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A multi-attribute decision model for setting production planning parameters

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ABSTRACT

Production and inventory-related decisions, which significantly influence each other and sometimes involve multiple attributes, trade-off assessment and uncertainties, serve a key role in the performance of make-to-stock (mts) manufacturing systems that are controlled by a constant work in process (conwip) order release policy. To benefit from established production planning methods, a crucial task in this context is to define suitable production parameter settings for a given planning horizon. To address this problem, we present a multi-attribute decision model to determine appropriate settings for the planning parameters, namely, cycle time, throughput rate, holding cost and stockout cost. The proposed model uses discrete event simulation to evaluate the performance of a conwip/mts manufacturing system in relation to the work in process and finished goods inventory. Analysis of variance (ANOVA) and a Kruskal-Wallis test are conducted to verify the significant effect on the analyzed parameters. The compromise solution that is recommended for the conwip/mts problem is obtained by considering a multi-attribute expected utility function that is representative of a decision maker's preferences and risk attitude regarding the probability distribution of the simulation outputs. In contrast with preview studies on planning parameter setting, the result compensates the low performance of one of the attributes as a result of the high performance of another attribute, based on the axiomatic structure of MAUT.

Based on the real data of a multi-product assembly line, a numerical application is employed to visualize the steps of this decision model and to demonstrate its usefulness in practical issues.

1. Introduction

The main focus of this study is conwip/mts production control systems [1]. From a planning and control point of view, an important issue in this context is to identify suitable settings for the inherent production parameters. Because the conwip/mts system performance can be affected by various factors, including work in process [2] and the finished products inventory, determining the best compromise solution by considering the uncertainties of multiple conflicting objectives causes challenging production planning problems.

A significant body of literature is dedicated to the discussion of the conwip policy from various perspectives. Hopp and Roof [3] present a production control method, which is termed statistical throughput control (STC), to satisfy a target throughput rate with minimum work in process and cycle time in a pull system production that operates according to the conwip policy. STC monitors the average throughput of the system after the completion of each job and adds or retrieves one card when it is out of a control interval, which is set according to a target throughput. Its application is demonstrated on single product, multi-product and assembly systems using simulation. A similar problem is discussed in Framinan et al. [4], who propose a card-controlling procedure for conwip/mts and make-to-order policies that employ extra cards that will be added or subtracted to the system.

The majority of publications are devoted to conwip employ simulation to investigate complex production systems. However, numerous studies integrate discrete event simulation with optimization techniques to improve a given objective function. Xanthopoulos and Koulouriotis [5] examined four manufacturing systems that are controlled by kanban, base stock, conwip, and conwip-kanban hybrid policies. Optimal or nearoptimal parameters for the control policies are obtained by integrating the simulation models with a multi-objective evolutionary algorithm. In this case, mean work in process and mean number of backo-

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rdered demands are simultaneously minimized, and the resulting nondominated sets are obtained for each control policy. The nondominated sets are compared in terms of several published metrics to compare Pareto fronts.

The impact of product mix on the performance of pull systems has been discussed in Onyeocha [6]. A simulation-based multi-objective optimization technique was adopted to examine the effect of different product mixes on generalized kanban control, extended kanban control and base stock kanban-conwip strategies for a healthcare parallel/serial assembly line with setup times. The average total service level, backlogs and work in process for each simulation experiment was recorded, and the Nelson's ranking and selection approach was applied to the results to compare the results and ascertain the best strategy.

Belisário and Pierreval [7] proposes a simulation-based genetic programming approach to learn how to decide when modifying the number of cards in pull systems is worthwhile. The objective function corresponds to the expected value of inventory and backorder average costs. Similarly, Onyeocha et al. [8] applied simulation and a genetic algorithm to investigate the effect of erratic demand on the performance of pull system production in a multi-product lean manufacturing environment. In this context, the objective function ensures the selection of control parameters that can achieve zero backlogs with a minimum inventory.

Analytical and optimization models have been employed to determine the production parameters in stochastic manufacturing systems. Park and Lee [9] develop an approximation algorithm that is based on a decomposition method to analyze a multi-product assembly system according to conwip policy. In the algorithm, a product-form approximation technique and a matrix-geometric method are employed. The objective is to obtain key performance measures, such as the joint stationary distribution of outstanding orders for each component, machine utilization, the mean inventory level of each component and the probability that an order will be filled from inventory. Aglan and Durmusoglu [10] propose a linear conwip control model that minimizes the average flow time and is developed for the case of lot splitting with sequence-dependent setup times. In a mathematical model by Ajorlou and Shams [11], an artificial bee colony optimization algorithm is applied to simultaneously obtain the optimal work in process level and job sequence order to minimize the total makespan time. A multi-product and multi-machine serial production line that is operated according to conwip policy is considered. For a conwip-based production system, Cao and Chen [12] developed a nonlinear mixed integer programming model to simultaneously determine optimal part assignment, optimal production sequences and optimal lot sizes. Pandey et al. [13] propose a distributed feedback control algorithm that is termed the adaptive logistic controller (ALC) for distributed supply chains. In this approach, each stage runs its manufacturing operations using a self-regulating production control system (SPCS), such as the use of buffered lines, kanban, base stock, conwip or inverse base stock. The ALC determines the parameters of each SPCS and lot size that are transported between each adjacent stage, with the objective of minimizing the sum of the transportation cost and work in process cost. Considering the scenario in which ALC algorithms were implemented, the ALC with quasi-gradient search has the worst computation time performance but the best solution quality. However, the computation time for the ALC algorithm can be considerably reduced by distributing it over several processors.

Contributions that involve discrete event simulation and multicriteria decision-making (MCDM) are discussed in several studies. Azadeh et al. [14] explored the incorporation of fuzzy set theory with discrete event simulation to model uncertain activity duration. A case study is developed to select a scenario to implement a maintenance program in a conwip system. Thus, the fuzzy simulation result is applied to establish a fuzzy multi-attribute decision making model to select the best scenario. Lu et al. [15] proposed a lean pull system implementation procedure by combining a supermarket supply with two conwip structures. To evaluate the most robust production control strategy, applied simulation, the Taguchi technique and TOPSIS were employed to support multicriteria decision-making. The study adopts work in process, cycle time and throughput rate as the performance criteria. Value stream mapping was applied to compare the current-state map and the future-state map of the case study. However, the incorporation of the stockout cost and holding cost in the performance criteria is a possible suggestion for improvement.

Chan et al. [16] explore the operational problems of scheduling rules via simulation and fuzzy multicriteria decision making techniques. Xu et al. [17] present a case study that integrates a simulation with an analytic hierarchy process (AHP), which is applied to the design of a transmission case line in a Korean automotive factory. This research considered the following criteria performance parameters: cycle time, work in process, throughput rate and investment cost. Rabelo et al. [18] employed simulation and the AHP to model the service and manufacturing activities of the global supply chain of a multinational construction equipment corporation. The AHP is a well-known MCDM method, which approaches problems in which uncertainties are not considered.

Persentili and Alptekin [19] employed simulation and a deterministic weighted sum model to compare the performance of a JIT-pull with an MRP-push strategy based on following performance measures: manufacturing lead time, work-in-process, backorders, machine utilization and throughput. Borenstein [20] develop a visual interactive multicriteria model that is aimed at the evaluation of a flexible manufacturing system with competing design alternatives. It considers a designer's preferences and wishes to customize the manufacturing system for a user's particular situation. This model combines visual interactive modelling and a deterministic weighted sum model to support a decision-making process. The alternatives were simulated and ScoreFlex software was applied to provide a global score to each alternative considering the following criteria: flexibility, risk, cost and performance.

We propose a multi-attribute decision model that is based on the theoretical background of discrete event simulation [21] and multi-attribute utility theory (MAUT) [22]. This model aggregates a decision maker's preferences in a multi-attribute expected utility function that considers the probability distribution of the simulation outputs and the influence of conflicting objectives over the decision attributes cycle time, throughput rate, holding cost and stockout cost. Within a wider decision-making perspective, this study differs from existing studies on conwip topics by considering the possibility of selecting an alternative of parameters setting in a context of uncertainty. MAUT has been applied to model several practical challenges in production management problems, such as the newsvendor problem with partial backlogging [23].

MAUT compensates the low performance of one of the attributes as a result of the high performance of another attribute. This compensation is the trade-off [22] that is provided by the axiomatic structures of MAUT in accordance with a decision maker's preference structure. MAUT uses a compensatory rationality that contrasts with noncompensatory MCDM methods [24]. Therefore, trade-offs and preference judgments concerning the levels of work in process and finished products inventory must be evaluated for the multiple attributes to identify the best compromise solution for a specific planning horizon.

The remainder of this paper is organized as follows: In Section 2, a conwip/mts multi-attribute decision model is proposed. Section 3 provides a description of the multi-product assembly line and the experimental results. A discussion of the results in Section 4