described how network of the problem is structured. Next, two kinds of comparisons are conducted; local (element) and cluster comparisons. Results of the comparisons are utilized to form unweighted supermatrix. The supermatrix is normalized, resulting in weighted supermatrix upon which limiting supermatrix is calculated. Finally, weights of alternatives are elicited from the calculated limiting supermatrix.