A Reference Model for Development of Production Scheduling Systems

Shigeru Fujimura
Graduate School of Information, Production and Systems
Waseda University
Kitakyushu, Fukuoka 808-0135, Japan

Abstract

Many kinds of scheduling systems have been installed for many kinds of manufacturing factories more than thirty years until now. A production scheduling system includes very important functions for production cost reduction and the improvement in customer satisfaction. However, not all systematization has been successful. Therefore, in order to realize homogeneous systematization to various kinds of production processes, a reference model for development of production scheduling systems with flexible extendibility and adoptability related to dynamic changes is desired. In System Technical Committee of Electronics, Information and Systems Technical Society, IEEJ, "Working Group of a Reference Model for Production Scheduling System Construction based on Business Process Modeling" was launched in April 2012. The purposes of this working group are to conduct investigation and analysis of a decision making process of production scheduling and provide a reference model for system construction which is applied when production scheduling systems are developed. In this paper, difficulties of constructing scheduling systems are reviewed, a novel reference model formed through the discussion in this working group is shown, and the systematization technique called “spiral evolution” for small and medium-sized enterprises is also introduced.

Keywords

Production Scheduling, Business Process Modeling, System Development

1. Introduction

With rapid growth of the information technology from the 1980s, many systems for production process control or production management using personal computers have been installed into many manufacturing industries. It was also the same time that production scheduling systems began to be introduced in production sites. Many kinds of scheduling systems have been installed for many kinds of manufacturing factories more than thirty years until now. A production scheduling system includes very important functions for production cost reduction and the improvement in customer satisfaction. However, since a production scheduling system needs the complicated decision-making mechanism, not all systematization has been successful. The decision-making mechanism is different in each purpose and production process of a manufacturing factory and the environment which surrounds a manufacturing company is changing with a product life cycle reduction continuously. Therefore, there are various difficulties in system development and whether systematization is successful is a great influence on a system engineer's skill. Then, in order to realize homogeneous systematization to various kinds of production processes, a reference model for development of production scheduling systems with flexible extendibility and adoptability related to dynamic changes is desired.

In order to provide such a reference model, the current system configuration processes should be investigated by cooperation of the both sides of a system user and a vendor company. In System Technical Committee of Electronics, Information and Systems Technical Society, IEEJ, "Working Group of a Reference Model for Production Scheduling System Construction based on Business Process Modeling" was launched in April 2012. The purposes of this working group are to conduct investigation and analysis of a decision making process of production scheduling and provide a reference model for system construction which is applied when production scheduling systems are developed. In this paper, firstly difficulties of constructing scheduling systems are reviewed, and a novel reference model formed through the discussion in this working group is shown. The systematization technique called “spiral evolution” for the small and medium-sized enterprises which the author is developing now according to this view is also introduced.

2. Difficulties of Introducing Production Scheduling Systems

Difficulties which have arisen in the current systematization are analyzed separating into the problems of scheduling business process and systematization. These problems are the views acquired by the brainstorming in the committee (Enoki and Miyatake (2012)).

2.1 Problems of Production Scheduling Business Process

(1) Problems occurred by a complicated production process

(1-1-1) Production is not performed in the same behavior as a scheduled instruction. A production process receives various disturbances caused by the complexity of itself, by those disturbances, delay is occurred in production and re-scheduling is needed for it immediately.

(1-1-2) There are too many constraints of a production process. The numerousness of constraints for a production process makes the problem difficult, such as constraints of the process chain producing a product, constraints about the production sequence of the product in a production process stage, constraints of equipment used in a production process and so on.

(1-1-3) Although leveling of a work load is required, it is difficult under various constraints.

(1-1-4) A bottleneck process stage changes with a combination of production items.

(1-1-5) A process in which job lot production and one-by-one production are intermingled needs to be synchronized between productions, and determination of lot size is difficult.

(1-1-6) The inventory management of work-in-process, especially a liquid or granular material, is difficult.

(1-1-7) To introduce of a new product or change of product structure Adaptive changes of a production process and scheduling approach are needed.

(1-1-8) When the production process is changed and also constraints and /or priority conditions are changed, the complexity of working rules increases.

(1-1-9) Since the production process is complicated, the schedules generated by different scheduling persons are different caused by use of each own knowledge. The evaluations to the generated production schedule also differ.

(2) Problems of complicated relationship between members of different departments in a company

(1-2-1) Negotiation between different production processes managed by the same production control department is difficult. When treating many products within one production control department, a whole production process is divided two or more sub-processes and one scheduling person controls each own sub-process. In the same way, for production control departments in the different factories, some scheduling person should communicate and negotiate anytime.

(1-2-2) Communication and negotiation with departments outside of a production control department such as business management, sales, manufacturing, and a materials management is serious. The authorized routine tasks are performed according to the rule beforehand defined between both departments and the other non-routine tasks also exist. Unclarity of the official authority in a company cause non-routine tasks, and these tasks cause various problems.

(3) Problems occurred by a delay of information

(1-3-1) Transfer of information required for adjustment of a schedule is delayed.

(1-3-2) Action required for adjustment of a schedule cannot be performed quickly.

2.2 Problems of Systemization

(1) Scope Determination Phase

(2-1-1) The purpose of system introduction is not clear. Although it should be basically clear at the beginning of development project, it may be spread by thought of participants, after their argument.

(2-1-2) The quantitative indices by which the effect on investment can be evaluated don’t exist. Therefore, the purpose will become ambiguous.

(2-1-3) The terminology is not unified which is used by a person in charge of scheduling in a company which introduces a system, and an engineering person in a system vender which offers a system. When the terminology which is peculiar to a company is used, the mismatched recognition causes big problems.

(2-1-4) The project leader which can take strong leadership does not exist.

(2-1-5) Since there is no positive intervention of a person in charge of scheduling, requirement analysis cannot fully be conducted.

(2-1-6) Communication of a user and a systems engineer is not enough.

(2) Business Process Analysis, Requirement Analysis and Functional Design Phases

(2-2-1) There is a problem in the precondition for analysis of the present status of a production process and a business process, and it does not become fundamental problem solving. Only paying attention to scheduling business process, analysis is done under the premise that the present operation rules with outside departments are right. There may be a problem in these rules themselves.

(2-2-2) In the hearing of business process analysis, only analysis of the current business is focused on from beginning to end, and improving actions are not discussed.

(2-2-3) When examining an improving point, the members who are directly related to it have not participated. Especially if the member who can make decisions has not participated, the improvement of the present rules cannot be decided and it may not be changed.

(2-2-4) There are a lot of information about a scheduling approach that is own knowledge from one of all members in charge of scheduling. From some other members, different knowledge may be extracted. On the other hand, schedule solutions made by different members are different and they evaluate a schedule solution from a different view point.

(2-2-5) It is difficult to systematize an experienced person's scheduling approach in a complicated production process and a business process.

(2-2-6) Functions realized by requests of a person in charge of scheduling may not be used by other persons.

(2-2-7) By system development based on only the functions which can be provided by a system vender, deviation from the purpose of systematization may be caused.

(2-2-8) A big problem may be caused in the future by not realizing the requested function completely, or changing the business process itself, after judgment of a system engineer whether it can be realized.

(3) Implement and Test Phases

(2-3-1) By the difference in the terminological recognition with a system designer and a developer, a system may not be developed correctly in accordance with a specification.

(2-3-2) In the portion which the detailed design is not done in the functional design phase such as timing of data updating or processing and synchronous consideration of parallel processing, a system development person may develop a different function from a system designer's desire.

(2-3-3) The difference in recognition of specification may not be aware at an early stage.

(2-3-4) When a fault in a system is occurred, if the problems are solved by adjustment with not essential provisional way, a bigger problem will be appeared later.

(4) On-Site Use Phase

(2-4-1) In the systematization to an individual company, many special functions are included. Therefore, when manuals with a detail description of functions, are not provided, it becomes a system which only a developer and an on-site proposer know and continuous use of it becomes difficult.

(2-4-2) The maintenance of the master data for addition of new products is trouble, and if it is not maintained, the system is no longer used.

3. Proposal of a Reference Model for Construction

The systematization requirements are itemized as follows to problems of the systematization analyzed in the

previous chapter. Indices of problems are added to each related requirement.

- Setup of a purpose of the systematization from a viewpoint of the whole company and quantitative indices (2-1-1)(2-1-2)
- Terminological common recognition (2-1-3)(2-3-1)(2-3-2)(2-3-3)
- Required member's full participation, and good communication (2-1-4)(2-1-5)(2-1-6)(2-2-3)(2-3-3)
- Exclusion of the complexity of a production process damaging to the purpose (1-1-1)(1-1-2)(1-1-3)(1-1-4)(1-1-5)(1-1-6)(1-1-7)(1-1-9)(2-2-5)
- Arrangement of the ideal business process of the routine and non-routine tasks, and operational rules between the organizations according to the purpose of systematization (1-2-1)(1-2-2)(1-2-3)(2-2-1)
- Top-down requirement analysis (2-2-8)(2-3-4)(2-4-1)
- Design of functions which suit not only in the present but in the future (1-1-7)(2-2-2)(2-4-2)
- Design of functions in which a system can respond to changes of a situation promptly (1-1-1)(1-1-8)(1-3-1)(1-3-2)
- Systematization which eliminates the processing based on the knowledge which the person in charge of scheduling has individually (2-2-4)(2-2-5)(2-2-6)
- Division of a whole decision-making function into several parts of it, and introduction of a simulation function (1-1-2)(1-1-3)(1-1-5)(1-1-6)

The system vendors has led system introduction to the customers. Therefore the conventional systematization is according to bottom-up approach using the basic functions provided by system vendors. This has made users have undesirable and harmful effects. On the other hand, for the systematization which satisfies the above-mentioned requirements, top-down approach is important. The proposed reference model consists of three portions, clarification of the systematization target, outline design and detailed design.

3.1 Clarification of the Systematization Target

Firstly, all the present condition which surrounds production scheduling is analyzed. Up to now, when developing a production scheduling system, only scheduling business process is focused on. However, analysis also including the environment which surrounds scheduling business is required. After analyzing the present condition and the future operation for such as the whole environment, the purpose and range of systematization should be clarified. In this section, this clarification procedure is shown.

Step 1 <Clarify the purpose of systematization>: The purpose is divided roughly into four categories, quality improvement, time reduction, cost reduction, and environmental protection. Firstly, current problems are extracted and according to these problems the most important purpose is set from four categories. These four categories conflict in many cases. If there are two or more purposes, the priority is determined beforehand and the purpose is realized in order according to the priority.

Step 2 <Narrow down analyzed target>: Out of the whole operation process, the operation process expected that an improvement effect is highest should be selected as the target process and the operation process expected that an improvement effect is quite low should be removed. These operation processes may straddle two or more sections.

Step 3 <Analyze the target operation process>: The flow of operation process is described as a business flow chart to show the procedure of the contents of work which have actually done according to the passage of time. In this flow chart, to specify the information relations, computer output reports and handwritten memo are pasted.

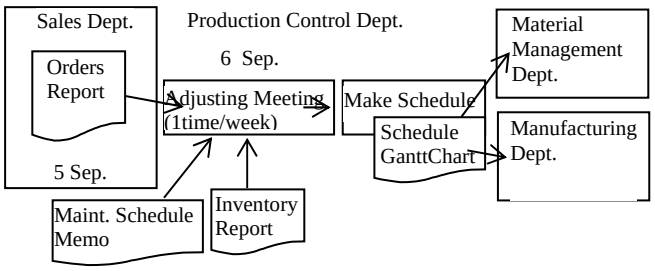

Figure 1: an Example of Business Flow Chart

Moreover, the information referred from a computer display is specified. The example of a flow chart is shown in Figure 1. By performing this arrangement by all the members in related sections, under the common recognition, all of them can reach consensus of the present whole business flow, rules between sections, relation with a system, inefficient and irrational parts and so on.

Step 4 <Analyze problems and actions>: Bottom causes which have caused the problem under analysis of the operation process of Step 3 is analyzed to problems extracted at Step 1. And actions to those bottom causes are planned. A general view of analysis of problems and actions is shown in Figure 2. The operational effect of actions to the purpose is evaluated and the priority of each action is determined. According to the priority of it, whether carry out its business improvement action is determined.

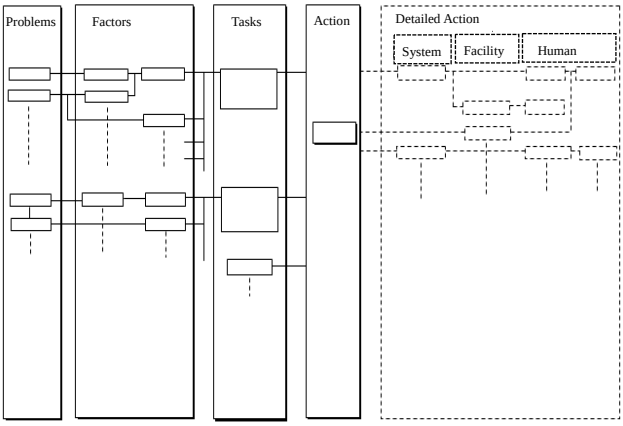

Figure 2: Analysis of problems and actions

Only when an action relates to introduction of a scheduling system, the next outline design is carried out. Otherwise, an implementation approach for it is considered separately.

3.2 Outline Design

In Section 3.1, overall analysis for business improvement was conducted and actions to problems were clarified. In this section, when the actions are for a scheduling system, the procedure about systematization is explained. The procedure of this outline design is proposed by Fujimura 2011, and an outline is explained here.

This procedure is for designing decision-making components called processing modules, to construct a model of multi-echelon decision-making scheduling system (Roy et al. 2004, Chatfield et.al. 2007, Leitao et.al. 2006, Vorst et al. 2000). The outline design does not consider the detailed contents of each processing module. They are considered in the detailed design procedure discussed in the following section. The outline design procedure consists of the three following steps.

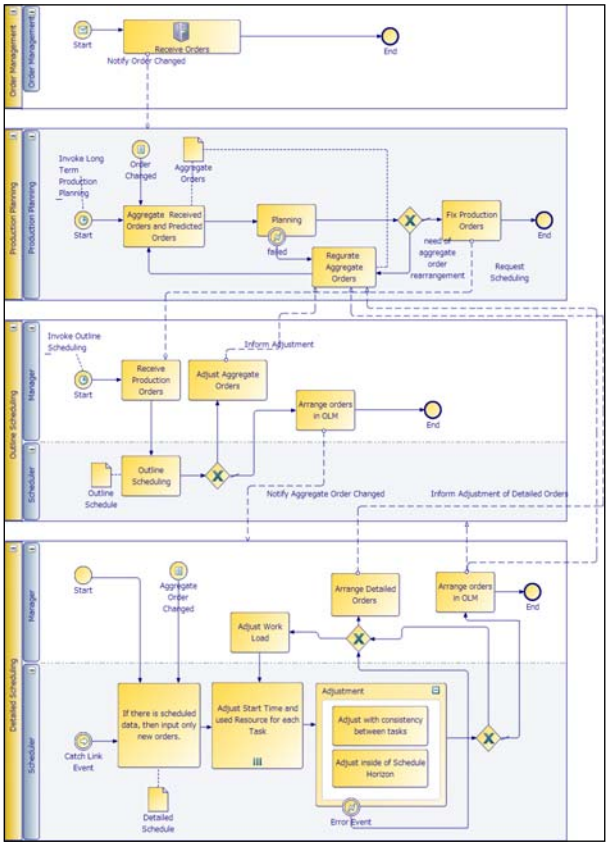

Figure 3: an Example of Design of Processing Modules using BPMN

Step 1 <Improve business process and production process>: Using BPMN (White et al. 2008, Allweyer 2010), the current operation process is analyzed. The portion which is not desirable may be included in the current process. For examples, there may be meaningless rules when the system which has already existed is untouched and there may be complicated operations by lack of the information cooperation between departments. In such situations an operation process needs to be revised. Moreover it may also be in a

complicated production process. In this case, simplification of a production process may make a scheduling operation process simple. In the conventional system development, the improvement of such a production process itself was an area which must not be touched, and it was rare to be touched for systematization. Therefore, having induced failure in many systems development cannot be denied.

Step 2 <Refine a model for composition of processing modules>: In the operation process model generated at Step 1, a whole process is divided into the processing modules in a multi-echelon scheduling system, BPMN pools are reconfigured according to these processing modules and the processing flow in each processing module is refined.

The following processing module for decision-making is extracted from the model of a whole operation process.

- processing modules for aggregated information: It is a processing module treating aggregated information for product, time, resource, process stage and so on. It is used in order to generate an outline rough schedule.
- processing modules for focused information: It is a processing module which generates a schedule while focusing on some of products, scheduling time horizon, process stages, and resources. For example, it is the scheduling focused on only a bottleneck process stage.
- processing module for detailed information: It is a processing module which derives detailed schedule information from the schedule information generated with the above-mentioned processing modules.

Step 3 <Clarify and Correlate roles of processing modules>: The contents of the data and timing of the message flow which exchanges the information between the processing modules arranged at Step 2, are clarified.

3.3 Detailed Design

A scheduling operation process is already divided into some processing modules, and the interface specification between processing modules is also clarified. The detail design is carried out to each of these processing modules.

Step 1 <Survey scheduling operation>: The scheduling conditions and rule which a person in charge of scheduling uses are investigated. In a hearing, extraction of the detailed information based on the global operation flow is important.

Step 2 <Arrange conditions and rules>: The constraints, priority conditions, and rule which were extracted at Step 1 are arranged. In this arrangement, these items are arranged so that these can be used general-purpose.

Step 3 <Design scheduling mechanism>: The scheduling method using the information arranged at Step 2 is designed. How to divert or customize existing modules, such as what is implemented on dispatching rules or optimization technique, is designed.

4. Systematization of Scheduling System for Small and Medium-sized Enterprises

In this chapter, the systematization technique called “spiral evolution” for the small and medium-sized enterprises is also introduced. The manufacturing process of small and medium-sized enterprises is continuously confused, and standardization of work, leveling of loads, visualization, kaizen and so on are always performed. Change of business environments, such as a manufacturing process, product mix configuration, and operations, is also frequent. The system introduction technique which suits such environment is proposed.

4.1 Development Process by Spiral Evolution

In order to reduce the expense of system introduction and maintenance, it is necessary to satisfy the following two requirements.

- A system in which a system engineer's customization is unnecessary and a user's maintenance management is possible.
- A system which can follow changes of the business environment from user's current condition to the future and also an ideal.

In order to satisfy such requirements, the systematization technique called “spiral evolution” which supports system introduction and maintenance according to transition of three states of change, discovery and updating is proposed.

The System has to be used continuously without stopping even when a business environment is changed. However, conventional systems need to maintain master information or to correct a system's own functions to such changes, and cannot be continuously used, in order to carry out these operations. By introduction of the concept of "spiral evolution", continuous usage of a system enables continuous use.

It is important to carry out various "discovery" to "change". The function to make the current problem or the problem which arises by "change" recognize immediately is required. Therefore, the current status of a manufacturing process is collected as tracking record information, and it is made visible. The collection must not be stoped even when a new product is introduced and unusual processing is necessary. Workers are made to recognize current problems visually and the information is made to share by all workers through making change visible immediately. Then, it must be possible to connect to new discovery.

Next, "updating" is performed to "discovery". Kaizen of a production process, change of operational rules or renewal of a system is performed for solving the problem "discovered". Such "updating" must be performed under continuous system use. In order to do so, it is the necessity which can take in the kaizen of a manufacturing process, and change of an employment rule without change of a system. In order to do so, it is necessary to take in the kaizen of a manufacturing process, and change of an employment rule, without change of a system. Moreover, when adding a new product, changing manufacturing equipment, or changing manufacturing recipe, it is necessary to update a system so that there may be no trouble.

4.2 System Configuration

This system consists of four functions such as an actual event acquisition function to collect the track record events of a production process, a data management function which manages the past information of a production process, a progress monitoring function for grasping the situation of a production process and a scheduling function to determine a detailed schedule for production orders. The information on production recipe which specifies a production method required to generate a production schedule is also managed. an actual event acquisition function is mounted on an Android personal digital device. The data flow between each function is shown in Figure 4.

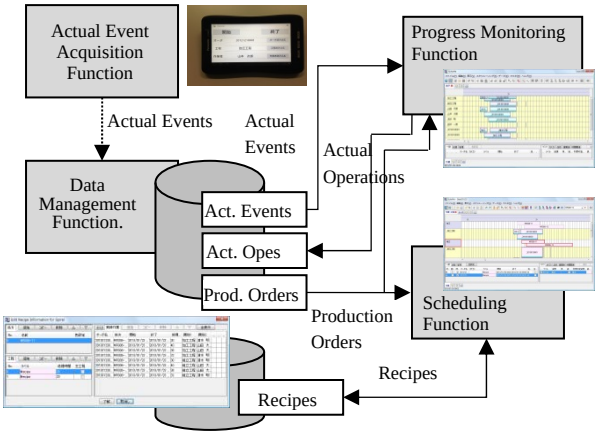

Figure 4: System Configuration

4.3 How to Use

(1) Getting started with acquisition of actual events

Firstly, the preparations for collecting actual operation data are made. For starting to use the system, it is important to extract event data for part of operations such as a portion only focused on the bottleneck process stage. Moreover, the fineness of actual event collection is not much small, and it minds not applying the burden of the collection to operators. And in order to collect event data, QR Codes of production order names, a process stage name, and an operator name, are prepared, and

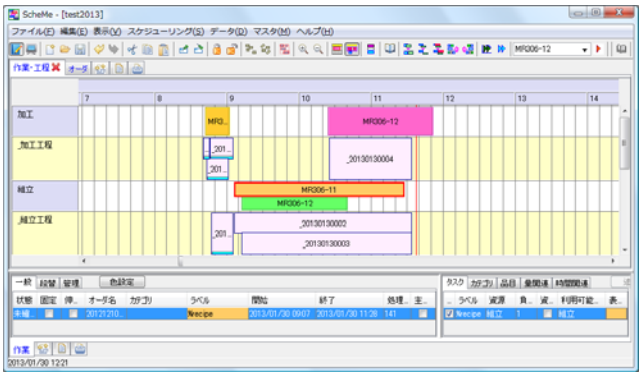

Figure 5: Overview of a Production Scheduling System

collection of event data is started by the actual event acquisition function. No information is given at the initial start-up of the progress monitoring function. However, after starting, the information on the vertical axis of a Gantt chart is automatically extracted from the attribute information included in events.

(2) Creating and updating recipe information with reference of actual operation data

Actual event information is saved in a database and it is referred to when generating the recipe information for scheduling. By registering recipe information, the required operations for order information are scheduled. The processing time specified by recipe is referred to make schedule of an operation. Various information, for examples, the variation in processing time, the delay time between operations with a precedence relationship and so on, can be recognized, and it becomes reference of renewal of recipe information. Furthermore, it leads to discovery of the problems of a production process, and can also become reference of rearrangement of a work procedure, kaizen of a production process and so on. When a new product is added, it is possible to add new recipe easily by referring to a recipe of the similar item which already exist, or referring to actual event information.

(3) Scheduling with production orders

After recipes are registered by (2), operations required by production orders will be scheduled. The scheduled operations for orders are displayed with actual operations as Figure 5. By displaying actual operation information with scheduled information, the situation of a production site can be recognized.

5. Conclusion

In this paper, the requirements for systematization of a production scheduling system were analyzed, and an example of the reference model for systematization which satisfies these requirements was shown. Moreover, the novel systemization approach based on the concept of the spiral-evolution is explained and overview of a production scheduling system for small and medium-sized enterprises using this concept was shown.

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Biography

Shigeru Fujimura is a Professor at Graduate School of Information, Production and Systems, Waseda University, Japan since April 2003. He received the B.E. and the M.E. degrees from Waseda University in 1983 and 1985, respectively. He also received the Dr. Eng. from the same university in 1995. He joined Yokogawa Electric Corporation in 1985 and worked until 2003. His research interests include Production Management, Production Planning and Scheduling, Intelligent Agent, Object Oriented Modeling and Business Process Modeling. He is member of IEEJ, IPSJ and IEEE.