



Implementation Framework of Advanced Planning and Scheduling System for Smart Manufacturing in SMEs

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Abstract

Background/Objectives: Small and medium-sized manufacturing enterprises (SMEs) are usually unable to properly respond to the rapid changes in the production environment.

Methods/Statistical analysis: We propose an implementation framework of advanced planning and scheduling (APS) system specialized for SMEs. The following are considered as the main factors in implementation of APS system: 1) establishment of on-site production data collection and management system for SMEs with poor IT infrastructure, 2) establishment of production scheduling system linking experiential knowledge of field production manager, and 3) construction of various scenario analysis system using simulation technique.

Findings: The proposed APS system can collect and manage the production data generated at the manufacturing site. Various production data can be stored, and realistic scheduling can be established according to actual situation of the site. Second, scheduling can be established in connection with the experiential knowledge of field managers. Using a technique for order or preference by similarity to ideal solution (TOPSIS) based approach, it is possible to select the optimal work priority assigned to the manager's empirical weight, and it is possible to make quick decision-making and rescheduling in various situations. Third, the simulation function is installed, and it is possible to analyze the forecasted scenario in terms of the productivity through the simulation result index.

Improvements/Applications: It is expected to contribute to the establishment of smart production of SMEs by efficiently managing the production data at low cost and improving the system utilization.

Keywords: APS (advanced planning and scheduling), SMEs (small and medium-sized enterprise), Production data, Simulation, Smart factory.

1. Introduction

Today, as the fourth industrial revolution in the world comes to the fore, the production environment is changing drastically: customer requirements are becoming more diverse and product life cycle is getting shorter. Therefore, production management problems at the manufacturing site are becoming more complicated, and their significance is increasing. As a result, many manufacturing companies are interested in building a smart factory that implements intelligent production management. A smart factory improves productivity, quality, and customer satisfaction by applying information and communication technology that combines digital automation solutions to the entire production process composed with design, development, manufacturing, distribution and logistics [1]. The Korean government is encouraging the propagation of various smart manufacturing methods as an implementation solution of its manufacturing innovation 3.0 strategy. For example, financial support for achieving key smart manufacturing technologies such as internet of things (IoT), big data, 3D printing, artificial intelligence, and cyber physical system (CPS) [2] has been strengthened.

However, despite the government's aggressive efforts, most small and medium-sized manufacturing enterprises (SMEs) are not getting the benefit of the support. This is because they do not even have a basic information processing system for tracking

production lots and defective parts and then the effectiveness of production management is limited. Most SMEs lack the human resources and capital required for research and development (R&D) that follows the global trend in technologies. Moreover, the utilization of information technology (IT) as knowledge-based capital is very low [3]. Therefore, it is difficult to introduce existing commercial production management systems to the SMEs.

In this paper, an implementation framework of an advanced planning and scheduling (APS) system is proposed for SMEs that have poor IT infrastructure and no basic information management system. An APS system is an IT-based production management system, and it is an essential element in responding to a rapidly changing manufacturing environment. The remainder of this paper is organized as follows. Section 2 presents the overview of APS systems along with related literatures. Section 3 proposes the implementation framework of APS systems itself, and Section 4 describes the main components of the proposed framework. Section 5 presents the conclusion and future research issues.

2. Literature Review

The APS concept emerged as an alternative tool to complement the limitations of the traditional material requirement planning (MRP) system in the 1990s. The APS system is an automated decision-making tool that helps companies reduce costs and increase productivity by using sophisticated mathematical



techniques to improve accuracy of demand forecasts, reduce overall inventory levels and improve inventory turnover [4]. In particular, the APS system has been originally applied to discrete manufacturing industries (e.g. electronics, electricity, machinery, etc.) and has been propagated into various fields such as fiber, chemical, and consumer goods [5]. Fundamentally, the APS system is most effective when employed in a highly competitive environment resulting from limited resources. In addition, the APS system is suitable for rapidly changing and quick response requiring environments and capital-intensive and processing sequence-sensitive environments [6].

Many SMEs in Korea are interested in developing and applying APS in order to cope with the rapidly changing business environment [7]. Related researches have also been actively reported. The literature on APS falls into two categories: 1) system design and development and 2) decision algorithm. There are the following instances in the first category. Shin et al. [8] derived system development requirements considering the environment of SMEs, and proposed a dispatching rule-based scheduling model to meet these requirements. Han et al. [9] developed a production capacity simulator and scheduler considering reconfigurable manufacturing system (RMS). Nam et al. [10] presented the necessity and direction of developing APS system for shipbuilding to improve supply chain management in the shipbuilding industry; then, a supply chain planning matrix, which is the standard of APS development, was proposed to the shipbuilding industry, and APS production planning module which can consider supply chain management was defined. Joo et al. [11] applied genetic algorithm (GA) to solve the scheduling problems and developed APS system for real-time automatic and manual production scheduling. Lee et al. [12] proposed an integrated production planning management module by integrating F-OPIS (factory online productivity innovation system) developed for SMEs and APS system based on time constraint and dispatching algorithm. Lee et al. [13] developed a simulation-based automation scheduler with flexibility in establishing the production plan by making it possible to change the quantity of tact time and the available process by systematizing and quantifying the manual production schedule.

On the other hand, the following literatures belong to the second category. Hwang et al. [14] classified the variables with a positive effect on the application of APS system into the objective and subjective factors, and designed and applied the improvement process through a multi-criteria decision making method. Kim et al. [15] presented key performance indicators (KPIs) that can be used in simulation-based APS and proposed a computational calibration methodology using analytic hierarchy process (AHP) technique. Han et al. [16] proposed a dispatching rule based scheduling system for SMEs and proposed a time constraint propagation mechanism.

In summary, the target user of APS system is usually system administrators. In addition, APS system has been actively studied and applied to SMEs, and APS is becoming a promising scheduling system for SMEs.

3. Implementation Framework

3.1. Design Concepts

In this paper, we propose an implementation framework of APS system specialized for SMEs. In particular, we deal with companies in the harsh environment with a poor IT infrastructure among Korean SMEs. In other words, the proposed framework aims at companies without information systems to collect production data generated in shop-floor via a point of production (POP) system composed of various sensors, bar-code readers, radio frequency identification (RFID) systems etc. In general,

SMEs with poor IT technology do not have a computerized device capable of collecting production data, and it costs a lot of capital to attach IoT devices to collect production data and perform professional management.

In order to successfully apply an APS system to SMEs with poor IT capability, even if there is no expertise in the APS system, it should be able to interpret and analyze the results. This feature is essential to secure trust from the field production manager. Therefore, the APS system should be equipped with an intuitively designed user interfaces as well as low development cost and high usability. In addition, a data management system that takes into account the poor information infrastructure of SMEs is required, and quick response to dynamic changes resulting from urgent order processing and shortened lead-time should be implemented.

Consequently, we consider the following functional requirements as the main factors in implementation of APS system: 1) establishment of on-site production data collection and management system for SMEs with poor IT infrastructure, 2) establishment of production scheduling system linking experiential knowledge of field production manager, and 3) construction of various scenario analysis system using simulation technique.

3.2. Principal Functions

The principal functions of the proposed framework are as follows (see Figure 1): 1) product data management, 2) production scheduling, and 3) verification and calculation based on simulation.

Product the data management: It should enable input and output management of production data (such as various standard information, order, materials, and status information of the production site) that was created and extracted through time and motion studies for the first time. It is compatible with Excel-based data set, enabling highly compatible management.

Production scheduling: It should provide a production schedule based on intuitive and understandable dispatching rules. In addition, it supports efficient decision-making that reflect empirical know-how of the production field manager, and quick rescheduling considering changing environment due to machine failure, emergency orders, etc.

Verification and calculation based on simulation: The scheduling result indicator derived through the embedded scheduling simulator is visualized in the form of a Gantt chart and a calendar. The derived simulation result index can be stored separately as Excel-based log file set, so it is easy to analyze comprehensive data of overall productivity.

In this way, the proposed framework can store core production data generated at the manufacturing site, and it can perform highly compatible management using Excel program. In addition, efficient scheduling can be achieved by utilizing intuitive and highly understandable dispatching logic and experience knowledge of field production managers. Moreover, various scenarios can be analyzed and verified using simulation techniques.

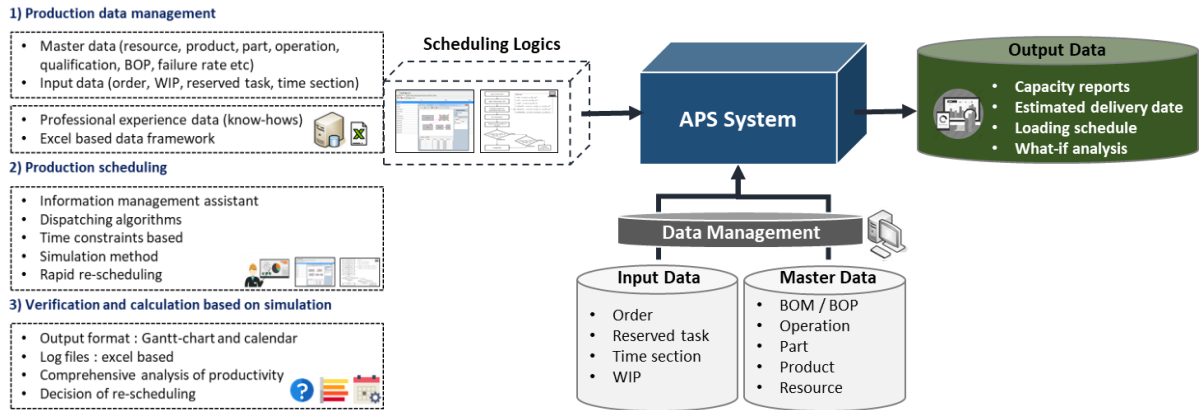


Figure1: Proposed framework [1]

4. The main Components

4.1. Production Data Management

The data management component assumes the absence of IT-based devices that can digitize production data from manufacturing sites, regarding the situation of SMEs with poor IT technology. Therefore, we should keep in mind that there is no precise and accurate production data, and thus, time and motion studies are required to generate and collect production data at the manufacturing site.

The initially considered scope in the time and motion studies specialized for SMEs is explicitly determined by a field production manager of target SMEs considering the ordered

products and on-site facilities. In addition, the time and motion studies are conducted with preference for products ordered from customers by month or week. For the first time, we are able to use video shooting techniques to simultaneously generate and collect production data. In this way, core master data (such as tact time, flow time, and lead time) are collected for each product and equipment, and then production data collection and modularization are performed. Note that equipment data should include human operators, considering that the SMEs have a high portion of manual works. The production data is stored and handled in the form compatible with an Excel spreadsheet, which is used by most SMEs in popular. The modularized production data is updated every 6 months or 1 year by a field manager considering the operation status of the field facilities and the change of order products. Figure 2 shows the procedure for collection and management of the production data

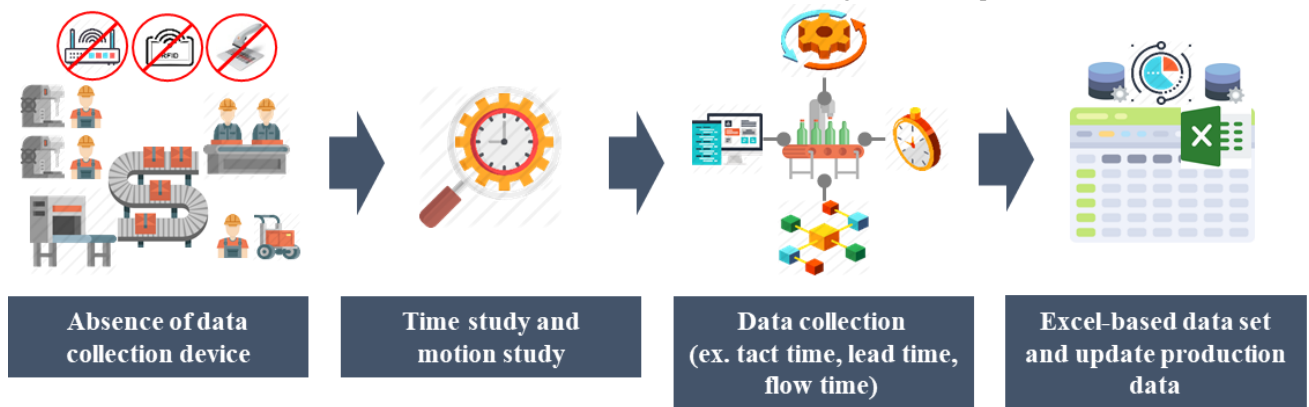


Figure 2: Procedure for production data management

4.2. Production Scheduling

Production scheduling component reflects the situation of SMEs, in which a production schedule is established on the basis of the experience of the field production manager. In other words, in most SMEs, the priority of product manufacturing work is determined by the decision of the production manager. Therefore, this paper proposes a scheduling establishment method that can meet the experiential knowledge of the production manager and various constraints at the same time.

The proposed method draws the optimal work priority based on the experiential weight of the field production manager, considering various production data (such as order quantity, set-up time, failure rate, processing time, lead time, unit cost, tardiness cost). In particular, the technique for order or preference by similarity to ideal solution (TOPSIS), which is one of the methods to solve multi attribute decision making, is applied to priority calculation, and the similarity score given to each criterion by the

empirical weight of the production manager determines the operation priority. As a result, it is possible to select scenarios according to various situations, to support decision-making to reflect the know-how of production managers, and to establish rapid scheduling. Figure 3 shows the proposed procedure for production scheduling.

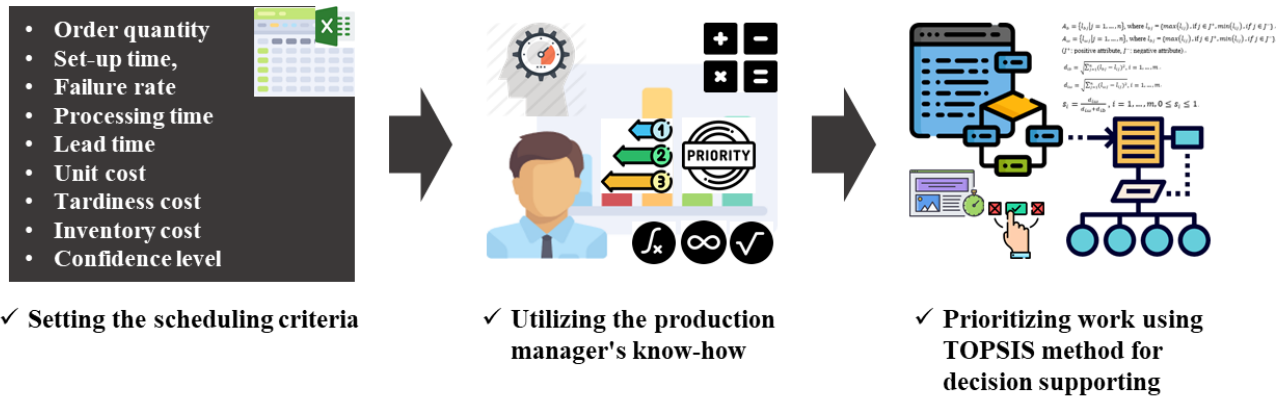


Figure 3: Procedure for production scheduling

4.3. What-If Simulation

A production schedule confirmed by the field manager can be verified and analyzed in advance through the what-if simulation component. In particular, the production manager can arbitrarily evaluate the urgency level via user interfaces for the production data registration and management, and it is possible to set the priority among the evaluation items for the individual unit work. In addition, dispatching and scheduling criteria can be selected, considering various information including delivery information,

cost information, processing time and lead time for each unit work. As a result, the utilization plan of individual production resources can be configured in accordance with a given production scenario, and changing environments due to addition/removal of production equipment or extension/reduction of work cycle can be verified in terms of productivity. The scheduling result is presented in the form of a Gantt-chart for intuitively understanding as shown in Figure 4. In addition, the simulation log is recorded in the form of Excel-based spreadsheets to support easy handling and comprehensive big data analysis.

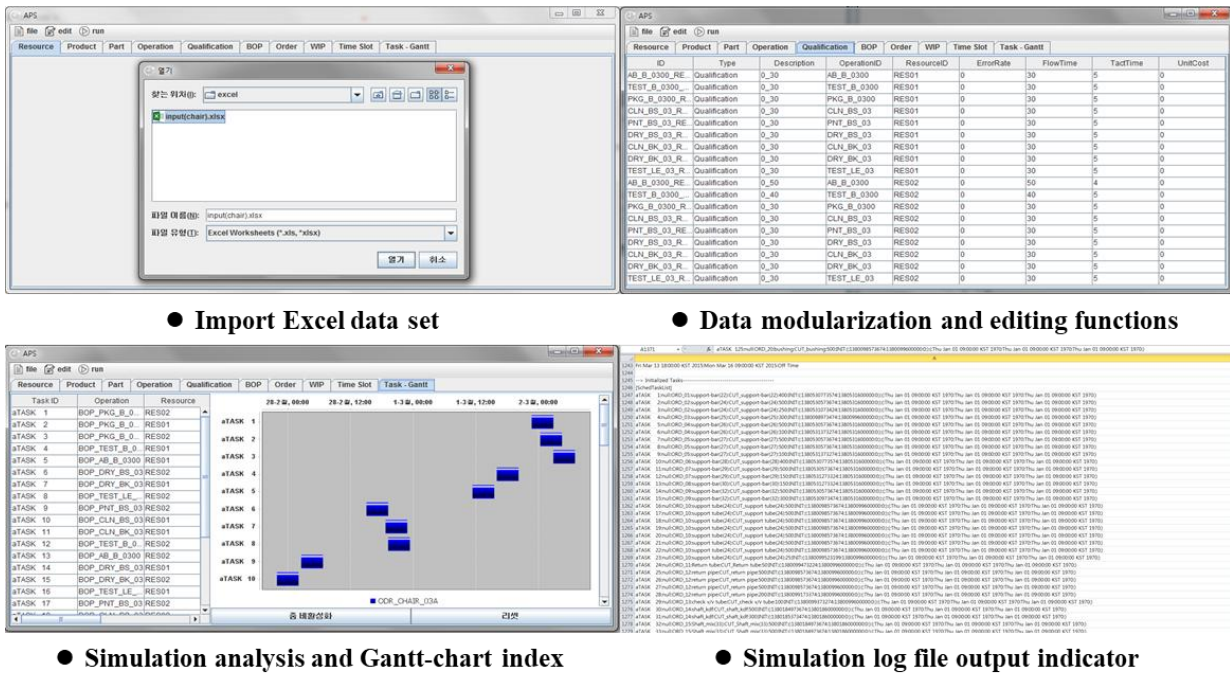


Figure 4: Implemented user-interfaces

5. Conclusion

As the wave of the fourth industrial revolution is on the rise, the Korean government has been encouraging propagation of smart manufacturing technologies such as IoT, big data, 3D printing, artificial intelligence, and CPS. However, most SMEs lack the expertise to implement the state-of-the-art technologies as well as the investment capability. In this paper, we propose an implementation framework of APS system for efficient production planning in the SMEs. The proposed framework has three main functions. First, it collects and manages production data, whereby realistic scheduling can be established according to actual status.

Second, scheduling can be established in connection with the experiential knowledge of field managers. By using a TOPSIS-based approach, it is possible to select the optimal work priority assigned to the manager's empirical weight, and it is possible to make quick decision-making via rescheduling. Third, it is possible to analyze the forecasted scenario in terms of the productivity through the simulation result index. The proposed APS system helps respond to uncertainty of the production environment through rapid and reasonable production scheduling in which the material plan and the resource capability plan are simultaneously considers. Therefore, it is expected to provide a realistic and faithful way to achieve the production goal. Moreover, by implementing only the key core functions, we expect to provide the greatest effect against input costs for application. For further

research topics, we will make a practical application of the proposed framework and enhance the calculation algorithms employed by the APS system.

<http://www.riss.kr/link?id=A100471067>.

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