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Review

A multi-attribute, rank-dependent utility model for selecting dispatching rules

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ABSTRACT

The use of dispatching rules is one of the most popular solutions used when handling dynamic scheduling problems. However, how best to select a suitable dispatching rule or rules depends on the stochastic behavior of the performance of the system with respect to multiple conflicting attributes. Previous studies based on multi-objective optimization approaches have not explored the subjective information presented by the decision-maker in relation to the multiple impacts that arise from the decisions made using the dispatching rule. This study takes into consideration a rank-dependent utility approach combined with a multi-attribute utility theory to identify the best dispatching rule for dynamic job shop environments. An additive, non-expected, multi-attribute utility function is modeled to represent the decision-maker's preferences and attitude to risk over the multiple stochastic consequences associated with each simulated heuristic. A numerical simulation with realistic data from a furniture hardware industry is performed to demonstrate the usefulness of the proposed decision approach, and the practical issues that emerge are discussed.

Contents

1. Introduction

Dispatching rules are an effective solution for dynamic scheduling problems. A large number of these heuristics has been developed over the past decades for dealing with various types of manufacturing environments. However, depending on the dispatching rule implemented in the system, the results achieved can be satisfactory for one performance attribute (or objective) but poor for another. As the aim of scheduling decisions is to maximize the performance of multiple attributes, selecting a suitable rule by taking into consideration the uncertainties of the system and the trade-off assessment among conflicting attributes is often a difficult task.

In the case of dynamic environments in which the schedule should be updated as jobs arrive and are completed, recent studies have focused on developing new dispatching rules or on comparing performances under various experimental conditions. In some studies, the best results are presented for each possible combination of various factors and performance objectives. Xiong et al. [1] investigated the influences of the due-date tightness and percentage of jobs. These have extended technical precedence constraints on the scheduling of mold and die manufacturing systems and fit-

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ting these in with batch releases. Using an analysis of variance, the performance of 20 dispatching rules (including four new rules that this paper proposes) have been evaluated with regard to the total tardiness and percentage of tardy jobs. Jia et al. [2] addressed the problem of scheduling lots and configuring machines in semiconductor assembly and test systems. They did this by using the Greedy Randomized Adaptive Search Procedure (GRASP) integrated with a discrete event simulation. Various heuristics have been assessed as to four objectives: weighted sum of key device shortages; weighted throughput; number of machines used; and makespan. In addition, they proposed three new rules based on the GRASP logic for setting up machines and assigning lots to them. Sharma and Jain [3] simulated nine dispatching rules while considering the effects of various shop utilization levels and sequence-dependent setup times. The performance of the system is measured in terms of the makespan, mean flow time, maximum flow time, mean tardiness, maximum tardiness, number of tardy jobs, total setups and mean setup time. Hübl et al. [4] studied the impacts of 12 dispatching heuristics on the average production lead time in view of the covariance level between the processing time and production lead time.

Various methodologies have been used to address the problem of selecting dispatching rules from a multidimensional perspective. El Bouri and Amin [5] developed a multi-criteria decision approach that integrates ordered weighted averaging (OWA) with data envelopment analysis (DEA). The OWA operator is used to assess the decision-maker's (DM's) optimism level with regard to the simulation results of 20 dispatching rules. This is followed by using a DEA model for aggregating the OWA scores to identify the most efficient solution for each combination of scenario and due-date tightness level. The performance criteria for their study were: makespan; mean flow time; machine utilization; mean tardiness; mean sum of earliness and tardiness; percentage of jobs completed on time; and maximum job lateness. Parthanadee and Buddhakulsomsiri [6] presented an approach for identifying the most appropriate set of dispatching rules for scheduling the canned fruit manufacturing process. Using a simulation, the impacts of nine scheduling rules on the flow time, number of tardy jobs, and average tardiness are explored. The performance data from the simulation experiment are compared by means of Tukey's multiple comparisons test and the multi-criteria TOPSIS method.

Fuzzy logic, in particular, has been applied for coping with factors such as the ambiguity and uncertainties that inherently exist in multi-objective scheduling problems. Asadi [7] focused on single-machine scheduling problems with the objectives of minimizing the makespan, total completion time, and total weighted completion time. Two models based on the likelihood profile approach and fuzzy mixed integer nonlinear programming were proposed to incorporate the fact that workers learn quickly on the job how to exercise their duties and that this reduces processing times. Abd et al. [8] proposed a Taguchi method integrated with fuzzy logic for the multi-objective scheduling problem in robotic flexible assembly cells. This approach identifies the best solution for four control scheduling factors, namely, the sequencing rule, dispatching rule, cell utilization, and due-date tightness. These are then used to optimize the performance of the cell with respect to the makespan; total tardiness; and the number of tardy jobs. Huang and Süer [9] developed a fuzzy dispatching-rule-based genetic algorithm (GA) to find the best combination of rules that provides the highest overall fuzzy satisfaction level. This fuzzy model considers the consequences with respect to the makespan, average flow time, maximal tardiness, and total tardiness. To determine the best schedule, a two-level fuzzy evaluation approach is performed. First, an individual fuzzy membership function is established to meet each performance objective. Next, the fuzzy operator aggregates these functions to obtain the overall fuzzy satisfaction level.

The combinatorial nature of several scheduling problems allows the use of population-based metaheuristics such as genetic programming (GP) and GA. Cheng and Huang [10] combined GA with a distributed release time control mechanism to minimize the total earliness and tardiness of job completion in unrelated, parallel machine scheduling problems. In addition, they developed a mixed integer linear programming model so as to evaluate the performance of the proposed algorithm. Đurasević et al. [11] investigated the use of GP for scheduling parallel, unrelated machines using arbitrary performance criteria. The performance of the proposed heuristic was compared with other GP methods for evolving priority functions in relation to weighted tardiness, weighted number of tardy jobs, flow time, and makespan. Nguyen et al. [12] presented four new multi-objective GP-based hyperheuristic methods for evolving scheduling rules in job-shop environments. In their study, the Pareto-front analysis is applied to assess the trade-offs among makespan, normalized total weighted tardiness, and mean absolute percentage error. Quin et al. [13] developed a multi-objective method for a semiconductor wafer fabrication system that combines GP with a simulation to generate composite dispatching rules. They compared the performance of the proposed method against traditional dispatching rules while taking into consideration nine simulated scenarios. The best results are identified for each of the following measures: average delivery time; wafer cassette throughput; mean processing cycle time; and due-date satisfaction rate. In a similar production environment, Chang et al. [14] proposed a GA-based simulation optimization model to dynamically select appropriate rules for three scheduling levels: lot dispatching, batch dispatching, and automated guided vehicle dispatching. The response surface methodology was applied in order to optimize the GA parameters. Zhang et al. [15] explored incorporating GA into tabu search so as to improve the efficiency of a schedule and to maintain its stability in job shop environments where thee are random job arrivals and machine breakdowns. The schedule efficiency factor is evaluated based on the makespan, while the starting time deviations for all the jobs between the new schedule and the original schedule represent the schedule stability factor. The use of artificial intelligence and machine learning methods usually provides better results as compared with traditional dispatching heuristics. However, the large computational effort and time required to deal with various shop-floor conditions can make such methods impractical for real-time scheduling problems. Thus, traditional rules seem appealing owing to the low computational effort they require and their ease of implementation.

The above brief literature review indicates a lack of studies that take into consideration the DM's preferences and his/her attitude toward risk owing to uncertainties inherent to the multidimensional performance of the job shop production system. Moreover, current models identify the best performing heuristics without assessing the trade-offs among probabilistic consequences associated with multiple attributes. As a result, the solution recommended may be inadequate, when the DM is willing to forego the advantages of a high level of performance in one attribute to compensate for the poor performance of another attribute. Hence, an approach that explores the DM's trade-offs and preference judgments in relation to the uncertainties of multiple conflicting attributes is required to address such problems.

In this paper, we present a multi-attribute rank-dependent utility model in order to identify the most appropriate dispatching rule(s) for dynamic job shop environments. This non-expected utility model uses a discrete event simulation to assess the performance of various heuristics in relation to the number of tardy jobs, mean flow time, and mean tardiness. Given these results, the rank-dependent utility (RDU) [16] approach is applied to model the DM's behavior under risk. The RDU extends Expected Utility Theory (EUT) by incorporating the DM's subjective perception of probabilities,