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A new AATP model with considering supply chain lead-times and resources and scheduling of the orders in flowshop production systems: A graph-theoretic view

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ABSTRACT

The present study attempts to synchronize the scheduling problem with determining the advanced available-to-promise (AATP) in a flowshop system to enhance supplier profitability and service level. In the proposed model the AATP, scheduling and graph theory concept have been combined to find the optimum resource allocation and enable accurate estimations of machines scheduling, production costs and delivery dates. To find the near optimum solutions for the large size problems a genetic algorithm is developed, first the orders are ranked based on their scores which are estimated then the optimum cost is calculated by balancing profitability and constraints such as the availability of the machines or the available material in each workstation. Some computer simulated experiments are provided to evaluate the performance of the proposed algorithm.

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1. Introduction

In today's competitive markets, customer satisfaction is a vital factor to gain more market share or even preserve the present share. One performance measure that impresses customer satisfaction is fast and reliable responding to customer orders [1]. Achieving acceptable level of this measure is just possible through accurate and comprehensive information about customer orders, available production capacity, raw materials and WIPs. Available-to-promise (ATP) is a mechanism which handles the mentioned information to help decision makers to accept or reject an order. After an order arrives, the ATP determines whether the order can be met at the customer desired time and reasonable price [2]. Pibernik has described three characteristics in his work to classify ATP models; *availability level, operating mode* and *the interaction with manufacturing resource planning* [3]. Based on the first characteristic the ATP models include two types, conventional ATP and advanced ATP (AATP). In the conventional ATP merely the amount of finished goods, at a certain point of time in the future, is determined. On the contrary, the AATP makes decision based on the supply chain lead times and resources including raw materials, work-in-process (WIP), finished goods and even production and distribution capacities. Considering supply chain lead times and resources enables these models to predict the future more accurately and increases the reliability of the firm quotes.

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Many researchers have mentioned customer satisfaction as an important competitive advantage and also applied the AATP model as an effective approach to improve it. They have considered different assumptions and represented a variety of models to make fast and reliable decisions in various production environments. Most of them emphasize the role of quick and reliable order fulfillment in customer satisfaction [1,3–8]. Some others try to show the importance and the effect of reliable and on time deliveries of customer orders on support of decision makers [2,9]. Even some researchers have focused on the increase of profitability and reduction in the number of missed opportunities which are acquired through on time delivery [10]. The main objective of all the above research instances is to illustrate the importance of customer satisfaction and improve firm's responsiveness to the customer orders, as a significant factor in customer satisfaction. All of them attempted to consider the assumptions by which their developed models were more realistic and able to predict the future more accurately. The most prominent assumptions considered previously include dynamic bill-of-material (BOM) [1,2,11] and multi-plant manufacturing [7,9].

According to the widespread attention to this field of study, in this research a model has been presented to generate quick and reliable responses to the orders. All of the mentioned research papers have considered the "production capacity" or the "output rate" as a predefined exogenous parameter in their models, while they have direct effect on the remaining production capacity. The most prominent contribution of this paper is to integrate the scheduling problem of the orders with the decision related to order acceptance–rejection. To this aim, in this study the machines in different workstations of a flowshop production environment are considered as nodes in an n-layer graph. When an order arrives, its production route among different machines would be mapped as a path in the graph. The length of all paths would be equal to $n - 1$. Also, primary time capacity of each node is equal to the time horizon (T). However their capacity would be consumed by the orders going through their paths which passed the nodes. This integration helps to increase accuracy and reliability of the firm quotes through machines capacity monitoring. To the best of our knowledge, no research has been devoted to the integrated scheduling-AATP problem so far.

Another important constraint to determine the AATP is related to the availability of the raw materials. In this study specific lead time and quantity are considered for every needed raw material. The cumulative amount of needed raw materials in each workstation is calculated dynamically considering the consumption of previous accepted orders. The delivery time of an order depends on the availability of raw materials and free capacity of the machines at points of the time the order arrives to the different workstations. In other words, if an order at time t is in workstation j, the availability of the raw material and free production capacity in work station $j + 1$ are not necessary at time t but at the time the order arrives to the workstation $j + 1$. On the contrary, previous studies have considered an order can be produced only when all the required raw materials or components are available [2,9,12]. Other significant features of the proposed model in this study are more accurate calculation of holding costs and detection of line bottlenecks in order fulfillment. Precise monitoring of WIPs and changing their states enables the model to calculate even their holding costs in the production line. Furthermore the variables trace changing of the WIPs states can also indicate the reason of delay in delivery of the orders.

Our experiments support the hypothesis that reduction in total cost resulting from integration of scheduling problem of the orders and determining the AATP is correlated to the variability in sizes and delivery dates of the orders. In other words, this hypothesis expresses that the priority, size and delivery date of the orders determine the precedence of them on machines. This paper is organized as follows: In Section 2 the related literature is summarized. In Section 3 the problem definition is presented. In Section 4 the model and its formulation is described. The solution method used to solve the model is presented in Section 5. Section 6 reports our computational analyses and the obtained results, while concluding remarks and future research directions are provided in Section 7.

2. Literature

Production capacity calculation and order fulfillment problems have been discussed in a great number of papers. One of the most effective applied approaches in this field has been ATP mechanism. The ATP concept was described first by Schwendinger [13]. In 1998, Beamon [14] presented two basic and integrated processes in a supply chain; process of the production planning and inventory control, and the process of distribution and logistics. He expressed that the ATP models belonged to the first process. While according to the recent studies and the new proposed models of ATP such as AATP, production and distribution capacities and material availability have direct effect on the ATP and the acceptance of an order. A comprehensive literature review was conducted by Fisher in [6], upon which the ATP-related planning tasks were classified. Upon the obtained results of Fisher, main objective of all the discussed papers [1–12] is generating fast and reliable responses to the orders and production planning, except the one developed in [10]. In [10], Cheng and Cheng applied the ATP mechanism to calculate accurate total cost of the orders to determine their bid price. One of the fundamental characteristics of the ATP models is the production environment in which the ATP models are applied. It means considering more assumptions which describe the production environment better leads to the more reliable ATP model. In this regard, studies on developing the ATP models for TFT-LCD manufacturing is a good example. Bongju et al. [4] presented the first ATP model for this kind of production environment. The main assumption they have considered was multi-site manufacturing. In 2009, Tsai and Wang [7] considered the problem of an Assemble-to-Order production environment in addition to the multi-site manufacturing assumption. They developed eight different cost scenarios to compare the ATP plans and performances. Lin et al. [1] considered alternative BOMs, another effective assumption in the TFT-LCD manufacturing environments.

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