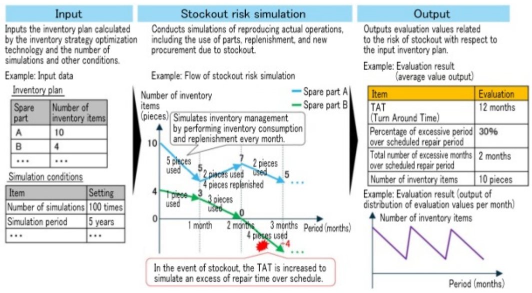
Inventory Strategy Planning Technology to Reduce Repair Time



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In our MRO business, which performs periodic maintenance, repair, and overhaul of sold products, delays in parts procurement may constitute a risk of prolonged repair periods, resulting in a disruption of customers' business operations. Therefore, it is required to have a reliable system in place at all times. On the other hand, however, products may consist of hundreds of thousands of parts or more, and it is not realistic to keep a huge level of inventory at all times.

To solve this problem, we have developed an optimization calculation technology for parts inventory level in our MRO business and implemented it as an inventory strategy planning system. This enables the prevention of prolonged repair periods due to stockout. This report describes the outline of the developed technology.

1. Introduction

Mitsubishi Heavy Industries, Ltd. (MHI) is engaged in MRO business for many of its products. In cases where parts are supplied by the customer, we do not need to forecast the demand for parts or manage inventory, but the customer needs to forecast and arrange for parts that will be needed in the future based on a full understanding of the product condition. Therefore, in recent years, as typified by PBL (Performance-Based Logistics) contracts, repair planning has been not performed by the customer but by an MRO provider such as us, who comprehensively performs product overhaul, procurement of parts for repair, and repair work, and provides a one-stop service that guarantees KPI (Key Performance Indicators) including operation rate, etc. We also value the merits and demerits of such services.

Under this type of contract, while our discretion in the MRO business expands, we bear risks of cash flow deterioration due to excess inventory or of prolonged repair periods due to stockout. So, it is important to balance these risks and determine the optimal point of the inventory level. Therefore, we have developed a technology to derive an inventory strategy (parts inventory plan) for operating the business with minimum risk, using optimization calculations, and a business system that can automatically formulate inventory strategies using this technology.

2. Number of inventory items optimization technology for MRO business

2.1 Outline and characteristics of MRO business

There are various contract types in MRO business as follows: (1) a contract type in which parts are supplied by the customer and the MRO service provider performs repair work only; (2) a contract type in which the MRO service provider performs repair work as well as the procurement of parts necessary for the repair work, and (3) a contract type in which the MRO service provider provides services to guarantee KPIs such as operation rate, the number of inventory parts of a product, etc. In recent years, customers have tended to expect and introduce one-stop contracts such as the contract types (2) and (3), instead of the contract type (1), to concentrate more on their core

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business. In the case of the contract type (1), the customer procures parts from each related company and then requests repair work to an MRO service provider individually, which makes it difficult to make an efficient repair plan since the parts procurement status cannot be taken into account, resulting generally in a tendency of a prolonged repair period (the period between the occurrence of a product failure and its return to the customer after repair). On the other hand, in the case of the contract types (2) and (3), the MRO service provider proactively performs parts procurement and repair work on a one-stop basis, which allows it to plan the repair proactively and results in the expectation of a shorter repair period. However, in these contract types, the MRO service provider bears risks of excess/stockout inventory, and therefore needs to have an inventory strategy (part inventory plan) to minimize these risks.

2.2 Number of inventory parts optimization technology

To develop an inventory strategy, we defined the probability of being able to allocate inventory without stockout (hereafter "fill-rate") for the sub-parts to be managed that constitute a product (assembly) subject to MRO, and set up two optimization problems: one to find the minimum number of inventory parts with the target fill-rate satisfied, and the other to find the number of inventory parts with the maximum fill-rate that adheres to the procurement constraints.

In general, the calculation of the appropriate inventory level is based on the assumption that inventory consumption follows the assumed distribution, and is calculated by adding the number of inventory parts consumed between a part order and the next part order and the safety number of inventory parts to prevent stockout even if demand and lead time fluctuate slightly. However, products handled in the MRO business often have the characteristic that it is impossible to know when they will fail, and the assumed distribution of replacement frequency and consumption of sub parts cannot be formulated, which makes it impossible to calculate an appropriate number of inventory parts with the aforementioned method. Therefore, we developed a method that can realize an inventory plan with the minimum number of parts to be procured based on the fill-rate and an inventory plan with the maximum fill-rate.

The method developed this time was realized by calculating the replacement ratio from the cumulative distribution (see **Figure 1** right) of the replacement ratio (plotting the probability of the replacement occurring for each number of replacement parts (see Figure 1 left)) of each sub part, which is compiled based on past maintenance records.

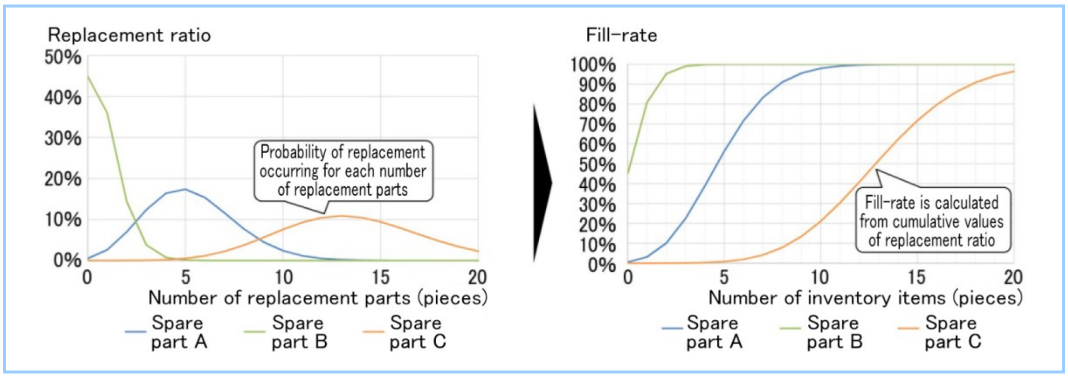

Figure 1 Calculation example of fill-rate of spare part

2.2.1 Method to find minimum number of inventory parts with target fill-rate satisfied

This method calculates an inventory plan that minimizes the number of parts to be procured while adhering to the constraints (**Table 1**) such as target values of the fill-rate of the assembly. The feature of this method is that the number of inventory parts that minimizes the number of parts to be procured is calculated from a combination of possible inventory levels by considering the fill-rate of all types of sub parts that constitute the assembly, instead of calculating the inventory level from the fill-rate of each sub part. This method reduces the number of parts to be procured more than the conventional method that calculates the required inventory level for each part individually.

Table 1 Constraint example

No.	Constraints
1	The fill-rate of a sub-part shall be based on the replacement ratio calculated from past actual results.
2	The fill-rate of an assembly (the product of the fill-rate of each sub-part) must not underrun the target value.
3	The inventory of a sub-part to be procured must not exceed the capacity of the warehouse.

2.2.2 Method to find number of inventory items with maximum fill-rate while adhering to procurement constraint

This method calculates the number of inventory parts that maximizes the fill-rate of the assembly while adhering to constraints such as inventory procurement limitations (**Table 2**). The characteristic of this method is that the optimization calculation using the method developed in Section 2.2.1 is repeated until the procurement limit is reached in order to maximize the fill-rate of the assembly. **Figure 2** shows the flow of this method. After the inventory plan is calculated, if the total procurement cost of parts in the calculated plan underruns the cost limit, the target fill-rate of the assembly is increased and the inventory plan is calculated again using the method described in Section 2.2.1. This calculation is repeated, and terminated when an inventory plan that exceeds the cost limit is calculated, to obtain the immediately preceding inventory plan, which is below the cost limit and has the maximum fill-rate of the assembly at the same time.

Table 2 Constraint examples

No.	Constraints
1	The fill-rate of a sub-part shall be based on the replacement ratio calculated from past actual results.
2	The inventory procurement cost must not exceed the cost limit.
3	The inventory of a sub-part to be procured must not exceed the capacity of the warehouse.

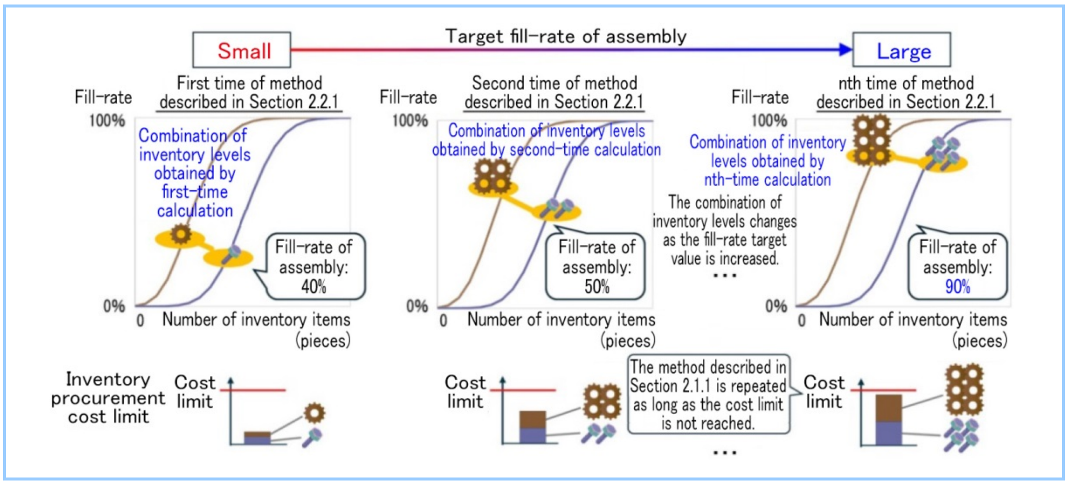

Figure 2 Flow of optimizing calculation

2.3 Stockout risk simulation technology

We developed a stockout risk simulation technology that takes into account variable factors that may occur in repair business to quantitatively evaluate the adequacy of the inventory plan developed in Section 2.2. This simulation simulates several years of the process to consume the inventory by stochastically generated repairs and parts replacement every month with respect to the calculated inventory plan, and to replenish the inventory based on the procurement lead time of the sub part. By conducting this simulation several hundred to several thousand times, trends in the repair lead time and stockout occurrence ratio simulating various failure timing are indicated (**Figure 3**). The output evaluation results allow for the confirmation of the average values of the evaluation shown in **Table 3**, as well as the monthly trends.

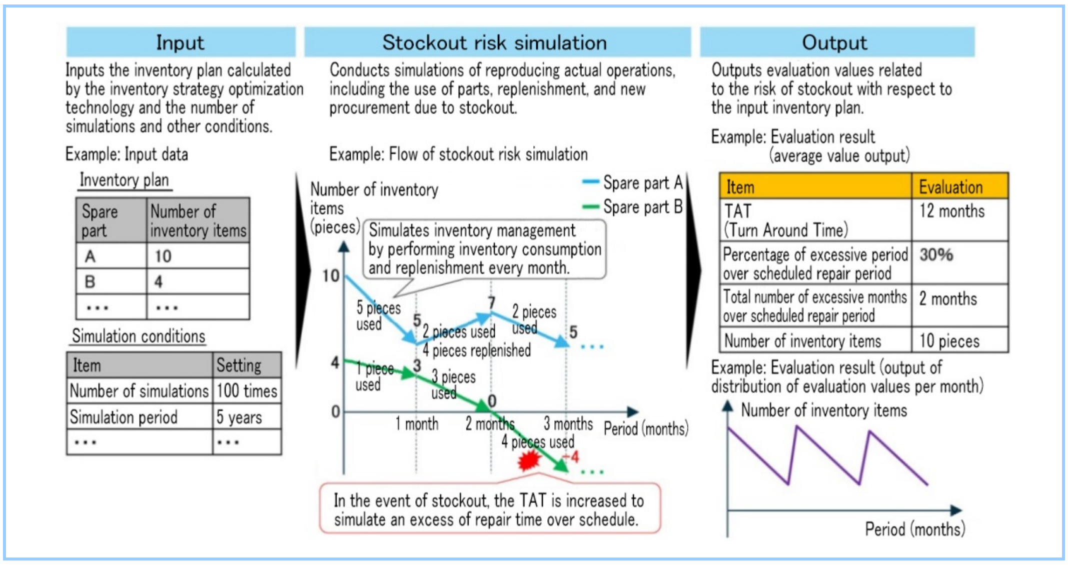

Figure 3　Stockout risk simulation flow

Table 3　Major evaluation values in stockout risk simulation

No.	Evaluation value	Description
1	Repair lead time	Represents actual time required to perform repair relative to period from its request to completion (unit: months) Calculated from total of following four periods ・Period for overhaul inspection ・Period from completion of overhaul to ordering of sub-parts ・Period for procurement of sub-parts ・Period for repair and assembly
2	Percentage of scheduled repair time exceeded	Represents percentage of TAT* (time from request to completion of repair) exceeding scheduled repair time for each simulation period
3	Total number of months exceeding scheduled repair period	Represents total period (in months) that TAT* exceeded scheduled repair period for each simulation period
4	Inventory level	Represents part inventory level (inventory monetary value) for each simulation period

* TAT: Turn Around Time

2.4　Inventory strategy planning system for MRO business

To make the technologies described up to Section 2.3 widely applicable to MRO businesses, we developed a business system that automates data input/output for each calculation process and uses a Web browser as the user interface. **Figure 4** shows the usage flow of the developed system. The system consists of two phases: one to perform inventory optimization calculations as described in Section 2.1, and the other to simulate the risk of stockout as described in Section 2.2. After the product data necessary for the calculations are registered, the system performs inventory optimization calculations given the constraint conditions assumed in the MRO business and tentatively determines the inventory strategy. Then, based on the inventory strategy, the system performs simulation calculations several hundred to several thousand times to check the calculation results. The results of the simulation calculations are indicated in a graph as shown in **Figure 5**, allowing determination of the risk of stockout occurring against the inventory strategy and the relationship with the repair period. Based on these results, inventory strategies can be determined.

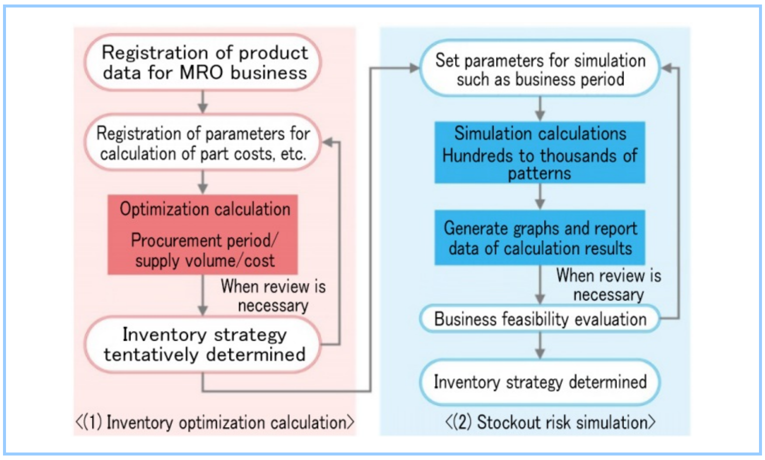

Figure 4 Usage flow of inventory strategy planning system

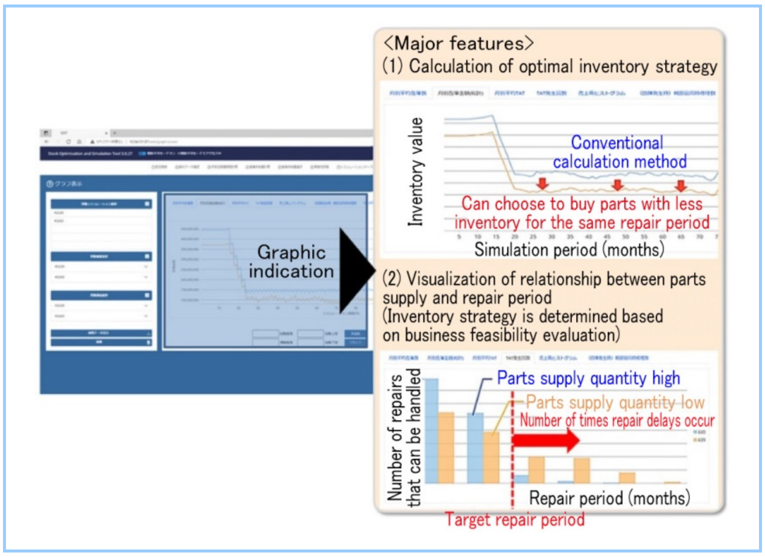

Figure 5 Graphical representation of inventory strategy planning system

2.5 Effectiveness verification

To verify the effectiveness of this technology, we calculated an inventory plan for a case in which 15 units of a product consisting of approximately 200 types of parts are repaired per year, and quantitatively evaluated the plan in terms of the procurement cost and fill-rate. We compared the inventory plans for 16 types of parts to be replaced among the component parts between those calculated by the conventional method and those calculated by the inventory strategy planning system (**Figure 6**).

The results showed that the method to find the minimum number of inventory parts with the target fill-rate satisfied as described in Section 2.2.1 reduced the inventory amount (parts procurement cost) by 21% and that the method to find the number of inventory parts with the maximum fill-rate that adheres to the procurement constraints as described in Section 2.2.2 could increase the fill-rate of the assembly by 5% within the same cost limit. In this way, the effectiveness of the developed technology was confirmed.

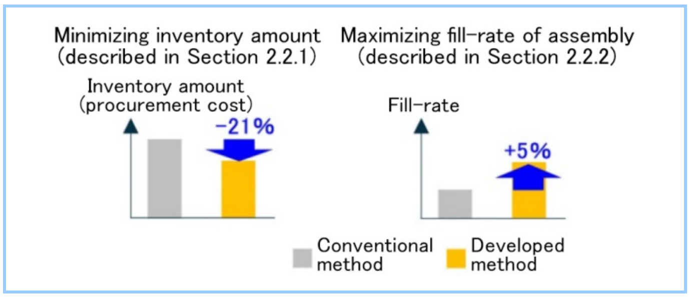

Figure 6 Results of effectiveness verification of number of inventory items optimization technology with respect to inventory amount (procurement cost) and fill-rate

3. Conclusion

This report introduced an optimization calculation-based technology to obtain an inventory strategy (parts inventory plan) to minimize the risk of excess/stockout inventory in the case where we comprehensively perform repair planning, overhaul inspection, parts procurement for repair, and repair work to shorten repair time in our MRO business, and showed through simulation calculations that this technology is capable of calculating the number of inventories to reduce the risk of stockout and to improve the overall equipment fill-rate, compared to the conventional method. This report also introduced a business system that implements this technology and enables the planning of inventory strategies. Going forward, we will gradually expand our MRO business and utilize this technology as a tool to build win-win relationships with our customers.

References

(1) Yo Morimoto et. al, Inventory Strategy Planning Technology Supporting Expansion of MRO Business, Mitsubishi Heavy Industries Technical Review Vol.59 No.1 (2022)