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STUDY ON REALIZATION OF MULTISTAGE PSI MANAGEMENT FOR JAPANESE PROCESS MANUFACTURING INDUSTRIES

Xiaomei Qin and Zhen Liu*

Graduate School of Engineering
Nagasaki Institute of Applied Science
536 Aba Machi, Nagasaki 851-0193, Japan
s4021001@campus.nias.ac.jp; *Corresponding author: liu_zhen@nias.ac.jp

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Abstract. *In the process manufacturing industry, DX (Digital Transformation) movement with the aim of new development is on-going quickly. A new evolution is made in the industry from a broad perspective of supply chain optimization through information collaboration that goes beyond the boundaries of companies. It is important to create new approaches that data is centralized, and multilevel data is combined to solve the problem such as simulations of PSI (Production, Sales, and Inventory) management with data. The authors have been researching the application of the profitability-oriented S&OP (Sales and Operational Planning) to the Japanese manufacturing industry, and proposing a mechanism for linking PSI information among multiple locations including sales company, production center, and logistics distribution centers in real time and with monetary level management. By use of a planning example of pharmaceutical company with multidimensional data model, this study proposes an inter-process receipt and delivery planning solution for the process manufacturing industry.*
Keywords: S&OP, Multistage PSI, Data model, Demand planning

1. **Introduction.** In the process manufacturing industry, which handles chemical products, medicine, petroleum, metals, glass, minerals, etc., DX movement with the aim of new development is on-going quickly [1]. It is necessary to solve essential issues faced in the industry, such as the shortage of veteran engineers due to the declining birthrate and aging population, the realization of the solution can keep up with shorter product cycles, and create new added value by leveraging data.

Unlike the discrete manufacturing industry, the characteristic of the process manufacturing industry is that the production style is not fixed. The existence of various production patterns, such as production of make-to-stock, made-to-order, and individual made-to-order, makes the manufacturing process complex. Moreover, in order to manufacture products with market trend and respond to customer needs in detail, these manufacturing processes must be carried out efficiently. In addition, there are many types of recipe and method to produce a product, which depend on the condition of the raw materials; the detailed adjustments of recipes are required frequently. Due to putting pressure on costs, it is difficult to standardize production [2]. The requirements to manage inventory quality and expiration dates in real time are achieved through the integration of manufacturing and administrative processes with an ERP (Enterprise Resource Planning) system. From the perspective of ensuring profitability and continuous growth, although ERP can improve administration more efficiently, but it is insufficient. It is extremely important to grasp the difference between plans and actual performance in real time. When the need

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of simulation to find the timing of switching manufacture patterns occurs, it is essential to visualize receipt and delivery information during manufacturing processes.

Specifically, the process manufacturing industry is undergoing a new evolution, such as simulation of production, sales, and inventory. "Optimization of supply chains" through information collaboration beyond the boundaries of corporate is going rapidly [3, 4].

In Japanese manufacture industries, PSI management, formerly known as "manufacturing and sales adjustment" or "supply and demand adjustment", is undertaken between management and business departments such as production, sales, and logistics. PSI is an acronym for Production, Sales, and Inventory, and PSI management refers to management that coordinates these three parties. It is deeply rooted in Japan as a management method centered on quantity control for operations within a single business entity. PSI management is a mechanism similar to S&OP [5, 6]. However, since PSI management manages only the physical distribution quantities, the coordination between quantitative and financial targets does not work well.

PSI management is a field-driven, bottom-up management method that takes the opposite approach to S&OP. It is difficult for Japanese companies that tend to have bottom-up organizations, to introduce S&OP which is based on a top-down organization.

Unlike companies in Europe and America, which have strong management skills as their weapon, Japanese companies have strengths in workplaces that emphasize flexibility and accuracy. It is necessary to manage supply and demand in a way that respects production and sales front-lines. Therefore, a realistic response would be to make unique improvements to the PSI management in Japan and try to bring its performance closer to Western-style S&OP [7].

The authors have been researching the application of the profitability-oriented S&OP to the Japanese manufacturing industry, and proposing a mechanism for linking PSI information among multiple locations including sales company, production center, and logistics distribution centers in real time and with monetary level [7].

During the process up to the finished product in the production of process manufacturing industry, it is necessary to perform simulations to identify the impact on production due to excess or shortage of inventory of raw materials, etc., and to determine the optimal timing for switching production patterns. Thus, visualizing the number shifting of receipt and delivery in a series of processes is imperative [8], which means that multistage PSI management solution is a need to be completed. Pharmaceutical companies [9] required multistage PSI management solution to control their receipt and delivery planning smartly. However, there is no available software for such management currently. Thus, by use of a planning example of pharmaceutical company and multidimensional data model, this study proposes an inter-process receipt and delivery planning solution for the process manufacturing industry.

In this paper, first, authors describe research method and data model construction, then indicate how to apply the multistage PSI management solution to pharmaceutical industry, and provide a case study for the solution. In the last two sections, authors validate the benefit of case study results, and reach the conclusion of the proposal of receipt and delivery planning solution.

2. **Research Method and Data Model Construction.**

2.1. **Research method.**

On realization of multistage PSI management, the corresponding research approach was taken as follows.

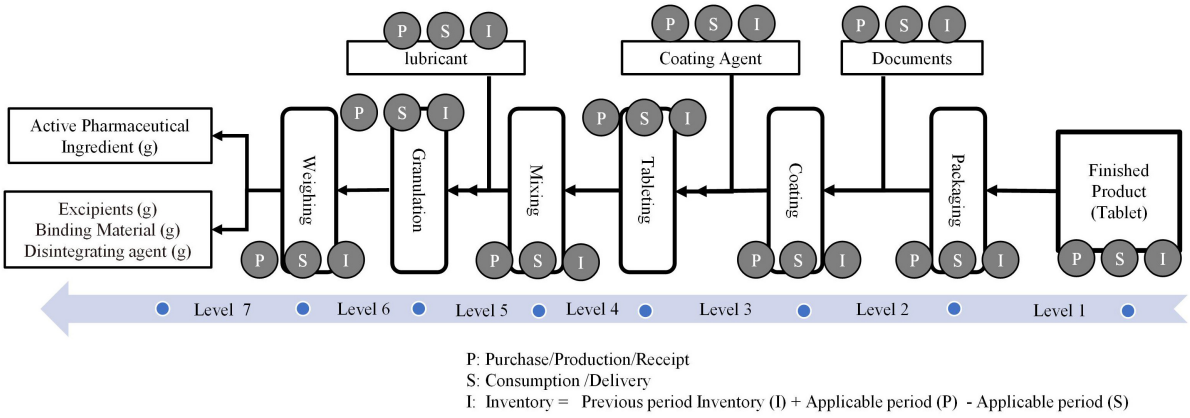

FIGURE 1. PSI structure (example of pharmaceutical production)

1) Selecting sample case

As shown in Figure 1, taking the general pharmaceutical process as an example, a series of receipt and delivery data from the input of active pharmaceutical ingredients/raw materials to the completion of final products such as tablets and powders is defined in the PSI format.

2) Building a data model

In order to visualize the intermediate transition process, constructing a multidimensional data model needs to be done, and an application of multistage PSI management needs to be developed, too.

3) Summarizing the benefit of case study

After verifying whether its own is compatible with the multistage PSI management typical sample provided from one customer, the benefits of the solution are summarized.

2.2. **Formation of multilevel PSI information.** To realize multistage PSI management, define P as the number of receipt, S as the delivery number for consumption, and I as the inventory in the stage as shown in Figure 1.

2.3. **Data model of multistage PSI management.** This study makes an assumption that multistage PSI data transition management will also be handled, along with data visualization in each process, which will be accomplished by use of a multidimensional data model [10, 11] based on CPM (Company Performance Management) software. In order to eliminate data redundancy management, there is another crucial point to make use of the function known as the "virtual dimension" or "replication dimension".

When product dimension is constructed, the items from active pharmaceutical ingredient to finished medicine are managed generally. Depending on the recipe and manufacturing method, intermediate products named at each stage are different. Taking these intermediate products uniformly as product dimension will make data model more simple and easy to use.

How to control the stages of multistage PSI management smartly plays an important role. A dimension named level is entered to control which stage PSI information is currently conducted. Levels 1 to 7 shown in Figure 1 are utilized in the case study.

The definition of relationship between parent and child products is another key point. Because a product has multilevel structure, it is a parent product, and sometimes it becomes a child one. Thus, creating only a data cube, which is composed of a parent product dimension and a child one, is very difficult to express the production process. Furthermore, on the viewpoint of data management, since the child product is also the

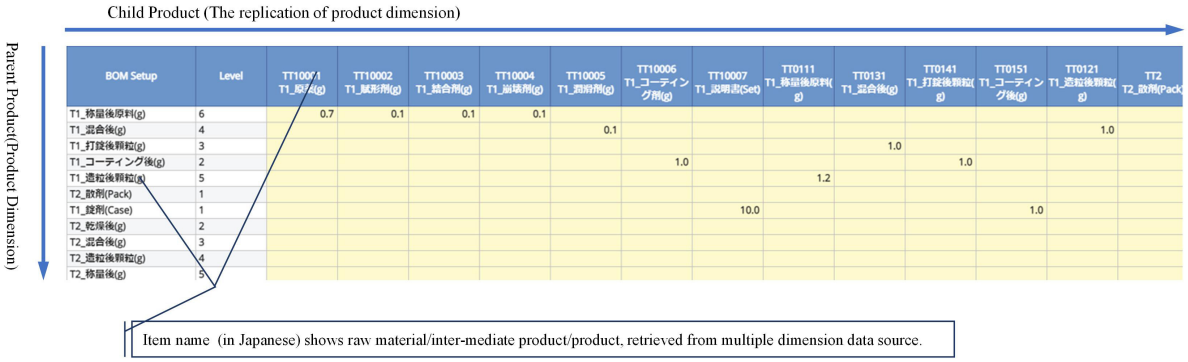

FIGURE 2. Multiple level data relationship

parent product at the next stage, storage and management of one product in two locations are redundant and undesirable. The use of the "replication dimension" is effective here. "Replication dimension" is a function that allows someone to refer to physically existing dimensional data like a copy. Based on the replication dimension, the relationship model between parent and child products is shown in Figure 2.

In this data structure, the ratio of child products required to produce the parent product at a certain stage, which locates at the intersection of the horizontal axis (child product) and the vertical axis (parent product), is stored. The vertical axis is the product dimension, and the horizontal axis is set as the replication dimension of the product dimension. As a result, when a parent product exists, it can represent the existence as a child product as well.

3. Application to Japanese Pharmaceutical Companies.

3.1. Profitability issues of Japanese pharmaceutical companies. Japan's domestic pharmaceutical industry, which has annual sales of 10 trillion yen, has been affected by the strategy of medicine price continuous reduction, and each pharmaceutical company is struggling to maintain profits [12]. As a result, the entire Japanese pharmaceutical industry has shifted to overseas sales, and most of the top manufacturers now rely on overseas sales for over half of their total sales. As the population aging, the burden of medical care on the population increases year by year, the government is also continuing to decrease medicine prices as a means of controlling medical costs. However, even if a new medicine is successfully developed and approved, there exists the risk that the research and development costs will not be returned, and the medicine will not be profitable. On the other hand, generic medicine tends to be less profitable because its price is kept at even lower levels. In the future, the biggest challenge for the pharmaceutical industry will be to utilize cutting-edge technology to gain competitiveness that can be used in a global scale [12, 13].

In this section, from the perspective of improving the profitability of Japanese pharmaceutical companies, a multistage PSI management system is devised to reduce costs when the company's business planning and performance actual results are controlled, and optimization of production is promoted as well. As demand changes over time due to production patterns in the pharmaceutical industry and seasonality, it is important to know when the best time is to switch production (e.g., switching from tablets to bag package), and where bottlenecks occur. In some cases, simulations may be necessary. This is also related to the rational raw material inputs and the reduction of management costs. As shown in Figure 3, there is a production route for tablets and bag packages, and it is a good tactics to consider when the planning is appropriate for recombination.

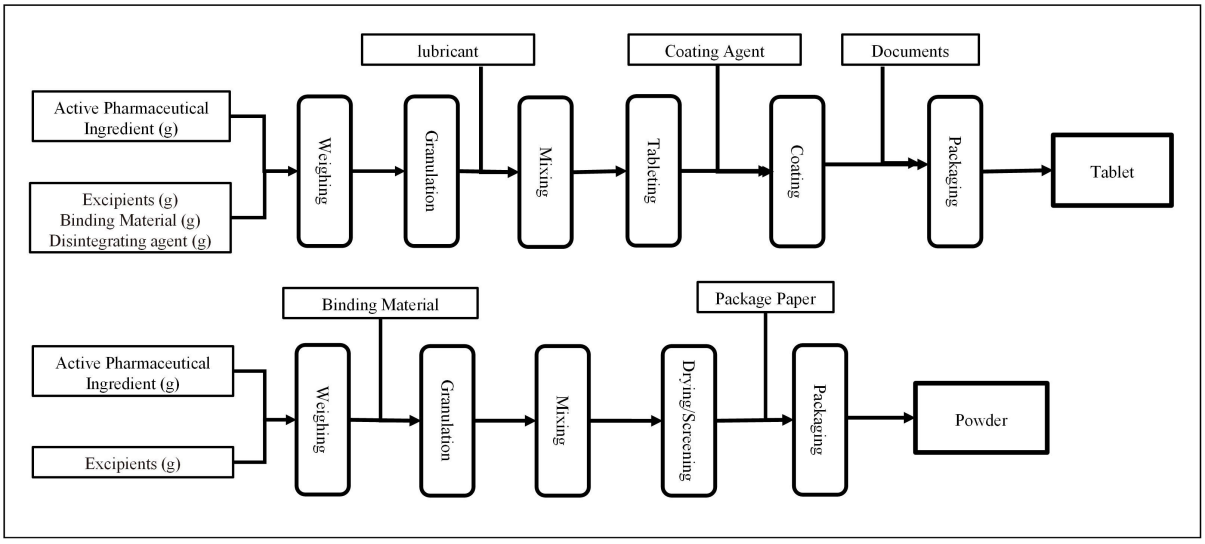

FIGURE 3. Pharmaceutical processes

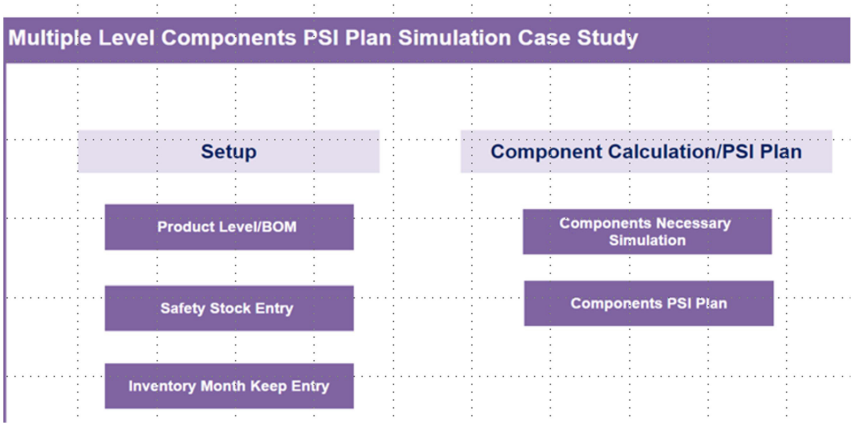

FIGURE 4. Overview of case study

3.2. **Case study of multistage PSI management.**

3.2.1. *Case study overview.* As shown in Figure 4, on the aforementioned production planning of the pharmaceutical company, the followings are requested to realize the receipt and delivery management during multistage processes:

1) Calculation of the required quantity of active pharmaceutical ingredients and intermediate products;

2) Visualization of multistage PSI

The corresponding application consists of the followings.

1) Basic configuration
   a) Setting each product and level
   b) Setting BOM (Bill of Material) rates between parent and child product
   c) Other settings such as standard safety inventory
2) Multistage PSI management
   a) Calculation of delivery quantity for components
   b) Visualization of multistage PSI management

3.2.2. *Case study details.* In this subsection, some detailed information is shown as follows.

1) Product level and BOM settings

A data cube, which consists of product, intermediate product and level dimensions, is used to manage BOM rates. The intersection of the horizontal and vertical axes shown in Figure 5 indicates the BOM rate. For example, 10 instruction documents are required for completion of 1 case tablet in Level 1.

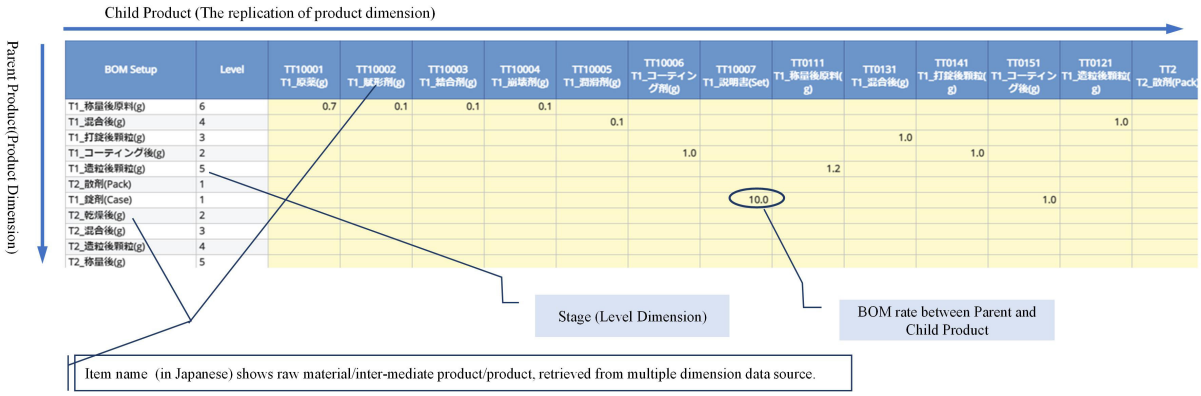

FIGURE 5. BOM rate setting by level

2) Calculation of component requirements

The monthly demand plan for tablets and powders is shown in Figure 6.

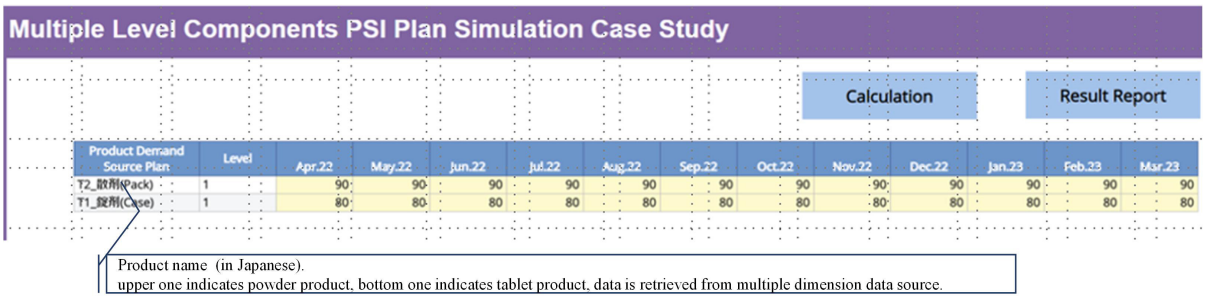

FIGURE 6. Demand planning for finished products

As shown in Figure 7, the requirements of each component including intermediate product or raw material based on the product demand forecast, BOM rate, and its own level are calculated.

3) Monthly based PSI results

Figure 8 shows the PSI (Purchase/Receipt P, Delivery for Consumption S, Inventory I) results of components, etc. at each month. The monetary amount of money is evaluated by multiplying the PSI quantity with the cost price of each product if needed. Purchase can be adjusted when the inventory status is under-stock or over-stock. As inventory and purchasing are controlled to optimal conditions, and the balance of production and demand is kept as well, the purpose of production cost reduction can be achieved.

4. **Validation.** Regarding the design of this case study system, the relationship between processing and data model is shown in Figure 10.

(1) BOM setup

The BOM rate is set by the dimensions of Month, Product, Product (replication) and Level, and then stored in the cube, which is called BOM_Ratio. This allows someone to

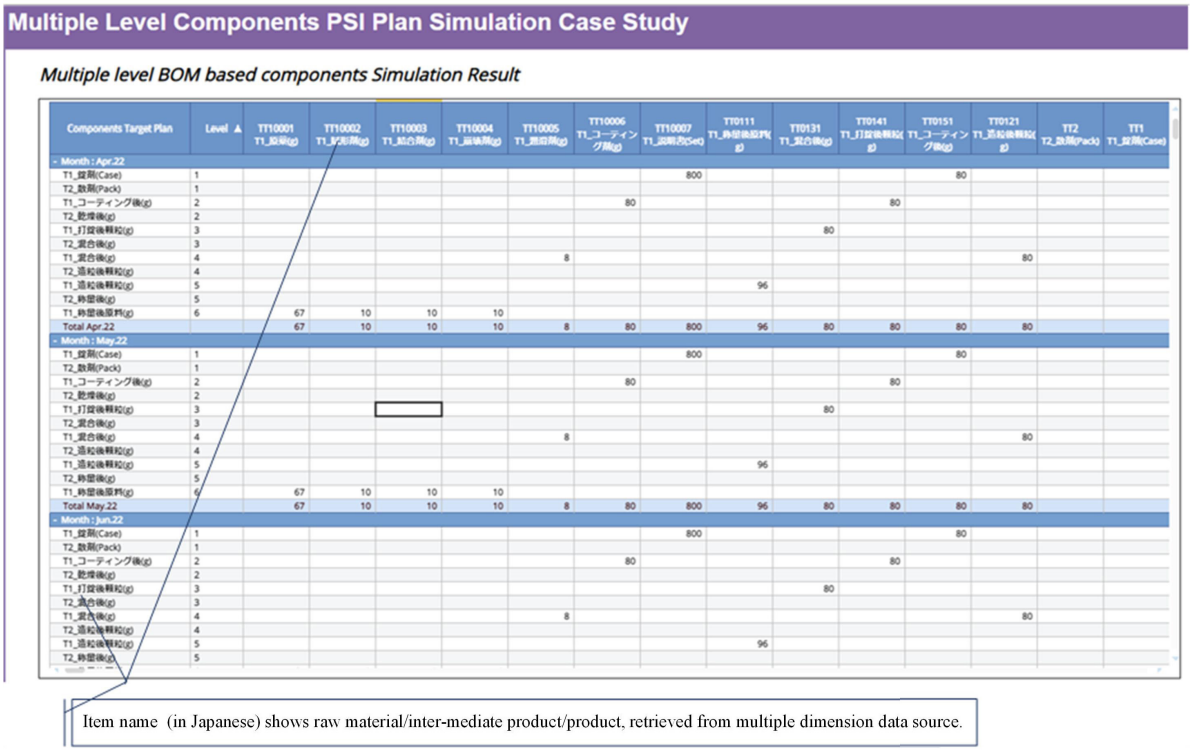

FIGURE 7. Requirement results of components

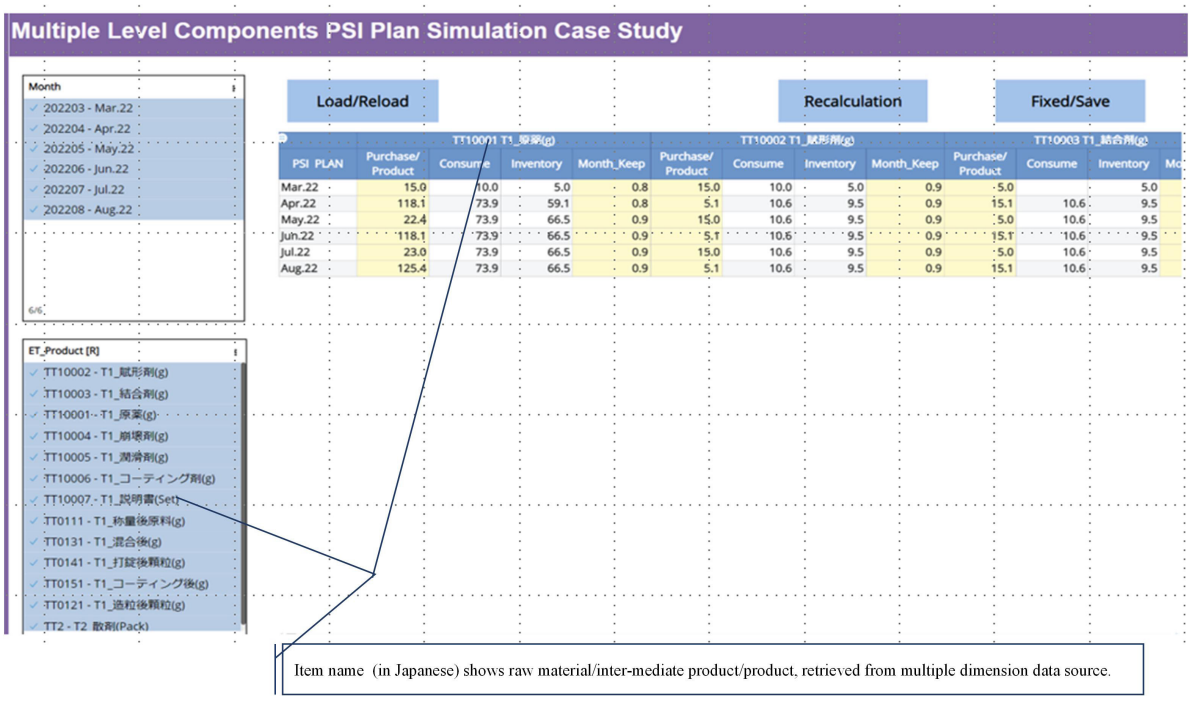

FIGURE 8. Multistage PSI management

understand the BOM rate between parent and child products at a certain stage. The cube is referenced in the following processes.

(2) Finished product production plan

This case study covers the finished products including pharmaceutical tablets and powders. The product demand plans are gathered from each sales company and assigned to

the plant. Thus, the production plan is formed finally. The production plan data is saved to a cube called Plant_Product_Plan, which is constructed by the dimensions of Month, Product and Plant.

(3) Multilevel calculation

The requirements (S) of raw materials needed at each stage and the intermediate product needed to delivery to the next stage are calculated by use of the BOM rate stated in (1) and the finished product production plan stated in (2). The calculation is started from the level_1 of the finished product, and the requirements for subsequent stages are also calculated sequentially. The calculation results are saved in a cube called Calculation_Result. Related inventory (I) at each stage is also updated.

(4) Multistage PSI plan

The quantities of P, S and I for each stage are determined based on (1), (2) and (3), and the PSI analysis can be done by month and stage. What-if simulation prediction becomes possible.

The application was verified against the test data shown in Figure 9, which was provided from one customer. Let us check how multistage PSI management can assist in product demand planning according to marketing change.

Assuming that this month is May, a trend of coronavirus infections heading into winter will be seen. Therefore, compared with the original plan, the quantity plan for tablet needs to be doubled from November to next March. The quantity plan for tablet shown

	【Materials】			【Granulation】			【Tableting】		
	AAA		(g)	BBB		(g)	CCC		(Tablet)
	Purchase	Delivery	Inventory	Production	Delivery	Inventory	Production	Delivery	Inventory
2019/03			1000						6000
2019/04	4000	3000	2000	300000	100000	200000	200000	177200	28800
2019/05		0	2000		100000	100000	200000	201500	27300
2019/06		0	2000		100000	0	200000	166800	60500
2019/07	4000	3000	3000	300000	100000	200000	200000	212000	48500
2019/08		0	3000		100000	100000	200000	156200	92300
2019/09		0	3000		100000	0	200000	228100	64200

FIGURE 9. Excel spreadsheet of PSI data

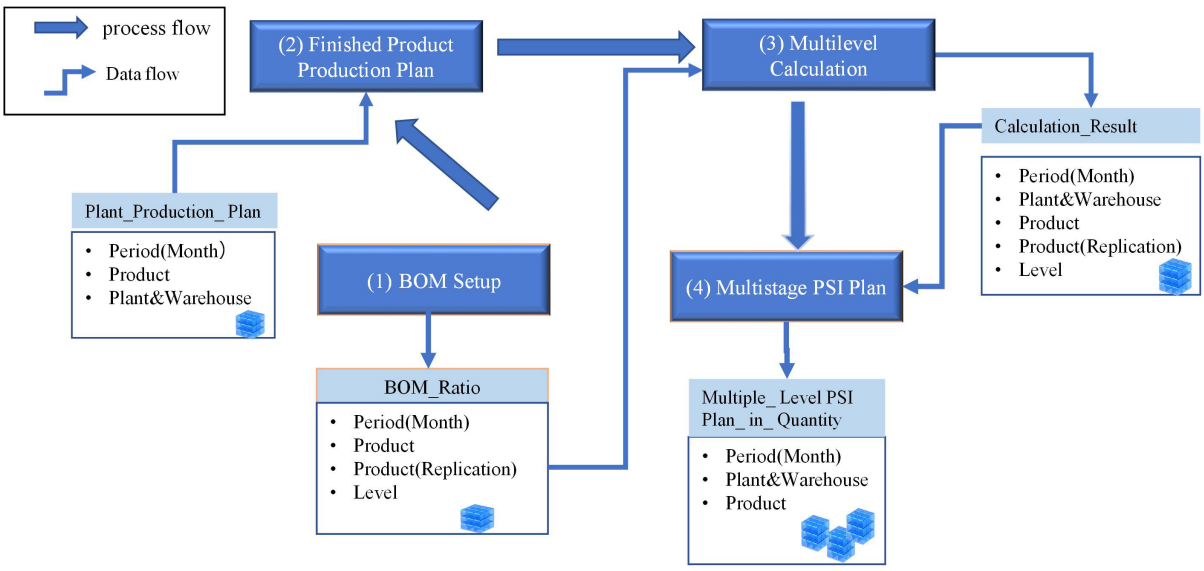

FIGURE 10. Data model of multistage PSI management

in Figure 6 is expected to be 180 cases each month starting from November. In this case, it is assumed that there will be a shortage of certain raw materials. For example, one 10-page document shown in Figure 5 is required for each case, paper needs to be provided. As it will be ready for production in advance before November, inventory risk is suppressed. As a result, there is no opportunity loss for winter sales.

By use of multistage PSI management during the production process in this way, inventory risks can be avoided, and opportunity losses can be minimized. Such optimization will be leading to increase sales revenue or decrease expenses for inventory management costs. In conclusion, gross profit is expected to increase as well.

5. **Conclusions.** This study describes how to perform receipt and delivery PSI advancement management for process manufacturing industry. Although the pharmaceutical industries are chosen as the case in Japan, the study results can be extended to other process manufacturing industries easily.

Regarding receipt and delivery planning within production processes, visualization for each process can be performed even on ahead of ERP planning. Monitoring can be realized whether receipt, delivery, and inventory for each stage are optimal. What-if simulation of switching production pattern can be completed when the seasonal trend comes, and the timing of purchase plan from third-party suppliers is also possible controlled.

The method on how to create receipt and delivery PSI management improves operational planning to a sophistication level, and can be considered to be valuable as a reference. Furthermore, this study will help IT vendors implementing DX to promote the generalization of multistage PSI management in Japan as well.

In the future, from the perspective of maximizing corporate value, optimization of operation planning is one key point. Data collaboration such as linkage of the operation data with supplier system, and linkage of PSI data with customer management system, needs to be extended.

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Author Biography

Xiaomei Qin received the B.Sc. degree in Applied Mechanics from Beijing Institute of Technology, China, 1989; and currently she is doing research in Department of Integrated Systems Engineering, Nagasaki Institute of Applied Science as Dr. degree course. Her main research interests include company performance management (CPM), business intelligence (BI) and data transformation (DX), especially targeted on S&OP/PSI management in Japan. She is a member of Japan Logistics Society. Ms. Qin is currently a Vice President of Eduscience Research Institute Ltd. as well. She has led and joined many research projects for manufacturing or financial service industries, etc.

Zhen Liu is a professor of Faculty of Applied Information Technology, Graduate School of Engineering, Nagasaki Institute of Applied Science, Japan. He respectively received the B.E. and M.E. degree from Jilin University of Technology, China, and the Ph.D. (Information Science) degree from Tohoku University, Japan. He was an associate professor in Jilin University, China, between 1982 to 1994, an assistant in Tohoku University, Japan, between 1998 to 2000, and an associate professor in Nagasaki Institute of Applied Science, Japan, between 2000 to 2005. He has been in the present position since 2005. His current research interests include big data and data mining, cyber security, welfare engineering, blockchain and artificial intelligence. He is a foreign member of The Engineering Academy of Japan (EAJ), a member of IEEE Computer Society, The Japanese Society of Artificial Intelligence (JSAI), The Institute of Electronics, Information and Communication Engineers (IEICE), and The Information Processing Society (IPS).