DEVELOPMENT OF A SUPPORT METHOD FOR PRODUCTION PLANNING BY USE OF STANDARDIZED WORK TABLES

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Abstract
As large enterprises have begun adopting multiproduct variable quantity production, smaller companies servicing these large enterprises have been forced to increase the pace of production planning and management work. Activities that effectively improve all functions (kaizen) related to production management hence need to be implemented on site. However, production planning software is not designed to link to standardized work tables used in production worksite management. This study develops a system that can be used in all stages of product development, from production planning to worksite management. We implemented it by adding a production planning function to standardized work tables. This system uses data (items, changeovers, work in process, delivery requests, etc.) and object-oriented optimization technology, which allows for the planning of the production schedule with little adjustment to the input parameters. We verified the performance of the proposed system by solving various production-related scheduling problems using the factory simulator QUEST. We used the macro function in Excel to create a standardized work table where the production schedule was properly listed based on the results of planning.

Keywords:
Kaizen, Smaller manufacturers, IoT, Platform, Standardized work table.

1 INTRODUCTION
Over the last few years, the demands of customers have become more diverse and factories engaged in mass production have gone abroad. Hence, the rate of the domestic production of a variety of models of a product in small quantities has increased drastically. Smaller manufacturers and factories have been forced to adopt multiproduct variable quantity production with short delivery times to satisfy the demands of large enterprises. This tendency is accelerating with time. For example, the labor population (as well as the population of Japan at large) is decreasing because of a decline in birth rates. The movement of the labor population from smaller enterprises to larger ones, and from the manufacturing industry to the service industry, has become evident. Under these circumstances, it is necessary to advance effective production management using the Internet of Things (IoT) for the purpose of maintaining a competitive domestic industry.

Smaller manufacturers tend to produce a variety of models of a given product in small quantities, where frequently repeated changeovers are a major bottleneck in production. Thus, they need to quickly plan the production schedule and require flexible production management. In this vein, effectively carrying out production management work on site is an outstanding challenge. In many cases, production management (office work) and manufacturing management (factories) are kept separate such that each department uses its own software. Therefore, production planning software is not designed to link to standardized work tables used in production management at worksites.

A system for standardized work tables that can be used from the production planning stage to the worksite management stage can yield the following advantages:

- Quicker handling of alteration to orders received at worksites
- Quicker handling of unbalanced workload at worksites, such as where more than one worker carries out production work in the cell line.

In recent years, new ideas in manufacturing, such as Industry 4.0 and the industrial Internet, have emerged. Industry 4.0, adopted by the German government in 2011, is a national technological strategy to introduce ICT (Information and Communication Technologies) into the manufacturing industry and integrate the Internet of Things (IoT) with manufacturing processes. One aim is to optimize all processes involved in manufacturing by using a CPS (cyber-physical system) to implement Industry 4.0 [1].

To improve the activities of smaller manufacturing enterprises using ICT, it is necessary to solve the problems of no digital monozukuri platform tool and shortage of technicians for introduction of the tool into their factories. To solve these problems, we develop in this study an economical system that allows the online exchange of information concerning “things” and “tools” related to production, such as devices used on worksites. The aim is to create a platform to support continuous activities to improve production and management by combining information obtained from the system with that pertaining to workers. This paper proposes a system that can be used from the stages of production planning to those of worksite management by adding a planning function for the automatic generation of standardized work tables to our platform.

2 CONCEPT MODEL AND IMPLEMENTATION
2.1 Definition of required conditions
The following are required to add a production planning function to our proposed continuous improvement activity support system:
● Production planning with little input for the given data (items, machines, work in progress, delivery requests, etc.) and adjustment parameters
● Support for ease of making minor adjustments to production preparation, improvement, and so forth, on the basis of information obtained through various devices as well as observation, by using three kinds of standardized work tables as user interface

Large enterprises use three kinds of standardized work tables to standardize work. These tables facilitate communication between supervisors and workers. We think that adding the perspective of the IoT to these tables can enable digital connection between devices, factory systems, and workers.

2.2 Required analysis of manufacturing systems considering international standards

The US-based AMR Research Inc. defines manufacturing execution systems (MES) as gap-filling systems between production planning systems and device control systems. In its three-layer model, the administration/planning system handles production planning, and the control system handles the movements of manufacturing machines and devices.

Manufacturing execution systems handle particular devices or processes, where the objects are products, lot sizing, workers, etc., covering the entire factory. Such systems are developed according to the MESA model, where functions necessary for the MES are arranged. The International Society of Automation (ISA) prescribes the linking of the production planning system and the MES according to IEC/ISO62264 (ISA-95). Thus, we created a structure from the viewpoint of the level 3 MES of the IEC/ISO62264.

2.3 Mounting method

We developed our continuous improvement activity support system on a level 3 MES. The design attended to two kinds of links, between layers (within a factory) and between work management and process management (between worksites). Figure 1 shows the relation between the MES and the upper and lower layers. The magnitude processing times between layers is different, as are the input/output data for the MES according to layer.

As shown in Figure 1, the transmission of information concerning that which should be produced, that which is produced, and the method and mechanism of production is important in the execution layer. Many users (factories) record the time, yield, and so on for each process on paper and maintain this information on Microsoft Excel or a similar software. The demand for information increases the burden on worksites and leads to delays. Therefore, we utilize three kinds of standardized work tables concerning what should be produced and what is produced.

With regard to the control layer, the IoT is needed in order to use sensors well and retain only the necessary information on the server because in many cases, old devices such as processing machines, inspection devices, and automatic conveyance apparatuses operate on it as well. Moreover, the plans formulated in the planning layer do not always proceed as planned, which compels extra measures at the worksite, and this can lead to new problems, such as a delay in delivery and extra cost of calculation. Thus, it is necessary to be able to visualize information exchange between the planning layer and the execution layer.

2.4 Continuous improvement activity support system

In Japan, “manufacturing” is referred to as monozukuri, which implies manufacturing with a high level of skill in production and manufacturing techniques. The word does not mean simply “making,” but craftsmanship. For linking worksites, Japan’s strength is “field power” based on coordinating techniques or activities for improvement activities: that is, monozukuri. “Coordination” implies creating high-quality products by designing parts or modules independently of one another. Fujimoto has pointed out that this sustains the strength of Japan’s manufacturing industry [2].

Classic management techniques have been fostered in and utilized on manufacturing worksites. In many cases, activities for improvement are left to the worksite, and information obtained through worksite experience is influenced by personal factors not shared among departments, which is a significant issue. At smaller manufacturing enterprises, supervisors need to perform they manage and address problem areas when called for.

Figure 1. The relation between MES and our system is shown. The system is created on Layer 3. The minimum quantity of necessary data is transmitted between the layers of ISO 62264.
They determine three elements—“cycle time,” “work order,” and “standard in-process stock” for wasteless work—and then determine appropriate work standards based on them. They need to quickly create a standardized work combination table every day. In the production of numerous models in small numbers with multiskilled workers, the management methods of large enterprises involving standardized work tables do not work well. Thus, we examine the use of standardized work tables such that it is suitable for smaller enterprises.

Figure 2 shows the concept of the support system for continuous improvement in activity developed with the required definitions of the conditions. The system is intended to improve process through analysis using the PDCA cycle based on a production plan submitted by the production planning system. The numbers in the figure show the problems that need to be solved. This paper reports problem 1.

We made a reproduction of the model shown in Figure 2 using the concept of connective factories from Industry 4.0. Hence, with reference to the digital factory standard (IEC62832), we arranged various mechanisms of the factory using the concept of layer [3]. Currently used methods require that models be defined, such as an object model for an object and an activity model for an activity, one by one. Defining processing machines and work procedures in the factory constitute a vast amount of work. In the IEC 62832 standard, the rules for creating reference models, management, and so on are defined in the upper layer instead of being defined one by one. This can help handle the task “changeovers” frequently occurring in factories in the production of many models in small numbers. We used the DELMIA V5 and Quest to generate the models.

3 RESULTS AND DISCUSSION

3.1 Choice of production planning software and comparison of movements

To determine the minimal functions of the production planning software required by monozukuri enterprises, we investigated the available domestic software. We retrieved software packages on the market using “production planning” and “production scheduler” as keywords, and created a list. We chose 20 popular packages from the list that were sufficiently economical for smaller enterprises. An analysis of the distributions of their functions showed the following:

- The time units used in the production schedules were not unified
- The necessary input items for production planning were “parts’ structure,” “process structure,” “production capacity,” and “information concerning orders received.”
- The function to generate Gantt charts was necessary.

We chose Object-Oriented Optimization (O2O) Technology as production planning system because it allows for production planning with little input (items, machines, work in progress, delivery requests, and so on) and few adjustment parameters [4].

To compare the capacity of O2O with that of software on the market, we chose three software that sampled data open to the public. Figure 3 shows the procedure for the comparison and the examination.
3 kinds of major software

O2O

<table>
<thead>
<tr>
<th>Input value</th>
<th>Conversion</th>
<th>Input value</th>
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<tbody>
<tr>
<td>Output value</td>
<td>Comparison</td>
<td>Output value</td>
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Evaluation using QUEST

Figure 3. Comparison of O2O and software on the market.

The concrete procedure was as follows:

1. The O2O input data were different in terms, formats, and so on from software on the market. Such sample data as "process structure," "information concerning orders received," and "information concerning production capacity and changeovers" were converted into O2O input data.

2. Using Gantt charts with the planning results of O2O and software on the market, production performance was examined.

3. All results of planning were reproduced in the factory simulation software QUEST, and such factors as production numbers and work in progress were compared and examined.

Gantt charts show only the conditions once the product has been manufactured. We created and executed a simulation model in QUEST according to the time taken for machine operation. The execution results of the software on the market and those of O2O are shown in Figure 4 (left and right, respectively), which shows that setting work in progress in the buffer stock shortened the time needed for changeovers and increased production efficiency. The figure also shows that the characteristics of software systems on the market and their results should be fully examined.

<table>
<thead>
<tr>
<th>Major software</th>
<th>O2O</th>
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<td>Just after</td>
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Figure 4. Comparison using QUEST.

The input values (kinds, numbers, units, expressions, etc.) of O2O were different from those of software on the market, but we found the best results with little input. We also found that O2O enables the shortening of production lead time because it handles one-flow production.

3.2 A method to link 3 kinds of standardized work tables with O2O

Figure 5 shows a way to link three kinds of standardized work tables with O2O by adding a planning function to the tables. Input data from the process capacity table and the production schedule, i.e., input data for O2O, were transferred to the management system.

The processing can be carried out in the following steps:

1. Read in the relations of parts, processes, machines, etc., and information concerning the orders received, etc., using Excel VBA, and store them in the system.

2. Convert the read-in data into O2O input values.

3. Choose the necessary values from O2O output values and store them in the system.

4. Write the planning results in the standardized work combination table.

3.3 External design and a prototype

We added an automatic planning function to the standardized work tables on Excel so that it would not interfere with the normal use of standardized work tables used widely at production sites. In the external design, we drew a transition diagram to describe how the screen changed during screen design and created a prototype with the following features:

1. A function for creating process capacity tables (only for supervisors)

The supervisor can save a process capacity table by writing the necessary data in an empty process capacity table and clicking “Save” (Figure 6). The addresses, names, and related items in the saved process capacity table are stored in a database. Excel sheets can be used as a database, and input data are managed with “database.xlsx” containing “user recognition tables,” “catalogue of process capacity tables,” “parts tables,” and “tables related to process items and machines.”

Figure 6. Input screen from the process capacity table.

2. Read-in function for process capacity tables

Using the name of a given input item, a related process capacity table is retrieved from the “catalogue of process capacity tables,” and the data in the table are read and saved in the database again (Figure 7).

3. Function to generate production schedule

As shown in Figure 8, the planning parameters were set using the dialog. Clicking “start planning” initiated the process (O2O boots). An interim schedule table was generated when the planning had been successful (Figure 9).
(4) Creating 2 kinds of standardized work tables
Clicking “make standardized table” causes a standardized work combination table (Figure 10) and a standardized work table (Figure 11) to be automatically generated.

3.4 Test and evaluation
We tested the performance of the prototype in terms of its users, and the results showed the following:
• It automatically performed all the steps of production planning and the creation of the standardized work tables for simple problems.
• In the case of complex processes (involving the distribution of processing to several machines), it was unable to automatically generate proper standardized work tables, although it executed production planning without difficulty in the case of straight production lines.
• It was able to use historical data.
• It was necessary to set the DTPicker of ActiveX control when the version of Microsoft Office was changed.

4 CONCLUSION
In this paper, we proposed a system to execute and manage manufacturing from production planning to the generation of standardized work tables. The system has the following features:
• It can create production schedules with few conditions.
• It can generate standardized work tables using the planning results.

The saving of the history of production schedules and standardized work tables using our system allows us to determine the characteristics of each process. In case of progress management in the PDCA cycle, the historical database makes it easier to find bottlenecks without a large amount of data.

The results of production planning software are not always good, and the output values need to be verified using QUEST. Moreover, the production schedules of factories with frequent changeovers are not verified, and supervisors need to observe the manufacturing conditions. Our system can compare the production schedule with the manufacturing conditions contribute to more efficient production.

5 REFERENCES