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Production Planning and Management Using Gantt Charts

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Abstract: In this paper, a support method for business planning and management using software is proposed in order to increase productivity in small and medium-sized industries. Our targets are job shop type production factories, which manufacture products that meet specific demands from numerous customers. For these factories to be successful, speedy operational planning and effective management of operations progress for different models in variable quantities are essential. Moreover, effective production and operations management needs to be promoted. Thus, it is necessary to obtain a tool that enables the maximization of throughput using a bird's-eye view of the entire shop floor and understanding it from the viewpoint of optimization. In our study, planning production and expediting follow-up are conducted using Gantt charts. The system is a simple analog tool that heuristically supports production management through worksite knowledge and experiences without conventional approaches. Furthermore, robotic process automation (RPA) was introduced to reduce the workload of workers. The effectiveness of this prototype system was confirmed by a review of different people in charge.

Key words: Gantt chart, MZ platform, visualization, Ho-Ren-So, open-source model.

1. Introduction

In recent years, there have been rapid changes in the manufacturing environment. Rather than making one standard product, manufacturers are forced to create various products for the market because of the diversification of consumer needs. This has stimulated the production of numerous models in small quantities. Furthermore, manufacturers are interested in reducing the inventory to enhance efficiency in the production system; this increases the number of orders to subcontracting manufacturers and reduces the lot size per order. Therefore, small-sized manufacturers have to meet various demands from their numerous customers, which results in normalizing individual and multi-item small-sized production.

Most metal processing factories that produce small parts, such as wheels, screws and the like, consist of several island-shaped job shops with several numerically controlled (NC) processing machines [1]. Individual machines in a job shop are relatively independent; but reworking occurs when the scheme and progress are not shared. For these enterprises, in order to conduct production activities effectively, it is necessary to utilize worksite information for production plans and conduct wasteless production. Therefore, planning operations for speedy production plans and effective management of operations progress for different models in variable quantities are essential.

Generally, it is considered that the introduction of a production management system can resolve productivity issues; however very few enterprises have introduced such systems [2]. In a production management system, operations and work procedures are unified and standardized. Moreover, the processes (work) must be conducted as defined by the workflow. For example, even if a worker can perform a process (work) more efficiently than instructed, it is not accepted. When work is not conducted as planned, it is considered to be an "error". Hence, the introduction of a production management system is difficult in

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cases where the work content depends mainly on manual work by skilled workers, and does not involve simple repetitive work such as assembly line work.

Furthermore, there are many types of software for production planning; however, they are not used in small and medium-sized enterprises (SMEs). For example, at a metal processing factory for different sized parts using machining centers, skilled workers conduct processing work according to the production unit of each customer's request and the processing order of each product; this requires complex job shop scheduling. Moreover, an additional difficulty in job shop scheduling is that unexpected requests for trial manufacturing are accompanied by short delivery expectations.

Currently, experience and an iteration of trials and errors go into the planning of production schedules. Therefore, in this study, we propose a tool that supports management heuristically through a Gantt chart and without the use of conventional approaches. Our prototype system is devised so as to enable not only work instructions to workers from the supervisor, but also, alter the process order of workers and visualize the progress conditions.

Fig. 1 shows a comparison between the characteristics of our tool and that of conventional ones. This paper reports on worksite issues, design content of the prototype system, and problems occurring through its practical use.

2. Background

The Gantt chart is frequently used to create production schedules. It is a bar chart that lists time intervals on the horizontal axis and tasks and workers on the vertical axis; hence, it shows the current schedule status as a bar graph. In 1903, Gantt [3] presented a paper titled "A Graphical Daily Balance in Manufacture" in which production process order in a graphic form was discussed; then, a systematic management method was developed. Clark, inspired by Gantt's work, published the book *The Gantt Chart: A Working Tool of Management* in 1922, which led to the wide use of Gantt charts in various fields. Manufacturers use computer software named "Production Scheduler" for production planning and manufacturing scheduling. The scheduler outputs the calculation results in Gantt chart forms for easy understanding. Many researchers and business practitioners have published numerous papers on job shop scheduling, among other manufacturing

	Conventional tool	Our tool
Production state	Mass production of small quantities of models, repetitive production	Production of variable models in variable quantities, test product
Management aim	Better management (KPI)	Production activities without waste
Solution	Planning with limited algorithm	Work support by simple software expand RPA
Technology	One or two algorithms, or technology dependent on genetic algorithm	Humans modify conventional algorithms based on their experience performance or use heuristic algorithms
Operation	Difficult	Simple
Cost	Expensive	Inexpensive

Fig. 1 Comparison between our tool and conventional ones.

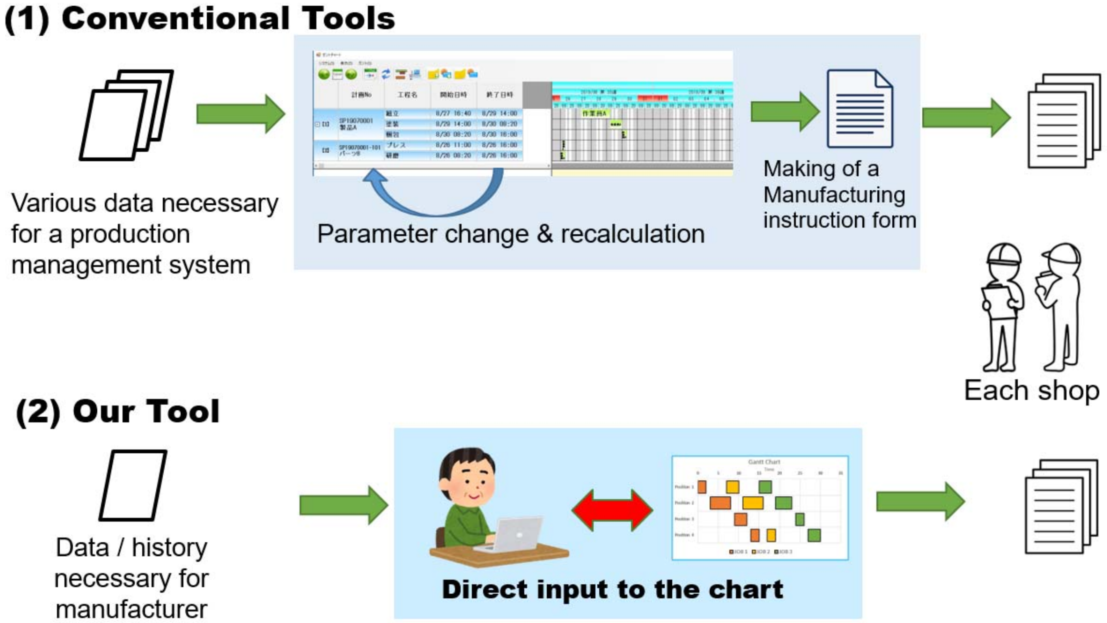

Fig. 2 Comparison of the use of Gantt chart in production planning.

scheduling issues. The job shop scheduling issue is considered to be the most difficult of all scheduling issues because of its complicated combination [4]. Jia et al. [5] proposed a genetic algorithm integrated with a Gantt chart to find factory combinations and schedules in a dispersed manufacturing environment. As research results are not intended for practical use, production schedulers are mounted with algorithms that are based on these results. The priority of production schedules is to find an approximate solution within a short period of time.

During the use of a production scheduler, planning requires considerable data in advance such as Bill of Materials (BOM); moreover, to increase accuracy, it is necessary to record many parameters and recalculate them (Fig. 2(1)).

General production schedulers require considerable scheduling logic and master data, which is difficult to handle. Furthermore, the logic to control the restricted conditions of the worksite and command the expertise of the managing worker is not always mounted. Therefore, we propose a new method to support existing production planning work. Our system enables little input work for the given data (such as items, machines, work in progress, and delivery requests) and parameter adjustment, and direct input to a Gantt chart and preparation of a work instruction form at the same time (Fig. 2(2)). Additionally, we believe that all staff should perform production management, including workers in the production/manufacturing site (instead of the supervisor controlling the site alone). To promote management activities at all levels, it is important to share improvement methods and field knowledge (like technical expertise), besides general knowledge regarding management.

A famous method to improve productivity by sharing information is "Ho-Ren-So". "Ho-Ren-So" is a business mantra or mnemonic acronym in Japanese business culture. It is an abbreviation of "Hokoku" (to report), "Renraku" (to inform) and "Sodan" (to consult), and it is also popular as a homonym of horenso, the Japanese word for "spinach". At shop floors, the main information transmission happens through instruction forms, which means there is only a one-way information transmission from the supervisor to workers.

SMEs with a shortage of staff are forced to take a work form with multi-talented workers; this makes it difficult to track all progress conditions. Therefore, we thought it would be important to add the "Ho-Ren-So" method to the management system. To improve performance with limited staff, it is necessary for the entire staff to improve all work-related activities.

In addition, it is necessary for workers to understand the supervisor's intention and be proactive instead of asking for his/her instructions; this means that a support tool is significant to turn the plan-do-check-act (PDCA) cycle with all staff. For this purpose, we considered the use of the Gantt chart. Fig. 3 shows how it is used. The Gantt chart that is made by the supervisor in the upper part of Fig. 3 is sent to workers, and each worker makes a judgment about his work conditions and performs the appropriate work. Before starting work, he alters the Gantt chart and informs his supervisor. Even if the Gantt chart takes on the role of "Ho-Ren-So", for example, a worker makes work content alterations or adds something according to her work conditions; this does not cause confusion because her supervisor knows the fact through the Gantt chart.

Fig. 4 shows a comparison of our method and an ideal production system using Information and Communication Technology (ICT). The ideal system was designed with a layer of IEC/ISO 62264 (ISA-95) [6]. For SMEs, the introduction of a backbone system is a heavy investment, and system selection is very

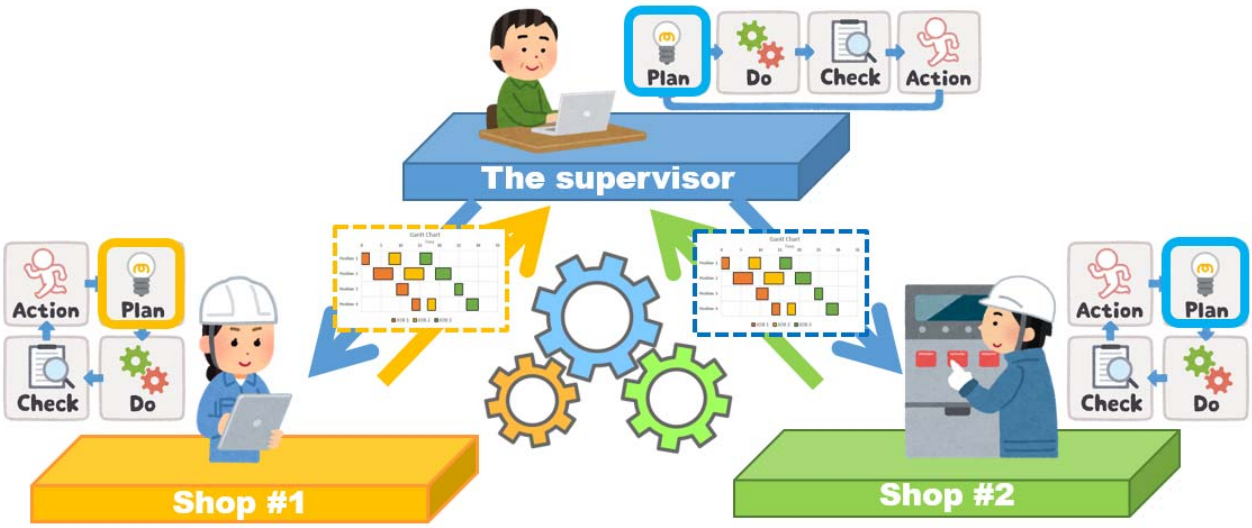

Fig. 3 Horizontal and vertical integration of production operation using the Gantt chart.

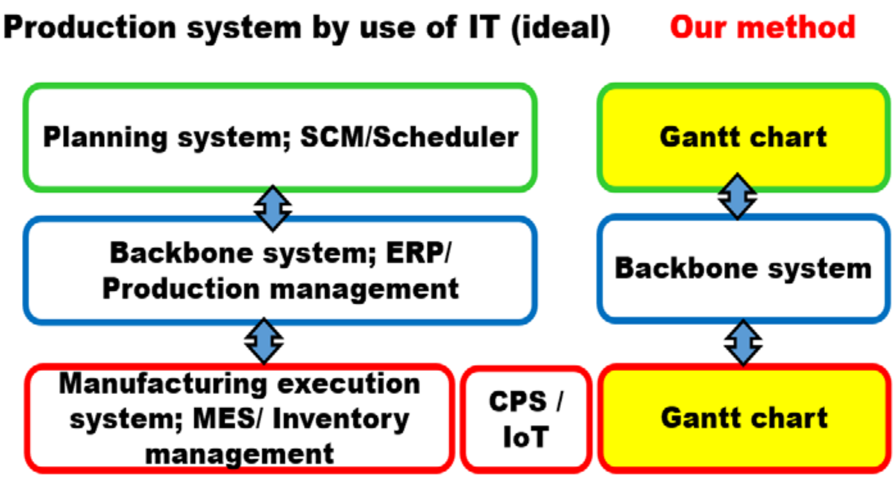

Fig. 4 System structures of our system and an ideal case.

Table 1 Conditions of the supposed enterprises.

Item	Supposed enterprise	Remarks
Production	Build to order	EDI, drawing attached
Period	About 2 weeks on average	3 months at maximum
Method	Individual production	No lot unit
Planning standard	Delivery standard	
Equipment layout	Job shop	
Worker & process	Cellular manufacturing	Intensive equipment
Model & output	Production of many models in small quantities	Sufficient quantities in stock
Instruction to process	Push production	
Changeover	Fixed changeover time	

difficult. Moreover, its effective operation requires an improvement in the operation process. In many factories, however, performance (such as operating time and yield of each process) is first recorded on paper and then, recorded in Microsoft Excel. The use of a Gantt chart system makes it possible to easily display performance by lengthening the chart bars or inputting progress rates according to the work progress using terminal units at the worksite.

3. Development Principle

3.1 Requirements

Table 1 presents the requirements of the manufacturers under study. These requirements were set based on the actual circumstances of the investigated shop floors.

The definitions of the workflow of the assumed enterprises are shown in Fig. 5. The received orders are handled as described in the following list:

(1) The order is received through electronic data interchange (EDI) from regular customers and by phone from new customers.

(2) Registered processing patterns are used for repeated products and standard process patterns (e.g. 00) for new products.

(3) Inventory reservation is conducted in production planning.

(4) In the process of preparing production instructions, in-house or outsourcing, product numbers, delivery dates, process time limits, and the like are decided. An instruction form is then created.

(5) In the process of inquirers to the shop, the process order is decided according to process time limits and changeover.

(6) After the end of processing, the processing time, processed numbers, number of defectives, and so on are input in the instruction form.

We utilized the MZ platform for the development of our system, considering cost-efficiency and open-source software [7]. The platform is a software development environment that was created by the National Institute of Advanced Industrial Science and Technology (AIST) for small enterprises. On the platform, programming is not conducted by inputting source codes; the basic operation is performed using the mouse. The design is created by combining and assembling software parts called components in the application order. This is a framework style platform. As our database, we chose MySQL, which is an open source relational database management system.

3.2 Basic Design

As shown in Fig. 6, we set a Gantt chart for the existing production management systems. We used the concept of data warehousing for smooth processing; the Gantt chart has a storage database for the necessary decision-making data from each of the databases (lower part of Fig. 6). This enables the worker to perform production planning and fill work instruction forms even when it is separated from the system (lower part of Fig. 6) because the chart operates on its own. The Gantt chart system is linked

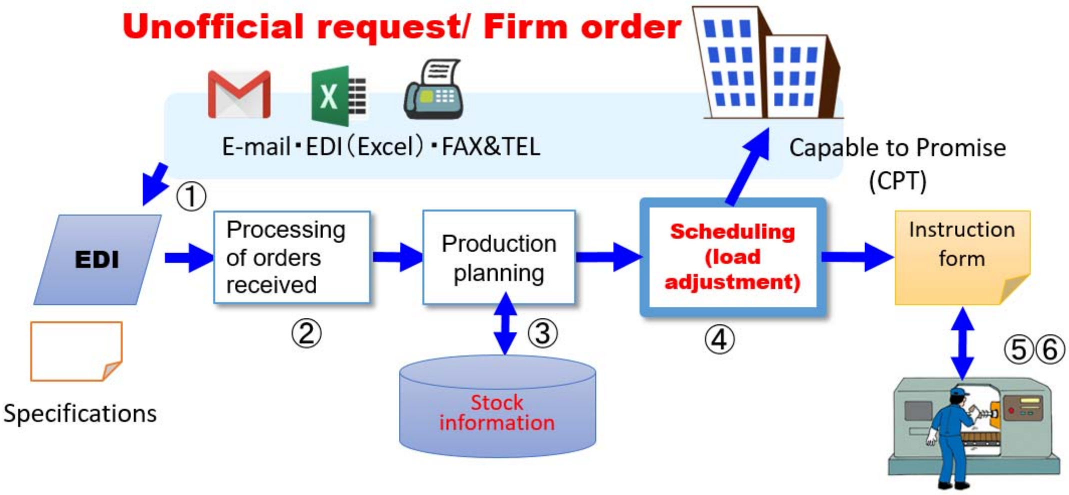

Fig. 5 Operation flow (assumed enterprises).

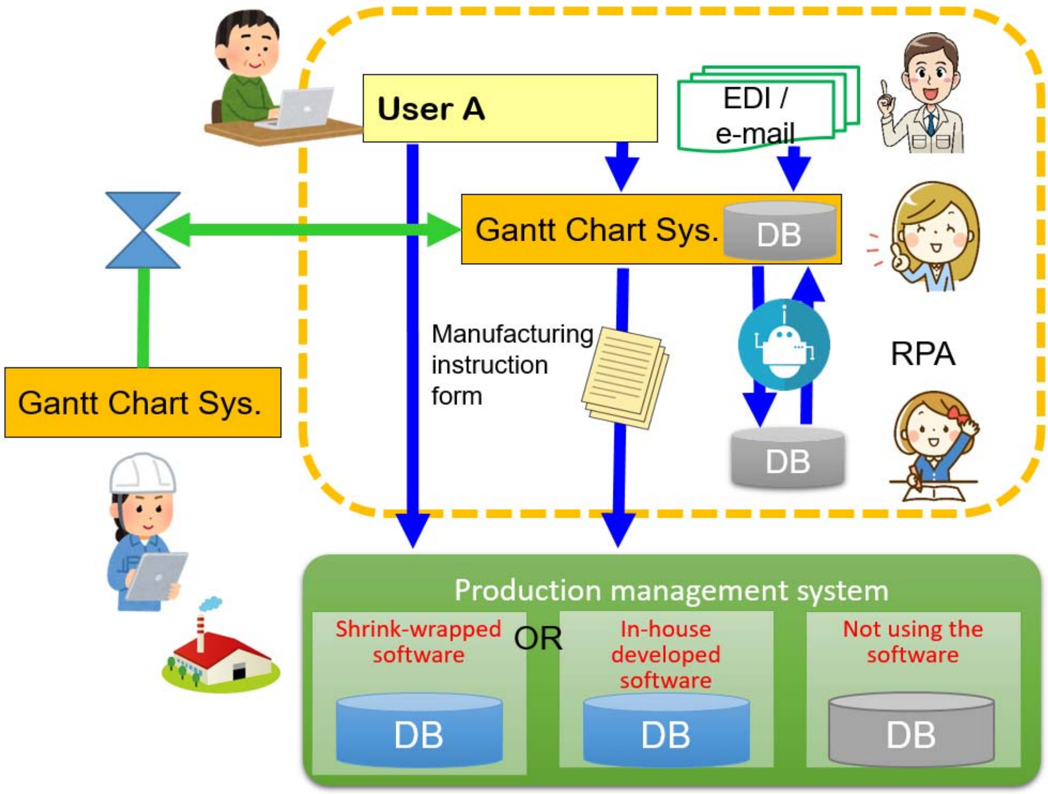

Fig. 6 Image of our prototype system.

to the robotic process automation (RPA) unit to support the user's task. RPA is a technology that aims to promote efficiency and automation mainly in white-collar operations through utilizing cognitive technology (such as rule engine, machine learning, and artificial intelligence (AI)). The reason we chose this technology is that we believe that an AI system would make it possible to automate most of the creation of work instruction forms in production planning, i.e., for items that are ordered regularly or in the past were recorded from order to delivery. Hence, we performed digital labor automation by collating information about orders received with the "Item Master" to decide a rough work process with reference to the "Process Master"; the supervisor conducted this every time he/she received an order.

On the left part of Fig. 6, the "Ho-Ren-So" unit is added to promote information ties between each shop and the office for higher productivity.

4. Design of the Prototype System

Our prototype system was composed of seven modules, as shown in Table 2. It was built with the smallest client server system (CSS) instead of three-tier architecture, considering the environment of our supposed enterprises. Here, it is assumed that only the server and multiple clients are connected to the same network for security reasons. An MZ platform and a database were installed on the server for the supervisor. To operate the prototype, the client in each shop only has to install an MZ platform.

Fig. 7 shows the operation of the system. In the Gantt chart, the vertical axis shows the processing machines, and the horizontal axis shows the time. This

Table 2 Module functions.

Module	Function
Database	Database on/off, execution of SQL query.
Master	Display of master information.
Order management	Manual processing of orders newly accepted from EDI data.
Gantt chart	Conversion of production planning to the Gantt chart. Modification of planning by expanding and shortening the chart.
Progress management	Registration of production performance.
RPA	Automatic processing of the data of orders newly accepted from new order data/history data.
Printing of a work instruction form	Making of a work instruction form from new order information and production plan.

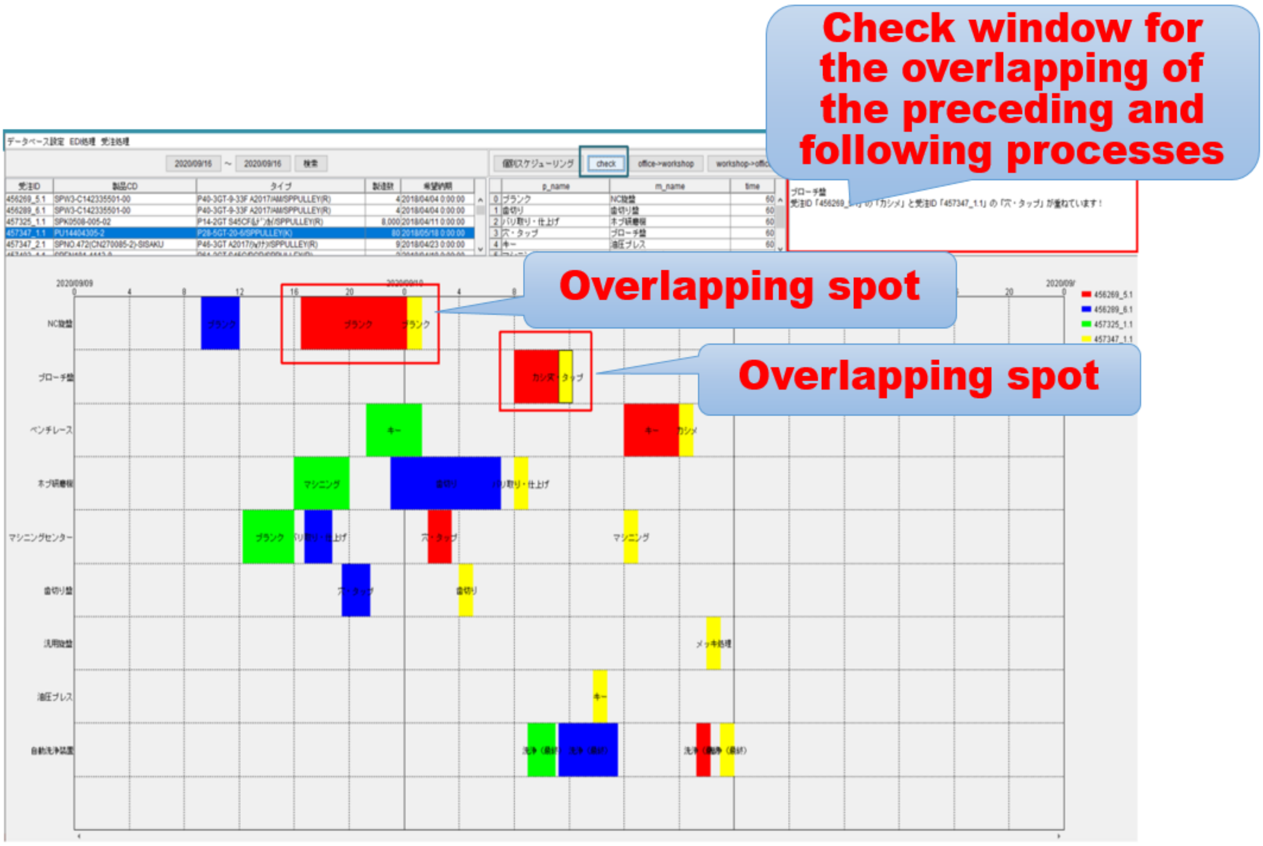

Fig. 7 An example of scheduling.

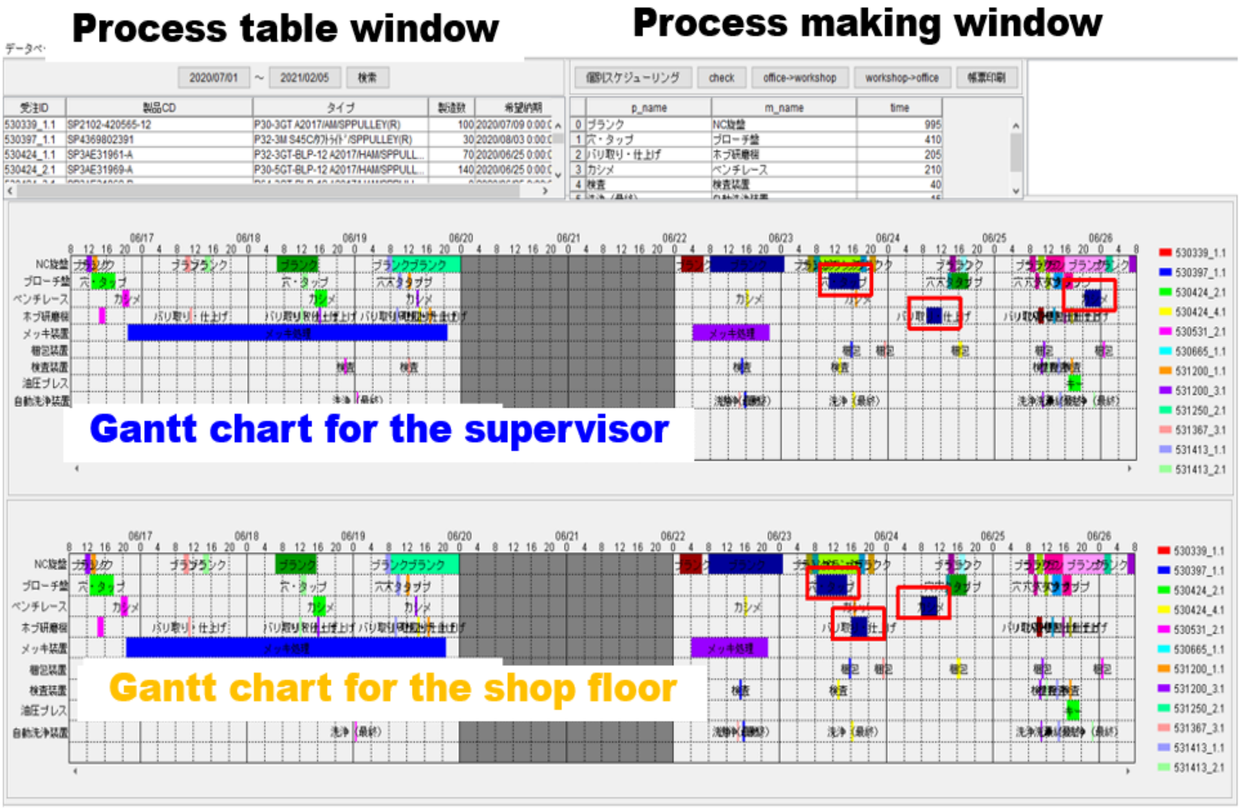

Fig. 8 Job adjustment between the supervisor and shops.

is a case where the RPA creates a draft pattern from the EDI data; the pattern is converted in the Gantt chart identically. The two squares in the printable area of the chart show the overlapping of the scheduled and new values. In this case, an error message is shown in the upper (right) window for the overlap check. When there is only one processing machine, the error indication is erased by moving the overlapping to either right or left.

Fig. 8 shows a case of job adjustment between the supervisor and a shop. This consists of three parts. The upper part is used to create a process using a product from the EDI data. The middle part converts the process using the product made in the upper part to a Gantt chart. The lower part shows the instruction results for the shop floor (client). In the case of a request for the order processing of a product from a shop to the supervisor, the bar of the Gantt chart is moved with the mouse and the confirmation request button is pushed. The supervisor checks the Gantt chart and if there are no overlaps, he sends a confirmation. If not, he alters the chart and presents it to the worker.

5. Conclusions

In SME, manufacturers are forced, such as wheel manufacturing with the production of different models in variable quantities, is forced to receive orders with enough time to spare and suffer opportunity loss. A solution for this is the blank spaces on the Gantt chart with no bars filled in; this requires visualization of workers, products (products in process) and processing machines in the manufacturing site.

One way to visualize them is to collect the states of machines and devices using ICT. However, in the product-making form where the job shop type equipment is its nucleus, it does not seem possible to establish digital continuity. More precisely, it is difficult to transmit the ideas or knowledge of the workers of each shop to the supervisor, which if possible may create a digital silo.

For visualization, the optimum tool is the Gantt chart, i.e., a chart with great applicability that has been used for a long time. Our system is an inexpensive decision-making support tool that enables precise information sharing in small schedules.

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