Expert Systems with Applications 38 (2011) 4829–4838

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

A real-time production operations decision support system for solving stochastic production material demand problems

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ARTICLE INFO

Keywords:
Unpredictable risks
RFID

ABSTRACT

Nowadays, shop floor managers are facing numerous unpredictable risks in the actual manufacturing environment. These unpredictable risks not only involve stringent requirements regarding the replenishment of materials but also increase the difficulty in preparing material stock. In this paper, a real-time production operations decision support system (RPODS) is proposed for solving stochastic production material demand problems. Based on Poon et al. (2009), three additional tests are proposed to evaluate RFID reading performance. Besides, by using RPODS, the real-time status of production and warehouse operations are monitored by Radio Frequency Identification (RFID) technology, and a genetic algorithm (GA) technique is applied to formulate feasible solutions for tackling these stochastic production demand problems. The capability of the RPODS is demonstrated in a mould manufacturing company. Through the case study, the objectives of reducing the effect of stochastic production demand problems and enhancing productivity both on the shop floor and in the warehouse are achieved.

1. Introduction

In make-to-order manufacturing environments, products are customized and production processes are started only upon receiving a customer's order. In order to satisfy customer requirements and meet the delivery time punctually, it is necessary to handle several customers' orders simultaneously and allocate them appropriate machines and production resources before production starts. Therefore, production scheduling and planning is an important process for avoiding delay in the production process and for improving manufacturing performance so as to fulfill customers' needs (Chan, Au, & Chan, 2006; Fayad & Petrovic, 2006). In general, different constraints are considered for formulating the most satisfactory production plan. These constraints are constant and predictable. However, in the actual manufacturing environment, shop floor managers face numerous unpredictable risks in day-to-day operations, such as defects in the supplies of components or raw materials, or errors, failures, and wastage in the various production processes (Poon, Choy, & Lau, 2007). The unpredictable risks not only entail stringent requirements regarding the replenishment of materials but also increase the difficulty in preparing material stock. Therefore, it is essential to handle such risks effectively and efficiently in order to keep production going smoothly.

Recently, researchers have been considering both machines and material handling equipment as constraints when addressing production material demand issues in production scheduling. Their researches considered only "off-line" scheduling problems, in which a schedule is generated within a time period and is not expected to involve any changes (Caumond, Lacomme, Moukrim, & Tchernev, 2009). However, these researches are incapable of solving stochastic production material demand problems. This is because the existing scheduling approaches solely focus on the allocation of production resources, such as machines and workers. The consideration of warehouse resources is in the form of fork lifts, but manpower is neglected. Warehouse resources are important for minimizing the risks as they are utilized to pick, transfer and store production materials between the warehouse and production lines when problems occur during the production process. Besides, the existing approaches can been seen as a process of allocation of equipment to production tasks before the production starts (Wong, Leung, Mak, & Fung, 2006). Such research does not take into consideration real-time equipment that is used to facilitate production. According to Poon et al. (2009), the consideration of real-time equipment not only helps improve the visibility of warehouse operations, but also enhances the productivity in the warehouse. Nevertheless, no attention was paid to the allocation of warehouse resources to facilitate production processes in the previous paper. The objective of this paper is to allocate warehouse resources effectively and efficiently for replenishing appropriate production materials between these two facilities, so that the production process can run smoothly.

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doi:10.1016/j.eswa.2010.09.162

This paper proposes a real-time production operations decision support system (RPODS) for solving stochastic production material demand problems. Different RFID reading performance tests are first performed to evaluate the reading performance of all RFID equipment and to verify the most suitable location for the installation of the corresponding hardware. Thus, a reliable RFID technology implementation plan is formulated to capture real-time production and warehouse information simultaneously. The captured information is stored in a centralized database and data are selected and sent to a forklift allocation engine to generate a set of order sequences for solving stochastic production material demand production problems on the shop floor. The engine is supported by genetic algorithms which are able to provide reliable solutions for complex problems within a short period of time. In doing this, the objectives of reducing the effect of stochastic production demand problem and enhancing the productivity both on the shop floor and in the warehouse are achieved.

The paper is divided into six sections. Section 1 is the introduction. Section 2 presents a literature review of related studies. The proposed real-time production operations decision support system is illustrated in Section 3. In Section 4 a case study is presented which reveals the improvement in productivity in the ABC Limited (ABC) as a result of implementing the real-time production operations decision support system. In Section 5, the results and a discussion on the findings are listed. Finally, a conclusion about the use of the real-time production operations decision support system is drawn in Section 6.

2. Literature review

2.1. Current situation in production environments

Due to the effect of the present financial crisis, many firms are facing the challenges of providing high quality products with short lead times in order to meet the growing requirements of customized production. Therefore, it is essential to ensure effective and efficient production processes during manufacturing. However, the manufacturing processes require different types of operations and activities on many machines and involving many workers (Pongcharoen, Hicks, & Braiden, 2004). However, human error is inevitable, particularly under stressful conditions (Poon et al., 2009). Because the job tasks are done by people from various educational backgrounds, the interpretation or understanding of the production status often varies from person to person. Besides, unpredictable risks, such as defects in the supplies of components or raw materials, or errors, failures, and wastage, always occur in the production process (Poon et al., 2007). It is necessary to replenish appropriate production material to the production lines for maintaining the productivity when problems occur. This can be defined as a "stochastic production demand problem". Christensen (1994) states that providing better and faster recognition of and response to machine malfunctions, rush orders, unpredictable process yields, human errors, etc., is one of the key requirements for maintaining competitiveness. In addition, in terms of risk, reducing the volatility of the production time is critical for maintaining or even increasing productivity (Sanajian & Balcıoğlu, 2009). Therefore, many researchers have suggested different approaches to minimize the effect of the stochastic production demand problem. One of the common approaches is production scheduling. By allocating appropriate resources, production operations and activities are performed effectively and efficiently (Baker, 1974). Nevertheless, the existing production scheduling approaches mainly focus on allocating production resources only. It is necessary to consider warehouse resources simultaneously as they are utilized to pick, transfer and store production materials between the warehouse and production lines when problems occur during the production processes.

2.2. Existing approaches to resource planning and capacity allocation in production and warehouse environments

Approaches to solve problems of resource planning and capacity allocation can be divided into two categories: mathematical programming and soft-computing methods (Wang, Wang, & Chen, 2008). In the mathematical programming category, linear programming (LP) and mixed integer linear programming (MILP) are the most common approaches. Aghezzaf (2007) adopts a mixed integer programming model for developing a capacity and warehouse management plan that satisfies the expected market demand with the lowest possible cost. Krüger and Scholl (2009) integrate integer linear programming with a rule based approach to solve resource constrained multi-project scheduling problems with transfer times. Jolayemi and Olorunniwo (2004) construct a mixed integer linear programming model for planning production and transportation quantities in multi-plant and multi-warehouse environments with extensible capacities. Özpeynirci and Azizoğlu (2009) adopt a mixed integer linear programming model to maximize the total weight over all operation assignments for solving operation assignment and capacity allocation problems. The existing mathematical-based modeling and exact solution methods are accurate but usually suffer from being very time consuming due to the complexity of the problems. It is essential to solve the problems effectively and efficiently within a short period of time. Hence, soft computing methods have rapidly emerged to attack the capacity allocation and expansion problems (Wang et al., 2008).

In the soft computing methods category, the genetic algorithm (GA) is the most popular method to solve resource planning and capacity allocation problems. With the help of GA, the problem of capacity expansion and allocation has been solved in the semiconductor testing industry (Wang & Lin, 2002). Mendes, Gonalves, and Resende (2009) integrate a genetic algorithm with heuristic priority rules to solve resource constrained project scheduling problems. Guo, Wong, Leung, Fan, and Chan (2008) propose a genetic algorithm for solving the order scheduling with multiple constraints for maximizing the total satisfaction level of all the orders while minimizing their total throughput time.

The existing mathematical programming and soft-computing methods just utilize historical information to model and solve the material planning and capacity allocation problems. However, missing information is revealed through historical decisions (Marar & Powell, 2009), and inappropriate solutions would then be provided by the existing methods. Therefore, real-time information collection and a sharing approach should be adopted to solve the material planning and capacity allocation problems.

2.3. Emerging real-time information collection and sharing approaches

Auto-ID (automatic identification procedures or data capture) has increasingly been involved in many service industries, purchasing and distribution logistics, manufacturing companies and material flow systems (Finkenzeller, 2003). Auto-ID refers to the information collection techniques that automatically identify the objects, retrieve information carried by the objects, and enter information into the database (Waldner, 2008). A unique code indicating the identity of the object is usually carried in labels or tags and in electronically readable formats. The major categories of Auto-ID technology in supporting warehouse material handling are: (1) Barcode technology; (2) Radio Frequency Identification (RFID) technology; (3) Smart cards and Magnetic stripes; and (4) Vision Systems. Among those technologies, barcode is mature and the most commonly used, while RFID is considered as the barcode replacement though it is still a relatively new and immature technology (Lu &