Applied Mathematical Modelling 38 (2014) 181–195

Contents lists available at SciVerse ScienceDirect

Applied Mathematical Modelling

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

Operational extended model formulations for Advanced Planning and Scheduling systems

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ARTICLE INFO

Article history:
Received 21 June 2012
Received in revised form 23 May 2013
Accepted 31 May 2013
Available online 27 June 2013

Keywords:
Scheduling
MRP
Advanced Planning and Scheduling
Mixed integer programming

ABSTRACT

Since the basic reasoning of Manufacturing Resources Planning (MRPII) systems is flawed, a new breed of concepts called Advanced Planning and Scheduling systems (APS) have recently emerged to overcome the problems occurring on the shop floor. In this study, we develop improved and extended mixed integer programming formulations for APS systems at the factory planning level. First, we develop a basic model which explicitly considers capacity constraints, operation sequences, processing times, and due dates in a multi-machine, multi-order, multi-item environment where an item can be processed on a given set of eligible machines. The extensions to the basic model include sequence dependent setups, and transfer times between machines. We also show that our model with a little modification could be used to quote delivery times for customer orders in case due dates are not specified. We provide numerical examples and our conclusions along with future research directions.

1. Background and motivation

The popular and widely used production planning systems, such as Manufacturing Resources Planning (MRPII), require to have the right part, at the right place, at the right time and in the right quantity with minimum cost. Unfortunately, the fundamental reasoning of those systems is flawed. In other words, production scheduling of parts, components, subassemblies, end items is based on fixed lead times with infinite capacity and backward scheduling logic [1].

Since Material Requirements Planning (MRP) function of MRPII systems cannot provide capacity feasible production plans, this unavoidably causes serious problems on the shop floor, such as varying workloads, changing bottlenecks, high Work-in-Process (WIP) levels, lower machine utilisation, less throughput, late deliveries that cannot be resolved easily in the short term. That is, MRPII is unable to prevent capacity problems occurring on the shop floor. Hence, this leads to the conclusion that capacity problems must be solved and prevented at the higher levels [2,3]. Unquestionably, MRP and production scheduling is closely related, and they should be integrated together to generate realistic production schedules for the shop floor, which leads to the problem of Advanced Planning and Scheduling (APS) [4].

In the 1990s, a new breed of concepts called APS systems emerged. APS systems are equipped with a range of capabilities, including finite capacity planning at the floor level through constraint based planning as well as the latest applications of advanced logic for Supply Chain Management (SCM) [5]. Recent APS sytems tend to take a holistic and collaborative approach to provide global optimisation [6]. This collaborative approach extends an e-plant chain beyond a production site, where an e-plant chain is an extension of the integration beyond a production site by means of improved distribution management, electronic data interchange, and coordination of multiple plants [7]. At present, the tendency from the classical

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0307-904X/$ - see front matter
http://dx.doi.org/10.1016/j.apm.2013.05.049

MRPII philosophy towards APS is evident as many industrial companies employ APS for solving different problems arising in the field of production and logistics [8].

Since the whole problem of planning and scheduling is rather complicated involving many elements and factors, it is not practical to solve the problem as a whole. For this reason, an APS system has a hierarchical planning framework that combines MRP with Capacity Requirements Planning (CRP) to allow feasible production plans to be created. Hence, a complete APS system has four major modules [9,10]: (i) strategic planning, (ii) demand planning, (iii) master planning and (iv) factory planning. Factory planning (FP) schedules customer requirements and dispatches manufacturing orders to the shop floor according to the master plan. In recent years, APS systems have become decision support tools including several capabilities, from finite capacity scheduling to constraint based planning [11]. These APS tools provide companies with capacity feasible production plans at different decision levels of the hierarchical planning framework.

In this paper, we do not intend to delve into the details of APS systems, rather develop mathematical models, namely mixed integer programming models (MIP) to show how optimisation models could be used in this context at the FP level. Interested readers can refer to the references for more detail.

There are also heuristic approaches to create capacity feasible schedules that take into account realistic constraints, such as sequence and machine dependent setups, parallel machines and multiple objectives [12,9,13]. These algorithms try to develop production schedules to balance demand with the resources of the factory. The best balance is achieved when all demands are satisfied and manufacturing resources are fully utilised at the same time [9,14,15]. In addition, APS systems are increasingly being used to make strategic decisions where the selection of outsourcing machine/operation, meeting the customers (single/multiple) due dates, minimising the makespan are the main objectives while satisfying several technological constraints [16].

The rest of the paper is organised as follows. In the next section, we provide the manufacturing environment which is a typical job shop, and define our problem. Then we present our basic model with multi-machine alternative where an item can be processed on a given set of eligible machines, and develop its various extensions (see [17] on extensions). The extensions to the basic model include sequence dependent setups, and transfer times between machines. The basic model without multi-machine alternative was initially proposed by Chen and Ji [4], and multi-machine alternative by Ornek et al. [18]. However, here we develop different formulations to solve the same type of problems in much less computing times. In the basic model and its extensions, it is assumed that customers dictate their due dates, and the factory tries to generate capacity feasible schedules under conflicting objectives, i.e., machine idle cost, earliness and tardiness costs. We also show that our model with a little modification could be used to quote delivery times for customer orders in case due dates are not specified. Since all APS systems are supposed to provide an efficient link between the MRP and scheduling system, the problem of estimating due dates under the condition of fulfilling customer requirements on the assumption that new orders arrive is of prime importance [19], because MRP systems assume fixed manufacturing lead times based on past data without considering the work-in-process (WIP), the number of planned and firmed production orders issued to the shop floor with associated lot sizes, alternative machine assignments, etc. Using unique fixed lead times, the workshop could be overloaded or idle. In Section 3, we present numerical examples and discuss the results. The conclusions and suggestions for future research are stated in the final section of the paper.

2. Problem definition and model development

In this paper we consider the same manufacturing setting as given in two recent papers by Chen and Ji [4] and Ornek et al. [18], which have real world applications, particularly in job shops. There are products with multi-level structures. A simple example is given in Fig. 1.

The root node F1 is the final product which consists of subassembly S1 and component C1. Subassembly S1 is made up of components C2 and C3. The numbers on the components indicate how many units of that component will be required for one unit of the parent item. Though this type of product structures are typical in industry, they are much more complicated

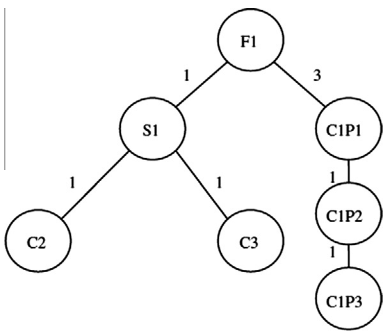

Fig. 1. A simple example of a product structure.