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공급망 관리 관점에서의 생산계획 솔루션 기능 분석

Functional Analysis of Production Planning & Scheduling Solutions from SCM Perspective

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요약

최근 들어 기업의 외부 환경은 글로벌 경쟁, 원가 절감과 이윤 확보에 대한 압박 및 신기술의 급격한 발전 등에 의해 매우 급속하게 변화하고 있다. 특히, 고객 요구 사항의 빈번한 변화는 제조 기업에게 심각한 도전이 되고 있다. 이러한 도전에 대응하기 위해서는, 고객 서비스 향상과 운영 효율성 제고를 위해 여러 관리 기능 중에서 생산계획 기능이 우선적으로 정립되어야 한다. 생산계획은 전체 공급망 관리 중에서 생산 프로세스에서의 단기적 의사결정을 다루며, 그 역할은 고객 주문과 제한된 자원 사이에서 균형을 찾는 것이다. 본 논문의 목적은 공급망 관리 관점에서 생산계획의 기능성과 시스템 아키텍처를 분석하고, 이를 기반으로 생산계획 솔루션들 간의 비교를 가능케 하기 위한 분류 프레임워크를 제시하는 것이다.

■ 중심어 : | 생산계획 | 공급망 관리 | SCM | APS | 생산일정계획 |

Abstract

External environment of enterprises are rapidly changing brought about mainly by global competition, cost and profitability pressures, and emerging new technology. In particular, frequent change of customer requirements is a tough challenge to manufacturing company. To cope with these challenges, a production planning and scheduling (PP&S) function might be established to provide accountability for both customer service and operational efficiency. PP&S deals with short-term decision making in the production process of whole supply chain. The task of PP&S is to seek a balance between customer orders and limited resources.

At present, many PP&S software solutions have been utilized in many enterprises to generate a realistic production plan and schedule efficiently. The aim of this paper is to analyze the PP&S functionalities and its system architecture from the perspective of SCM (Supply Chain Management), and propose the PP&S solution classification framework to facilitate the comparison among various solutions.

■ keyword : | Production Planning | Supply Chain Management | PP&S | APS | Production Scheduling |

I. Introduction

Most enterprises are struggling to change their existing business structure into agile, product- and customer-oriented structures to survive in the competitive and global business environment[1]. In

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today's dynamic manufacturing environment, production planning and scheduling (PP&S) plays a pivotal role in meeting due date on time and allocating resources optimally. PP&S in a typical manufacturing organization is a sequence of complex decisions which depends on a number of factors, such as number of products, complexity of products, number of production sites, and number of work centers in each production site[2].

PP&S deals with short-term decision making in the production process of whole supply chain. The task of PP&S is to seek a balance between customer orders and limited resources. Production planning usually fulfills its function by determining the orders to be executed and by determining the required capacities and materials for these orders in quantity and time.

The function of production scheduling on the other hand is to provide the release and execution of orders according the conditions of production planning in a certain situation. In other words, production scheduling is the process of selecting and assigning manufacturing resources for specific time periods to the set of manufacturing processes in the plan[3].

At present, many PP&S software solutions have been utilized in many enterprises to generate a realistic production plan and schedule. In order to introduce a PP&S solution, it is necessary to understand the position of each solution within the entire spectrum of functionalities, and to thoroughly investigate the functionalities of each solution.

The aim of this paper is to analyze the PP&S functionalities and its system architecture from the perspective of SCM (Supply Chain Management), and provide the PP&S solution classification framework to facilitate the comparison among various solutions.

The rest of the paper is organized as follows: Section 2 describes the concept of SCM and APS (Advanced Planning & Scheduling) solution architecture from the perspective of SCM. Section 3 describes functional requirements of PP&S and its software architecture. In the section 4, PP&S solution classification framework is proposed, and 10 major solutions are compared according to the criteria by proposed framework. Finally, the last section summarizes results and suggests directions for future research.

II. SCM and APS System Architecture

When economic uncertainties predominate, costs rise and consumer preferences change, so manufacturers must constantly improve enterprise performance to identify and capture opportunities. To survive in this ever-changing environment, organizations need to improve and innovate their business processes. A business process is an ordered set of related, structured activities, which express how the work is done within an organization across the time[4][5]. Recently, for successful business process innovation, the concept of supply chain management (SCM) has gained importance. A supply chain (SC) is a network of organizations that are involved, through upstream and downstream linkages in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer[6].

Supply chain management is the task of integrating organizational units along a supply chain and coordinating materials, information and financial flows in order to fulfill customer demands with the aim of improving competitiveness of the SC as a whole. This definition is best visualized by the house of SCM as depicted in the [Figure 1][7].

In the SCM house, the roof depicts the ultimate aim of SCM, namely improving competitiveness of a SC

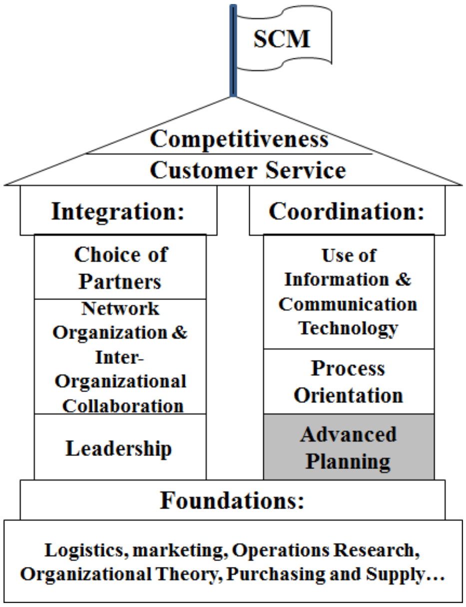

Figure 1. SCM House

as a whole. The roof of the house of SCM rests on two pillars: 'integration of organizational units and 'coordination of flows'. The left pillar (integration) consists of choice of partners, network organization/ inter-organizational collaboration and leadership. The right pillar (coordination) consists of use of information/ communication technology, process orientation and advanced planning.

As shown in [Figure 1], AP (Advanced Planning) or APS (Advanced Planning & Scheduling) is a major building block of SCM house. APS refers to a manufacturing management process by which raw materials and production capacity are optimally allocated to meet demand. APS is especially well-suited to environments where simpler planning methods cannot adequately address complex trade-offs between competing priorities.

In fact, APS systems have represented a natural evolution of planning approaches for the manufacturing area since the 1970s. The first system approach was Material Requirements Planning (MRP), which evolved later into Manufacturing Resources Planning (MRP II), Distribution Resources Planning (DRP) and, during the 1990s, into Enterprise Resources Planning (ERP) systems.

APS systems arose to fill the gap of ERP systems, which are basically transactional systems and not planning systems. ERP's planning capabilities, although fundamental to the planning process, are limited when not leveraged by an APS system.

APS systems have been launched independently by different software companies at different points in time. Nevertheless, a common structure underlying

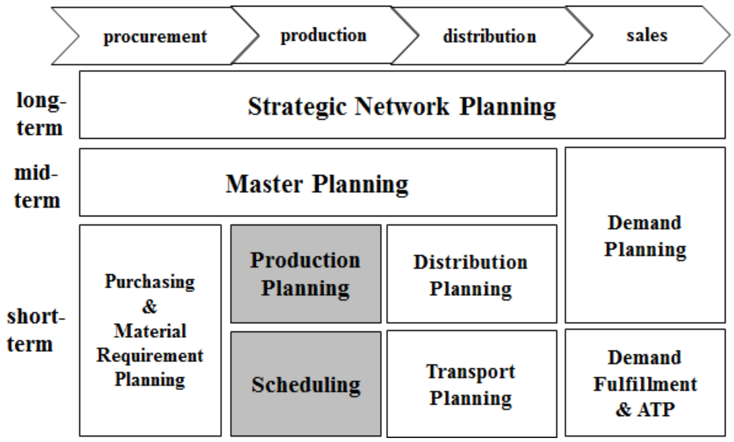

Figure 2. APS System Architecture

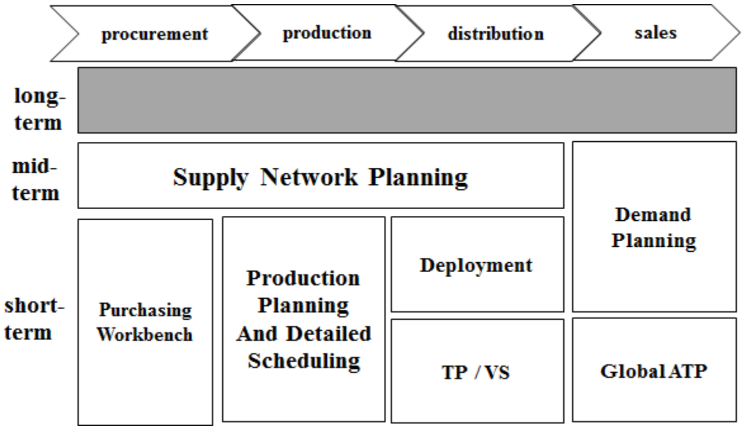

Figure 3. APS System Architecture of SAP APO

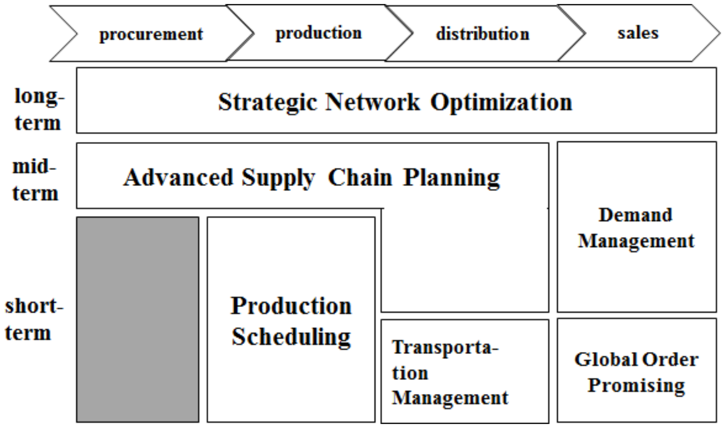

Figure 4. APS System Architecture of Oracle SCM

most of the APS systems can be identified. APS system typically consists of several software modules, each of them covering a certain range of planning tasks.

Based on the SC planning matrix which is a 2-dimensional matrix with the axis of planning hierarchy (long-, mid-, and short-term) and major SCM processes (procurement, production, distribution, sales), common APS system architecture is established by using the vendor-independent names that try to characterize the underlying planning tasks of the respective software modules as depicted in [Figure 2][8]. APS system architecture consists of 9 modules, in which there are two modules called production planning and scheduling belong to PP&S function.

As a whole architecture, for example, APS system architecture of SAP software[9], called SAP APO is shown in [Figure 3], and the architecture of Oracle SCM solution [10] is shown in [Figure 4][11]. As shown in [Figure 3], SAP APO solution does not provide the functionality of strategic network planning within its APS system architecture. Its PP&S function is called 'production planning and detailed scheduling'.

And as also shown in [Figure 4], Oracle SCM solution does not provide the functionality of purchasing and material requirements planning. It's PP&S function is called 'production scheduling' within it's architecture.

In this section, in order to understand the functionalities of commercial APS solutions in more detail, widely-used APS solutions such as SAP APO and Oracle SCM is analyzed based on the general APS system architecture which was well established by previous research.

III. PP&S Functions and Its System Architecture

PP&S deals with short-term decision making in the production process of SCM. The task of PP&S, which is the one of major building blocks of APS system architecture as shown in [Figure 2], is to seek a balance between customer orders and limited resources.

The solution approaches for PP&S can be classified into 3 areas as depicted in [Figure 5][12] : (1) Mathematical programming such as LP (Linear Programming) and mixed integer programming, (2) Heuristic method, and (3) Simulation method.

Widely used meta-heuristic techniques are as follows [13]: Genetics Approaches, Ants Colony Optimization, Bees Algorithm, Electromagnetic Like Algorithm, Simulating Annealing, Tabu Search and Neural Networks. For example, the scheduling optimization for PCB production, that is, on maximizing throughput and minimizing total assembly time and head moving distance was addressed[14]. In this study, three problems－the automatic nozzle changer assignment problem, the nozzle assignment problem, and the component pick-and-place sequence problem－are investigated

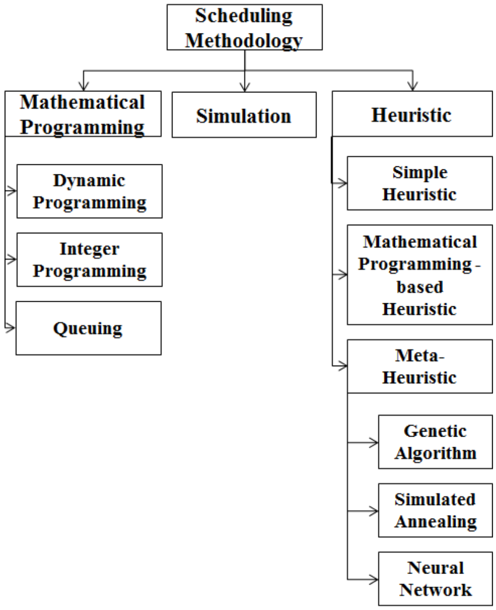

Figure 5. Solution Approaches for PP&S

using a modified artificial bee colony algorithm to enhance the production efficiency of placement machines. Zhang and Wong developed an enhanced ant colony optimization (E-ACO) meta-heuristic to accomplish the integrated process planning and scheduling problem in the job-shop environment. The results show that with the specific modifications made on ACO algorithm, it is able to generate encouraging performance which outperforms many other meta-heuristics[15].

The other classification framework categorizes PP&S solution approaches into 2 types: (1) optimization, and (2) simulation. Within a given time bucket, optimization approach finds an optimal solution which is a combination of resource and product. It is called as a static combinatorial optimization approach, and typically applies LP methods. On the other hand, simulation approach defines decision variables called handle such as step target, equipment arrangement, dispatching rule. It

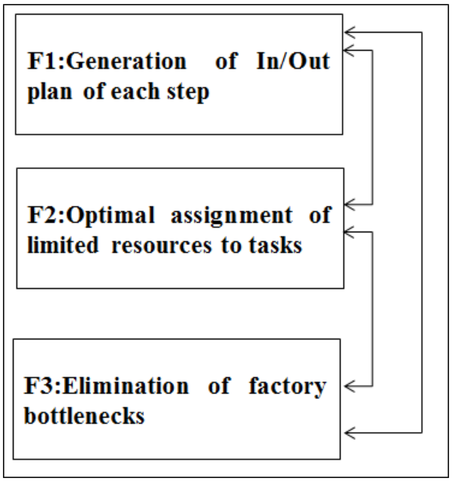

Figure 6. Required Functionalities of PP&S

finds an optimal solution continuously to change the decision variables according to the processing status, and is called as a dynamic optimal feedback control approach[16].

In the PP&S, two main type of decision making must be made properly and timely: (1) When to release a lot into production (launch decision), (2) The decision as to what each piece of equipment should work on next (dispatching decision).

To provide a good (or optimal) solution to these decision makings, required functionalities of PP&S system is summarized to 3 main functions: (1) Determining the best sequence of tasks on a resource by generating input/output sequence of orders, (2) Optimal assignment of limited resources to tasks to fulfill a set of orders, (3) Elimination of factory bottlenecks and capacity adjustment. [Figure 6] shows functional requirements of PP&S.

Moreover, as a software system, software architecture of PP&S system consists of 5 modules as depicted in [Figure 7]: (1) data management for master data such as machine, routing, part, layout and so on, (2) schedule generator, (3) schedule editor, (4) schedule performance evaluator, and (5) user interface.

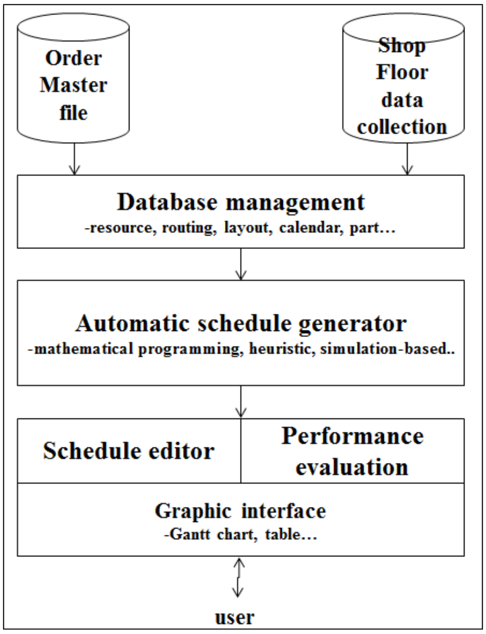

Figure 7. Software Architecture of PP&S

As an illustrative example for explaining the implementation of PP&S functionalities, Mozart PP&S system has been developed by VMS solutions co. ltd. in Korea[16-19].

The functional architecture of Mozart system is comprised of 4 subsystems: (1) factory planning (FP), (2) scheduling (APS), (3) lot pegging (RTF: return to forecast), (4) simulation engine (LSE).

Overall planning and scheduling procedure of Mozart system is as follows: (1) FP determines daily Fab-in and -out plan which meets the weekly target. (2) APS generates tool schedule within which dispatcher selects a lot. (3) RTF (return to forecast) equipped with backward planning engine provides the progress of each demand and generates step target through demand and lot pegging. (4) LSE (loading simulation engine) fitted with forward planning engine is a what-if simulator which estimates moving and WIP trend. satisfying functional requirements F3

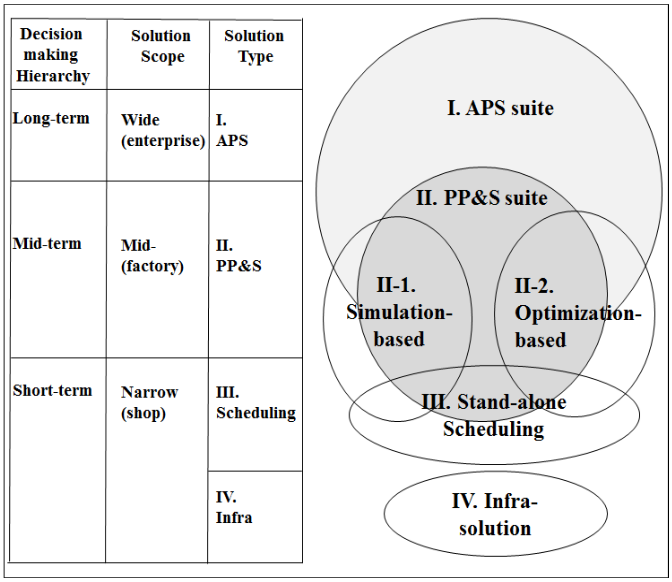

Figure 8. PP&S Solution Classification Framework

of [Figure 6]. Mozart system satisfies all functional requirements of PP&S system defined in the PP&S functional requirements of [Figure 6] as follows:

(1) In/out plan (F1 of [Figure 6]) is generated by Mozart FP and RTF (Lot pegging and backward planning).

(2) Optimal assignment of limited resources to tasks (F2 of [Figure 6]) is done by Mozart APS and Mozart LSE by forward simulation.

(3) Elimination of factory bottleneck and capacity adjustment (F3 of [Figure 6]) is done by capacity filtering method during the pegging process.

IV. PP&S Solution Classification Framework

There are not a few commercial systems for PP&S system in the world. In order to evaluate and compare their functionalities with each other, solution classification framework is needed. The classification framework for PP&S system in this paper is based on 3 criteria as follows:

(1) Planning scope according to the SC planning matrix is categorized into 3 types:

① Wide-perspective: Support of long/mid/short-term planning decision making within the whole SCM level.

② Intermediate-perspective: Support of mid/short-term planning decision making within the factory level.

③ Narrow-perspective: Support of short-term planning decision making within the shop level.

(2) Solution approach is classified into 2 types:

① optimization-based

② simulation-based

(3) Software type is classified into 2 types:

① Application software: a domain-specific type.

② Infrastructure software: a general purpose type, which provides solutions for widely-used algorithms, for example, ILOG CPLEX optimization package[20].

According to the above 3 criteria, PP&S solution

Table 1. Comparison of 10 PP&S Solutions

Category No.	Solution scope	Solution approach	Product Name	Company name	Nation	Application area	Web site
I	APS	Optimization	APO PP&DS	SAP	Germany	General	www.sap.com/solution/lob/scm.html
I	APS	Optimization	i2 production scheduler (now JDA8)	JDA software	USA	General	www.jda.com
I	APS	Optimization	eGPS	ADEXA	USA	Semiconductor-specific	www.adexa.com
I	APS	Optimization	T3 Plan & T3 Schedule	Zionex	Korea	General (mainly, high tech industry) -Samsung SDI, -LG Display -Samsung display	www.zionex.com
II-1	PP&S	Simulation	Mozart	VMS Solutions	Korea	Fab-specific -Samsung semiconductor, -Samsung LCD, -HanKook tire, -SK Hynix	www.vms-solutiosol.com
II-1	PP&S	Simulation	AutoSched AP	Applied Materials	USA	General	www.appliedmaterials.com
II-1	PP&S	Simulation	Simul8-planner	Simul8 corporation	USA	General	www.simul8-planner.com
II-2	PP&S	optimization	Preactor	Siemens	Germany	General	www.preactor.com
III	Scheduling	optimization	Asprova	Asprova corporation	Japan	General	www.asprova.com
III	scheduling	optimization	Taylor	Taylor scheduling software	USA	General	www.taylor.com

classification framework is established as depicted in [Figure 8]. In this paper, major 10 PP&S solutions are identified, and evaluated based on the classification framework as described in [Table 1].

V. Conclusions

Manufacturing industries are under great pressure caused by the rising costs of energy, materials, labor, capital, and intensifying worldwide competition. In other words, external environment of enterprise are rapidly changing brought about mainly by global competition, cost and profitability pressures, and emerging new technology. Moreover, in the upcoming era of fourth industrial revolution, the most distinctive feature of smart production is the personalization of products tailored to the individual needs and preferences of consumer.

In these situations, PP&S solutions play a pivotal role to retain customers by meeting due-date whereas this task is so difficult because it should efficiently utilize resource capacity under the careful consideration of many interacting constraints. So, many enterprises are seeking proper software solutions for PP&S.

In this paper, PP&S functions and its system architecture from the perspective of SCM are reviewed and clarified. And, based on these results, PP&S solution classification framework to facilitate the comparison among various solutions is proposed. Within this framework, several PP&S solutions are classified and positioned according to their characteristics. By using this framework, practitioners who consider the introduction of computerized PP&S solutions in manufacturing firms can prepare evaluation and benchmarking sheets for selecting most suitable solution with ease and in less time.

Among them, the functional features of one specific solution are described in detail. But, detailed functionalities of each PP&S solutions based on the proposed PP&S functional and system architecture are not addressed in this paper which should be improved as a further research.

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