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Technical Paper

Capacity planning for packaging industry

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ABSTRACT

This paper presents a capacity planning system (CPS) to generate a feasible production schedule, improve production efficiency, and avoid overcapacity for the packaging industry. CPS applies the concept of workload leveling and finite capacity planning to assign orders to production lines by considering several production characteristics such as drying time, quantity splitting owing to the cutting pattern of the product type, and the variability of machine capacity threshold. CPS consists of five modules, namely, order treatment module (OTM), order priority module (OPM), lot release module (LRM), workload accumulation module (WAM), and workload balance module (WBM). The experimental design is used to evaluate the effectiveness and efficiency of the proposed CPS with five factors (number of orders, order size, order size variance, order priority, and balance policy) with various levels and three response variables, namely, machine workload balance, order due date deviation, and lateness. Moreover, this result extends into finding the best settings of order priority and balance policy to generate the best favorable responses under the given three environment factors.

1. Introduction

The packaging industry is a competitive and potential industry, as mentioned in various surveys. Packaging is an essential item and component of the complex supply chain that extends from food and beverage products, pharmaceuticals, apparel, shoes, and agricultural products to various consumer goods. To store and protect a product during storage and shipping, it must be packaged before being delivered to an end user. Moreover, just as it is a vital item in developed markets, the packaging industry is also becoming increasingly prominent in developing markets, especially Asia. Sales of packaging in Asia accounted for a total of 36% in value terms in 2012. Meanwhile, North America and Western Europe have total shares of 23% and 22%, respectively. In 2012, Eastern Europe was the fourth largest consumer of packaging with a global share of 6%, closely followed by South and Central America with 5%. The Middle East represented 3% of the global demand for packaging, whereas Africa and Australasia each had a 2% share. The study indicates that this segmentation of the market is expected to change significantly by 2018. Asia is predicted to represent over 40% of the global demand, whereas North America and Western Europe lose out noticeably (Smithers Pira, 2013), as shown in Fig. 1.

Packaging is considered a complicated manufacturing process. However, increasing production efficiency and avoiding overcapacity are critical and can only be achieved by fine planning and scheduling. The complexity of packaging manufacturing can be observed from the characteristics of the process. For example, each process has different numbers of anticipated production loss owing to the special characteristics of each machine in each process. Therefore, in addition to updating the inventory when calculating production quantity, factory managers must also consider this production loss when placing order quantities for production. Each product may have also undergone different production lines based on customer demand. Certain customers may demand single-colored packaging. Therefore, single-colored packaging will be processed by a single-colored printing machine, whereas multi-colored packaging will be processed by a printing machine that is capable of printing multiple colors.

Packaging is classified as a conventional industry. Many companies have basic functioning material requirements planning (MRP) and master production schedule (MPS) systems. However, most planning and scheduling is done based on the experiences of production planner managers because of the inadequate functions or capabilities of the systems. Moreover, most factory managers have not considered the production capacity of factories. Others are sales people who continue to receive orders from customers because the concept embraced by sales is infinite-capacity planning, which is in contrast to production planner manager. Moreover, most sales people might only focus on inventory checking of finished products if a customer requires an urgent request for quotation (RFQ), thereby occasionally resulting in overcapacity. Overcapacity can damage a company's reputation in the long term given its inability to deliver

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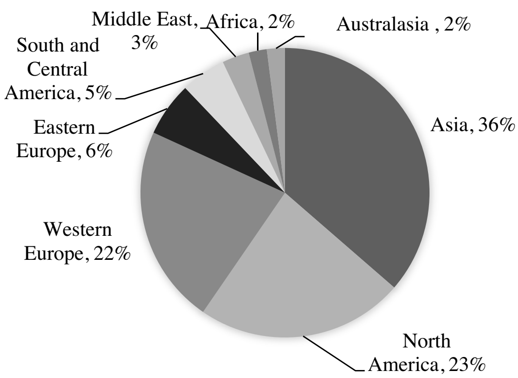

Fig. 1. Global packaging market share (Smithers Pira, 2013).

orders on time based on the customer's request and also results in losing its potential customers.

This research proposes the development of a capacity planning system for packaging. This capacity planning system can quickly generate production schedules for production lines to meet the downstream requirements. To solve these problems, the system is developed using Microsoft Visual Basic for Applications (VBA). The system can quickly assign order priority by taking into account the order quantity and supply capacity, thereby resulting in a more balanced machine loading in production line. Moreover, experimental design is performed to evaluate the effectiveness and robustness of the proposed system under various factors and factor levels. Finally, the optimal settings under different environment factors are obtained.

This study is divided into five sections, and the remainder of this study is structured as follows: Section 2 is literature review, which involves job releasing and scheduling, advanced planning and scheduling, and finite and infinite-capacity planning in various industries, such as IC packaging, TFT-LCD, and semiconductor. Section 3 provides the problem definition, constraints, assumptions, modules, and the mathematical equations of the modules. Section 4 presents the experiments and results generated by CPS. Section 5 draws the conclusions and recommendations for future research.

2. Literature review

Related research on scheduling problems, capacity planning, and advanced planning and scheduling (APS) are reviewed in this section. In the scheduling problem, Brah and Loo [1] investigated the performance of scheduling heuristics in a flow shop with multiple processors. The study also examined the effects of problem characteristics (number of jobs, number of machine stages, and number of parallel processors at each stage) as well as the performance of heuristics by using regression analysis. Certain heuristic methods are available for flexible flow line scheduling. Kochhar and Morris [2] considered two problems, namely, entry point sequencing, which decides the order of the jobs presented to the system; and dispatching, which decides which job to start next at each machine. The approach considers various line phenomena, such as setups, finite buffers, blocking and starvation, machine downtimes, and the current and subsequent states (at rescheduling intervals) of the line. Then, Kurz and Askin [3] explored scheduling flexible flow lines with sequence-dependent setup times. Ramezanian et al. [4] proposed a new mixed-integer programming model and heuristics for multi-stage capacitated lot sizing and scheduling problem with availability constraints. Giret et al. [5] presented a state-of-the-art review of sustainable manufacturing operation scheduling, a subject that has been eliciting increasing interest from researchers in recent years.

In capacity planning, various CPS research alongside the modules implemented in various industries is reviewed. Choi and Seo [6] have developed a finite-capacity planning of a flexible flow line by using a capacity-filtering algorithm. They addressed issues in a flexible flow line such as a semiconductor fabrication (fab), liquid-crystal display (LCD) fab, or printed circuit board (PCB) fab. They presented capacity-filtering algorithms for generating a finite-capacity loading profile from an infinite-capacity loading profile at a processing stage in a fab. In addition, two types of finite-capacity planning problems are described, and methods to use the algorithms in solving these problems are presented. Performance analyses that use a real-life case study show that the proposed method is superior to existing methods. Habla et al. [7] proposed a finite-capacity planning that is based on a reduced level of detail modeling of the process flows. Moreover, they only considered bottleneck steps, and mixed-integer programming (MIP) is proposed to determine completion time targets for bottleneck steps of the lots. Langrage relaxation method is applied to solve MIP. Moreover, Mhiri et al. [8] proposed production planning in the semiconductor industry and used MIP to project the production lot trajectories for remaining subsequent steps, and considered finite production capacity. However, a heuristic was later proposed that neglected equipment capacity and results in the development of infinite-capacity planning. In the following year, Mhiri et al. [9] proposed a finite-capacity planning heuristic by considering lots' priorities, cycle time variability, and equipment saturation. This algorithm helps plant management to define feasible target production plans. Chen et al. [10] developed a capacity planning system that considers the capacity and capability of equipment for multiple semiconductor manufacturing fabs. Based on pull philosophy and the assumption of infinite equipment capacity, the system determines each lot's release time, start fab, and the capability of the equipment. They developed CPS with three main modules. In a wafer fabrication plant, Chen et al. [11] also developed a capacity requirements planning system (CPRS) based on the assumption of infinite capacity. Furthermore, Chen et al. [12,13] developed an infinite-capacity planning system (ICPS) that considers considering the capacity and capability of machines. The capacity of jigs is also developed for an integrated circuit packaging plant. ICPS consists of five modules: work-in-process (WIP) pulling module, lot release module, resource selection module, workload accumulation module, and workload balance module. Simulation is also used to evaluate ICPS performance, and results show that ICPS can effectively balance the workload of production resources: machines and jigs. Lim et al. [14] presented a simple novel graphical approach to address two common production planning problems in SMIs, which are warehouse space allocation and production capacity planning. Chen et al. [15] also proposed a similar CPS to determine the capacity of machines and kits in integrated circuit final test plants. However, in this study, an experimental design is conducted with four factors: workload balance heuristics, MPS variation, MPS variation frequency, and product mix. The simulation results are analyzed by using descriptive statistics and ANOVA. The results show that CPS is effective and efficient in balancing the workload of resources, including machines and kits. In TFT-LCD industry, Chen et al. [16] studied capacity-planning problems in two-stage thin-film-transistor liquid-crystal display (TFT-LCD) production networks. Capacity planning problems are extremely challenging for the TFT-LCD industry because of the following characteristics: (1) multi-stage, multi-site, and multi-generation production network with limited configuration flexibility; (2) an economic cutting ratio that varies at different sites; (3) multiple capacity types at each production site; and (4) a complex product hierarchy and rapidly changing demand. Given the limited configuration flexibility, capacity expansion at different production sites must be coordinated to prevent bottlenecks at other sites. More-