Intelligent Manufacturing Planning System Using Dispatch Rules

Subjects: Automation & Control Systems

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Specifically, a number of jobs were sorted together based on the material used and then consolidated for subsequent processes, i.e., assigned to the corresponding machines. To achieve the optimal sorting for the received orders, a combinatorial dispatch rule was proposed, which were Earliest Due Date (EDD), First In First Out (FIFO), and Shortest Processing Time (SPT).

Keywords: manufacturing industry ; dispatch rule ; Earliest Due Date (EDD) ; First In First Out (FIFO) ; Shortest Processing Time (SPT) ; Make-To-Order (MTO) ; Industry 4.0

1. Introduction

In the era of the Fourth Industrial Revolution, many countries aspire to embrace the digital transformation of manufacturing or production plants. However, many Small and Medium Industries (SMI) or Small and Medium Enterprises (SME) are not ready for the industrial revolution, especially in Malaysia [1]. In recent years, there are many Industry 4.0-related programs and incentives offered by the government, such as the Readiness Assessment, Intervention Fund, Domestic Investment Fund (DISF), and Automation Capital Allowance (Automation CA), with the aim of assisting the SMIs and SMEs to work towards Industry 4.0 [2]. Industry 4.0 growth is inevitable and may impact the traditional business manufacturing industry that is labor-intensive and cost-sensitive [3]. In fact, market demand is very dependent on the economic conditions, the rise of new markets, and product diversity [4]. The integration of planning and scheduling not only satisfies customers' requirements but also optimizes the resources and achieves on-time delivery. Insufficient modal and lack of advanced technology are some of the main reasons that many old players in the industry resist the digital transformation [5]. First of all, when SMEs begin the transition to Industry 4.0, they refuse to start from scratch, and secondly, SMEs tend to become overwhelmed by the multitude of technologies that are currently available on the market [6]. Ultimately, most of the processes in the manufacturing industry are similar as in **Figure 1**.

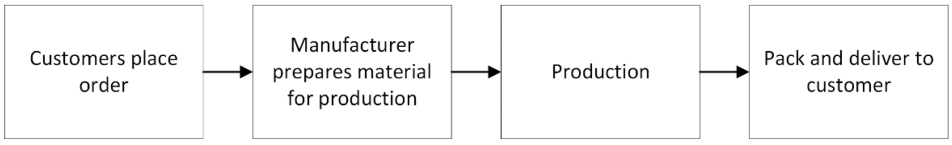

Figure 1. The process from customer order to delivery.

Figure 1 shows a simple process of production. It shows that proper production planning is important because each step of the process affects the others. In conjunction with this, the main goal of production planning is to achieve high customer satisfaction with a low cost [8]. Production planning can be divided into the product structure, material requirement planning, and uncertainty management [9]. As the customer demand is increasing, the manufacturers realize that most of them are facing the same problem in the production stage. This resulted in the emergence of modern production planning tools and methods in the late 19th century.

In the past, traditional manufacturing systems focused on reducing cost and improving efficiency. However, they have not been able to follow the current trends, such as agile manufacturing, networked manufacture, mass customization, intelligent manufacture, and et cetera [10]. In fear of being eliminated by the competitors, a lot of SMIs and SMEs were forced to transform their business model. The transformation allowed them to cater to fluid customer demand. However, their demands may change often and dramatically in some cases [11].

Resource limitation is one of the common challenges. Hence, scheduling is essential to handle the allocation of resources based on the job sequence [12]. The output of the schedules is a production plan to estimate the start and end times for

every job and machine. The jobs are planned according to certain optimization criteria while the scheduling performance is evaluated based on performance indicators such as costs, resource utilization, and adherence to deadlines. To strengthen the competitiveness of Malaysia as a production location, the manufacturing industry has to respond quickly and more flexibly according to the business models.

The objectives of production planning are to reduce inventory levels, increase machine utilization, and improve customer responsiveness [13]. Based on these objectives, many manufacturers are willing to provide customization services to improve customers' satisfaction [14]. For example, Make-To-Order (MTO) is a business model that refers to a just-in-time philosophy due to the zero-inventory level between the stage of production and distribution [15]. This is to cater to personal customization, as shown in **Figure 2**.

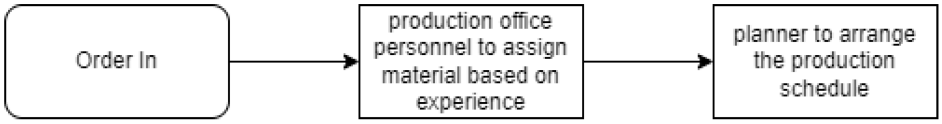

Figure 2. Manual production planning.

Due to the different requirements of every customer, production has to produce products according to the needs of the customer. In this situation, productivity is restricted due to the maximum capacity of each machine. This is where material management plays an important role in production. When a manufacturing process has ended for one order, the next order may require another raw material. This may cause a long changing material lead time, as the operator has to request the raw material needed, and then perform material handling until the machine is set up.

Besides that, the complexity of sorting the orders at the stage of production planning will be higher due to the different order and delivery dates set by the customers. This may also affect the on-time delivery. It is difficult to achieve sorting optimization with so many different parameters in the production planning phase, such as time, product quality, and profit. Moreover, the performance of production planning will be inconsistent due to human involvement. **Figure 2** shows the manual production planning:

Traditionally, once a customer makes an order, the order is submitted to the production office. The production office personnel manually assign the material according to the customer's request based on experience. Then, those orders are sent to the planner to arrange the production schedule. However, each order is printed out as a hard copy. If there are any amendments, they are recorded on the hard copy, which is inconvenient. From the system layer point of view, the process of the data transfer still requires human involvement.

The optimization of production scheduling is viewed as a complicated task. Therefore, most of the schedulers prefer to employ simulation-based software or a manual decision-making process [16]. Researchers integrated domain expert knowledge to generate the decisions. Priority dispatching rules were used for production planning, such as First-in-First Out (FIFO), Shortest Processing Time (SPT), and Earliest Due Date (EDD).

2. An Overview of SMIs and SMEs in Malaysia

According to the World Bank, approximately 98.5% of the business establishments in Malaysia are SMEs, which proves the importance of SMEs in Malaysia [17]. However, they are lacking resources in some respects, such as talent, funds, and technology. **Table 1** shows the definition of SMEs in Malaysia.

Table 1. Definition of SMEs in Malaysia.

Category	Manufacturing	Services and Other Sectors
Medium	**Sales Turnover: RM15 mil to RM50 mil OR Employees: From 75 to 200 people**	**Sales Turnover: RM3 mil to RM20 mil OR Employees: From 75 to 200 people**
Small	**Sales Turnover: RM300,000 to RM 15 mil OR Employees: From 5 to 75 people**	**Sales Turnover: RM300,000 to RM3 mil OR Employees: From 5 to 30 people**
Micro	**Sales Turnover: Less than RM300,000 OR Employees: Less than 5 people**	**Sales Turnover: Less than RM300,000 OR Employees: Less than 5 people**

The definition of the SME in Malaysia was reviewed in 2013. Lately, it was endorsed during the 14th NSDC Meeting in July 2013, and all sectors were covered. **Table 1** shows that SMEs are defined as a company with a sales turnover that is not more than RM50 million or where the maximum number of full-time employees is 200 people in the manufacturing sector. Besides that, for the services and other sectors, SMEs are defined as the company's sales turnover, not more than RM20 million, or the number of full-time employees not more than 75 people. Due to the ever-changing market demand, it will be incredibly challenging for SMEs to adopt Industry 4.0 effectively. With the consideration of return-on-investment, some may remain with their existing technology if they can still survive in the moment.

3. Optimization Algorithm for Scheduling

Production scheduling needs to send the information to the machine at the shop floor once the orders are scheduled and update the status once the order has been done. There are two major scheduling algorithms, which are the exact optimization methods and the approximate methods. **Figure 3** shows an overview of the scheduling algorithms.

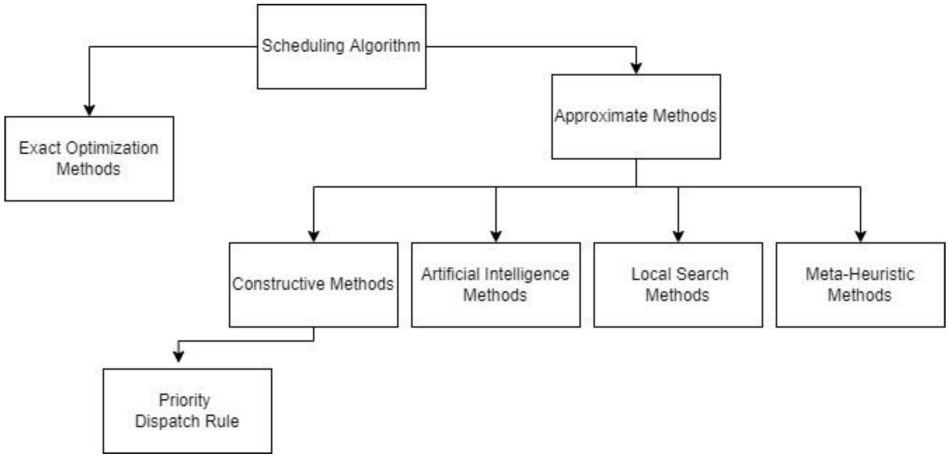

Figure 3. Types of scheduling algorithms.

The exact optimization methods were applied to solve the scheduling problem from the 1950s to the 1980s. For example, the efficient rule method, the mathematical programming method, and the branch and bound method. As the scheduling problems become more complex, the exact optimization method is not suitable for a practical scheduling problem because it is unable to reach a solution efficiently [20].

The past decade has seen the rapid development of the approximate methods in solving scheduling problems. For example, constructive methods, artificial intelligence methods, local search methods, and meta-heuristic methods.

Generally, the exact optimization algorithm, such as the mathematical programming method and the branch and bound method, are more suitable to solve problems with a small size. In contrast, approximate algorithms such as metaheuristic methods can solve large-scale problems [21]. However, no single approach can solve all Job Shop Scheduling (JSP) problems [22]. Hence, hybrid methods are used for different situations in JSPs.

3.1. Artificial Intelligence (AI) Methods, Local Search Methods, and Metaheuristic Methods

Recent advances in AI have enabled intelligent solutions to handle scheduling problems in real-time [23]. However, the AI methods require a distinct cyclical nature that demands constant iteration, tuning, and improvement to find the best solution. The local search method is a greedy methodology used to solve a big combinatorial optimization problem within a reasonable time [24]. As the local search method is very dependent on time, it can achieve optimization if there is sufficient time given. Metaheuristic methods use a set of intelligent strategies to explore and exploit the search base to find the optimal solution [25]. Many metaheuristic methods focus on reducing the makespan in flow shops [26]. The metaheuristic method can solve large and more complex problems than the local search method. Other than that, Chiang et al. [27] applied clustering methods to optimize storage location planning and consolidated picking strategy for 98 orders with a preplanned storage space. This indicates that the time required for local search methods or metaheuristic methods can be saved with the help of domain knowledge.

In summary, AI methods are suitable for dynamic job shops to deal with random job arrivals with unexpected machine breakdowns. Local search methods are more efficient to solve large combinatorial optimization problems, while metaheuristic methods are more efficient to solve larger and more complex optimization problems in a reasonable time

frame. These algorithms are usually iteratively learnt and modified to reach the desired result. This may not be suitable to implement in the case study that sorts orders based on their urgency and product customization.

3.2. Dispatch Rule Algorithms in Constructive Methods

The constructive method is one of the methods in the approximate methods that solves the JSP efficiently in a dynamic environment [28]. Since production in the roofing industry relies on individual customers [7], i.e., the dynamic environment, constructive methods were utilized for the scheduling algorithm. One of them is the priority dispatch rule. As a priority function, dispatch rules calculate the priority values of the operation so that the operation will process from the job with highest priority [29]. In manufacturing, especially in the roofing industry, the business model is based on the MTO.

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