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Technology

Business Reform and DX in Raw Material Procurement

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Abstract

In the steel production process of Japan, raw materials such as iron ore and coal are imported from overseas. To improve business competitiveness, it is important to respond quickly to external changes such as overseas conditions and weather. Nippon Steel Corporation has been promoting DX through various data linkage and optimization of ship allocation and transportation in order to improve its ability to respond to changes in raw material procurement. In this paper, we report on DX initiatives in raw material procurement.

1. Introduction

In the iron and steel production process, raw materials such as iron ore, coal and so forth are imported from overseas, and various steel products such as those used for automobiles, ships, bridges, household electric appliances, etc. are respectively produced through the process of blast furnace, converter, continuous casting, rolling, annealing, surface treating and so forth (**Fig. 1**). The total management from the procurement of raw materials to the production and sales is important for stably manufacturing and supplying steel products that satisfy the quality demanded by customers. The total amount of iron ore and coal (raw materials) consumed by the entire Japanese steel industry reaches as high as several hundred million tons per year, and all of it is procured via import from overseas. Currently, in addition to the large changes in the raw material prices as shown in **Fig. 2** affected by the overseas conditions, transportation is also frequently affected by the deterioration of weather. Under such circumstances, in order to supply high quality steel material products stably, the control of the material procurement supply chain is becoming increasingly important.

To enhance its response capabilities to changes, aiming at reform to data-driven business by utilizing digital technologies, Nippon Steel Corporation has continued to promote business reform and DX by linking various kinds of data and optimization of ship allocation and transportation. Hereafter, we introduce how the business reform and DX in the material procurement business has been tackled.

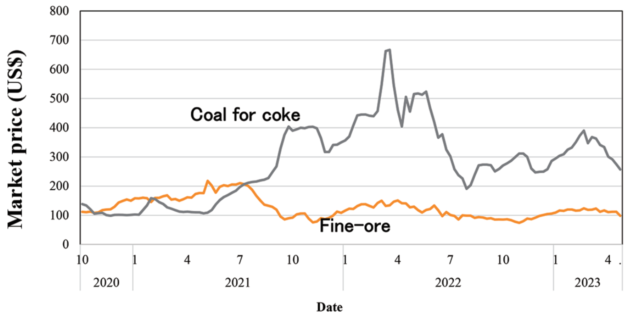

Fig. 2 Changes in raw material prices

Fig. 1 Flow from raw material procurement to steel production and sales

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2. Improvement of Raw Material Ship Allocation Planning

2.1 Raw material ship allocation business

The entire amount of iron ore and coal (raw materials) consumed by Nippon Steel is procured from overseas via import. In the iron and steel production, coal is smothered to coking coal in a huge coal coking furnace. Coke is charged into a blast furnace together with iron ore, and by melting them under a high temperature, and by reducing the oxidized iron contained in iron ore with coke under a chemical reaction, iron (pig iron) containing 4 to 5% carbon is produced. The pig iron is composition-adjusted variously, and processed to final products such as sheet, plate and billet.[1] Since a huge amount of raw materials, pig iron, semi-products and products are handled, the logistics generated daily are massive.[2] In order to satisfy the customers' quality demand, and to maintain high quality of products, the adjustment of the steel material chemical compositions is essential, and for the realization thereof, the formulation of a production plan and logistic plan in the raw material transportation and in the production process plays an important role.

Against such a background, Nippon Steel has continued to tackle the optimization of raw material procurement and logistics, aiming at the corporate wide optimization and sophistication of production and logistics pertaining to raw materials.

The objects of such initiative cover a wide range from the head office to steelworks (**Fig. 3**). The objects for the head office are determined as the general framework in the form of yearly and quarterly plans in pluralities of steelworks, considering the merit from the corporate wide viewpoint. Under the plan so determined, respective steelworks are structured to formulate daily plans so that the daily business under such general framework can be conducted. Specifically, the objects of the head office are: ① ship chartering planning to secure ships for the transportation of raw materials, taking into account the corporate wide amount of tapping of iron (production amount of pig iron) and the amount of production of coke, ② ship allocation planning to the port of loading to determine the port of loading (iron ore mine, coal mine) of secured ships, taking into account the amount of purchase, ③ ship allocation planning to the port of unloading to determine the allocation to the steelworks of the ships with raw materials loaded at the port of loading and ④ raw materials blend planning which determines the blending ratio of the raw materials to be consumed, taking into account the amounts of raw materials thus transported, blast furnace tapping and coke production.

Furthermore, based on the ship allocation plan and the blend plan so determined by the head office, the steelworks needs to formulate the storage yard allocation plan in the huge material yard for the temporary storage of the unloaded raw materials. They are: ⑤ yard allocation planning which determines the early raw material receiving and storage yard, and the yard for raw material delivery, ⑥ receiving planning which determines the starting time of the operation of the unloading and transportation facilities based on the yard allocation plan, ⑦ delivery planning which determines the starting time of the operation of the transportation facility at the delivery site (silo type storage tank and so forth) based on the yard allocation plan and ⑧ formulation of blend plan which adjusts the blend plan on a quarterly and monthly basis determined by the head office function. For these objects, a system has been developed which realizes the central control of the information of the raw material demand and supply by the head office and steelworks in an integrated way, and together with optimization technology has been introduced to the respective objects.[3]

Hereafter, as an example, the optimization system of the raw material transportation ship allocation[4] of a business of the head office, and its application to actual business are explained.

2.2 Optimization system of raw material transportation ship allocation

2.2.1 Business content

This business determines the ship allocation plan at the port of loading and unloading of the respective ship based on the chartered ship allocation information (type of ship, amount of load, current position), charterable ship information, contract amount of purchase, and the respective steelworks raw material consumption information, while abiding by the restricting conditions in securing inventory. As the cost of transportation by ship differs depending on the contract ship type, type of contract and the pattern of the route to the ports of call, it is possible to suppress cost by optimizing the fleet organization and the transportation route.

However, under the situation wherein the transportation from China with a short term of transportation being mixed with the

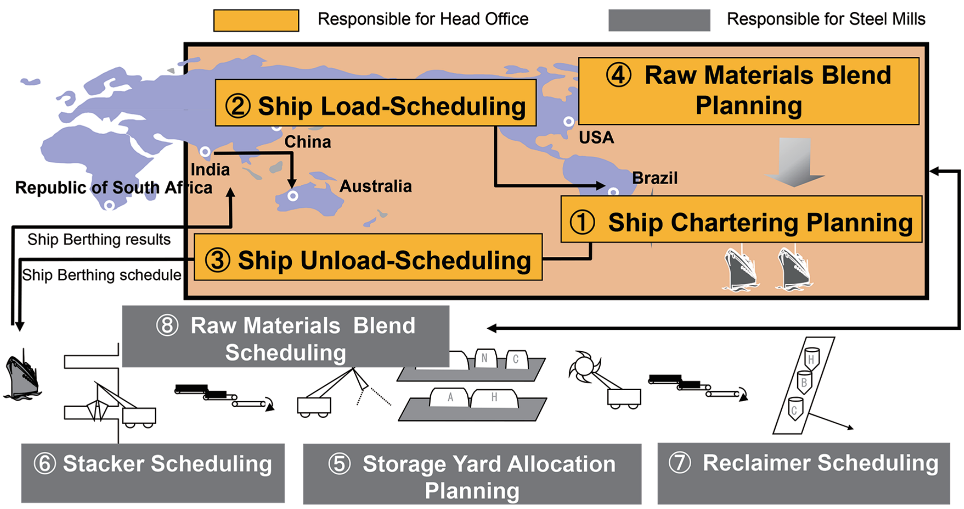

Fig. 3 Target of planning, scheduling and logistics related to raw material

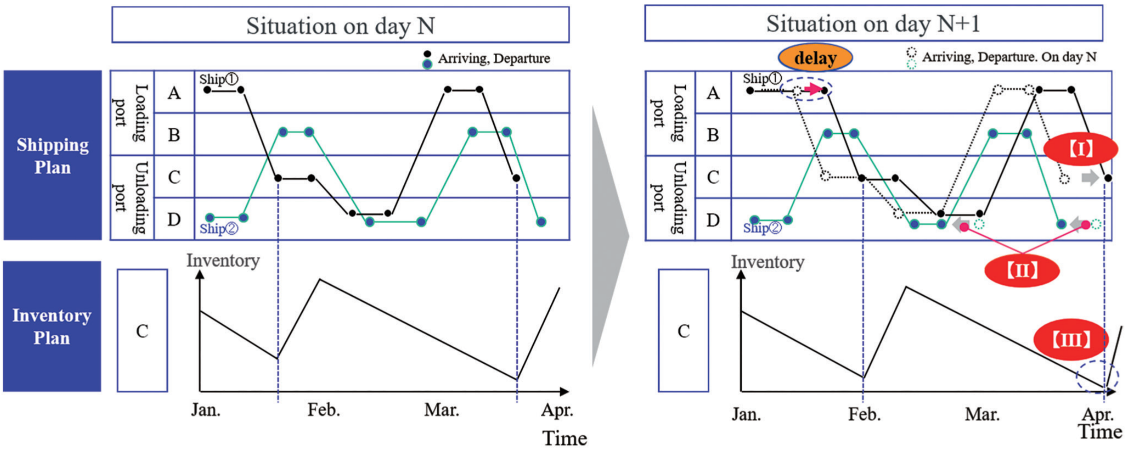

Fig. 4 Effects of change in shipping plan

transportation from Brazil with a long transportation term, it is not easy to optimize the ship allocation plan six months in advance, taking into account the movement of the ship on an hour by hour accuracy basis at the unloading berth, while avoiding the shortage of inventory in the steelworks.[5, 6]

One of the features of the business of raw material demand and supply is that the scope of influence of a change in a plan spreads to time and physical distance respectively. In a simple example as shown in **Fig. 4**, the ship allocation planning to the two loading ports A and B and the two unloading ports C and D is discussed. For ship ① staying at loading port A and scheduled to depart on day N, when the departing schedule is changed to N+1 day, not only its arrival at the port of unloading C steelworks is delayed, but also the arrival at the next D steelworks and furthermore, the next port of A of loading is also delayed (Influence【I】). Furthermore, for ship ② which has been operated according to the plan on day N, the schedule at the unloading D steelworks needs to be changed (Influence【II】). Due to Influence【I】, the possibility of a shortage of inventory reveals itself at C steelworks in April (Influence【III】). Even in the case wherein the numbers of ports and ships are limited, it is known that even one change will exert its influence in a wide range on time, distance and the amount of inventory in the port of steelworks. In the actual ship allocation planning, the numbers of ports and ships increase, and a function which covers all of such influences and optimizes them is required.

2.2.2 Scheduling function structure

In formulating a long-term plan, the element of the combinations of ports and ships and simultaneous consideration of the influence on the amount of inventory cause a problem from the viewpoints of computational scale and time. Upon formulating the three-month term ship allocation plan, based on the assumption of 10 unloading sites, 3 brands and 200 ships, there are 10^{760} unloading patterns, and the larger the number of brands, the larger the computational load. To cope with the huge amount of such conditions, a computational system has been constructed which is divided into the long-range decision hierarchy which determines the general framework on a long-term basis, and into the detailed operation decision hierarchy which precisely optimizes the port entrance and departure time schedule based on the information fixed as a result of the decision of the said general framework (**Fig. 5**). Furthermore, by dividing the formulation period based on the time axis in each hierarchy, the solution to the problem within a limited time which has remained insolvable in the past has become possible with the distinctively developed technology which links mathematical programming and simulation in the hierarchical dividing term, and repeats it in the respective hierarchies.

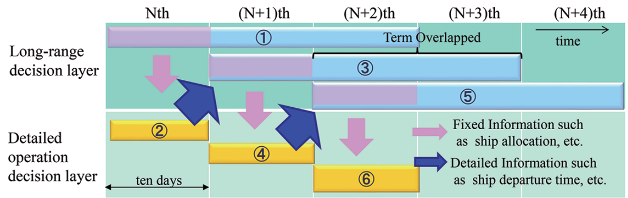

Fig. 5 Overview of the hierarchical dividing term and moving horizon algorithm[4)]

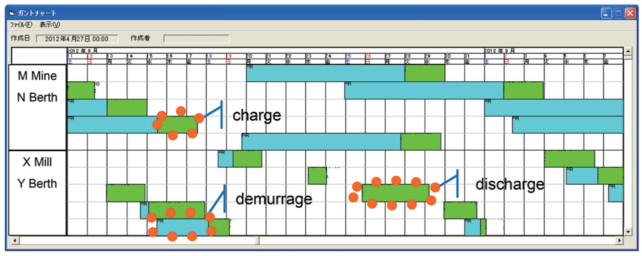

Fig. 6 Example Gantt chart of a scheduling result

2.2.3 Result of formulation

As an example of formulation, a Gantt chart of a scheduling result is shown (**Fig. 6**). At the port of unloading, ship demurrage is short, and smooth entry to port was realized (demurrage at the port of loading is given as a designated condition). Furthermore, by increasing the ratio of large ships that exceed a Capesize carrier calling at only one port for unloading, owing to the reduction of the extra charge incurred due to unloading at multiple of ports, reduction of the transportation cost has been facilitated.

2.3 Application to business

2.3.1 Evaluation index in formulating plan

Although various efforts for developing optimization systems of ship allocation planning and various production planning have been made to date, in the application to actual business, a large discrepancy is seen with the result of the adjustment by persons in charge in the business of actual ship allocation, which sometime remains a problem in actual application. Two factors of “uncertain evaluation parameters in formulating plan” and “insufficient restricting conditions (given conditions)” are enumerated. In the development of this time, in order to clarify the evaluation index, an evaluation formula has been developed which defines the index based on the plan formulated by prior persons. In defining indexes, the best value (or ideal value) of each item is rated as 5, the average value of the plan formulated by persons is rated as 3, and the actual worst value is rated as being in the neighborhood of 0 (**Fig. 7**).

Each index value is represented on a spider chart (**Fig. 8**), in which the conditions improve as they go further toward the outside, and a plan is judged as exceeding the level of the plan formulated by persons when the index value becomes 3 or higher. With the evaluation based on these indexes as standard, through study on the addition and/or releasing of the various restricting conditions (predetermined conditions), improvement of the ship allocation schedule optimization system is expected. Furthermore, even when a disagreement takes place as to the restricting condition due to the change in the external circumstances, by following this index, the evaluation of the healthiness of this optimization system is possible.

2.3.2 Effect in application to business

Owing to the setting of evaluation indexes, the addition of setting of various predetermined conditions, and the adjustment of the optimization system, application to the planning work has been made possible, thus reducing the planning work hours by 70% (**Fig. 9**). It has also become possible to formulate an optimized plan promptly when a change occurs in the predetermined conditions like the change in the production amount.

Furthermore, as the simulation by inputting the conditions of the cases sorted according to the production amount and/or the amount of the raw materials has been enabled, it is possible to use the system to grasp the extent of the influence when a plan is changed.

Thus the application of the optimization system to business and the utilization of the simulation function could contribute to the improvement of the raw material transportation efficiency by 10% compared to that of the past.

3. Enhancement of Information Exchange Frequency through Linkage with Ship Company Information

In Nippon Steel, for the control of the allocation of the ships engaged in the maritime transportation of raw materials such as iron ore and coal, a system which enables the capture of the navigational information on a real time basis was constructed, and its operation was started in May, 2023. In the navigational control of the inbound import raw material carriers, so far, due to the influence of weather, sailing days and/or lay days varied, and accordingly, review at appropriate timings of the navigational plan was necessary. By grasping the most recent navigational information of the inbound import raw material carriers, and by linking the information with Nippon Steel’s demand and supply control system, prompt decision-making based on the most recent navigational schedule and/or the forecast of the raw material inventory has been enabled.

Upon constructing the system, the system is linked to the information supply platform “Lighthouse” of Mitsui O.S.K. Lines, Ltd. pertaining to maritime transportation (**Fig. 10**). The system is structured to manage the data of the shipping company which operates

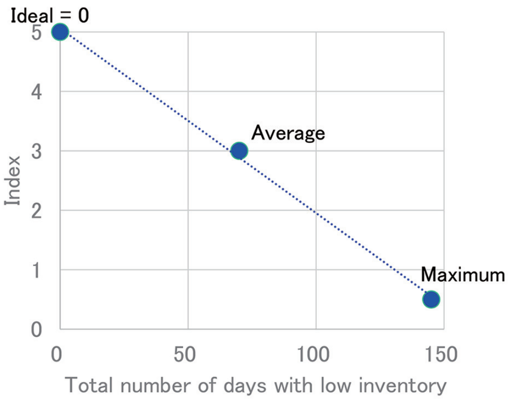

Fig. 7 Examples of index

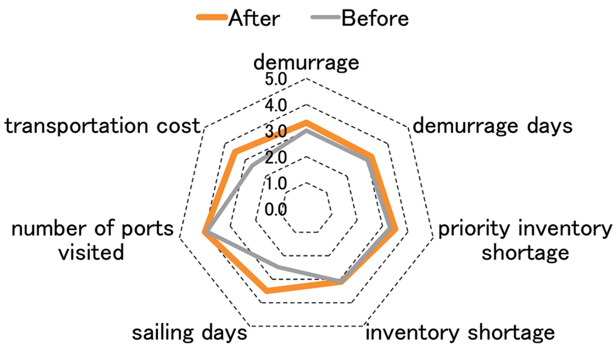

Fig. 8 Evaluation of optimization results by spider chart

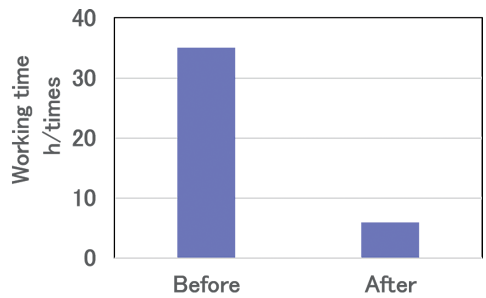

Fig. 9 Changes in planning work hours

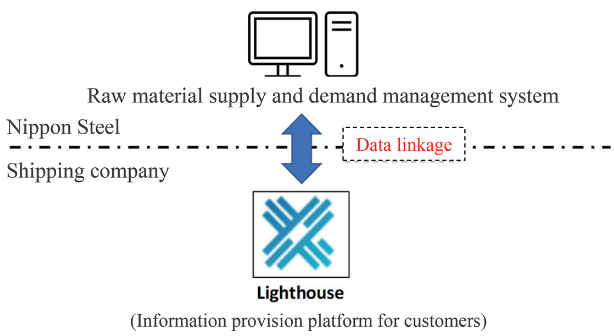

Fig. 10 Image of system linkage

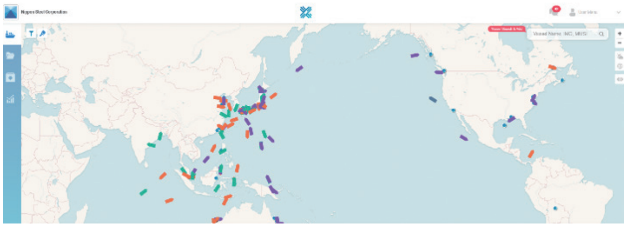

Fig. 11　Vessel movement confirmation on Lighthouse

the inbound import iron ore and coal carriers for Nippon Steel, and on the “Lighthouse”, confirmation of the ship navigational status on a real time basis is possible (**Fig. 11**).

The data can also be linked to the ship allocation optimization system, and a system environment could be constructed which allows for the formulation of optimized plans even when the navigational plan of a ship is changed.

4. Prompt Decision Making by Visualization of Index

As aforementioned, in the manufacturing and delivery of steel products, linkage among respective departments in raw material procurement-manufacturing-sales is indispensable. Data linkage among respective departments as to the amount of production in the production plan and the cost incurred during manufacturing is important. Particularly when the raw material market price varies greatly, it is necessary to grasp rapidly the extent of the influence on the cost index, and take appropriate actions (**Fig. 12**).

Even if the variations of the raw material price index are captured, in order to formulate an evaluation index comprehensively linking the content of the contract with each supplier, and the production state and various actual results in Nippon Steel, huge amounts of human resources, work load and time are required. On the other hand, by implementing the arrangement of data tables and data files, and by formulating business routines for rules, for this work, a simplified and automated system was built with Robotic Process Automation (RPA) and Visual Basic for Applications (VBA), and a workflow which rapidly transmits the evaluation Key Performance Indicator (KPI) was realized (**Fig. 13**).

Due to construction of the system, the totalization work load was reduced by 90%, and the frequency of data transmission increased by eight times. Thus by taking the totalization work out of human hands, the shift of human resources to more highly value-added business such as extracting problems identified by the evaluation KPI and to the implementation of countermeasures have become possible. This initiative is considered to be an example in which one of the expected results of the utilization of digital technology, namely empowerment and enhancing the value of working hours, has been achieved.

As an example of the use of the evaluation KPI in the data linkage system, the forecast transition of the manufacturing cost index is shown (**Fig. 14**). By considering the portion of the cost variation corresponding to the change in the raw material market price with respect to a certain base value, forecast of the influence of the raw material market price for the coming half year has been enabled. In the case that the raw material market price varies on a daily basis, by observing with an appropriate frequency the evaluation KPI totalized and transmitted in the same manner, it is possible to capture the change in the tidal current at an early stage. The index is shared not only by the raw material procurement departments, but also by all departments concerned including sales and technical departments. Discussion and promotion of countermeasures by the respective departments on an identical index basis is an important aspect of the data-driven business. We will utilize the evaluation KPI maximally, and utilize the outcome for the enhancement of business competitiveness.

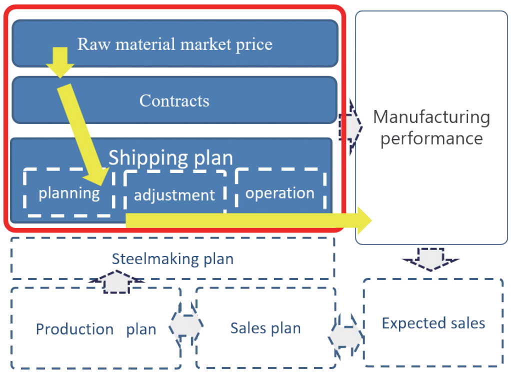

Fig. 12　Overview of data linkage in each department

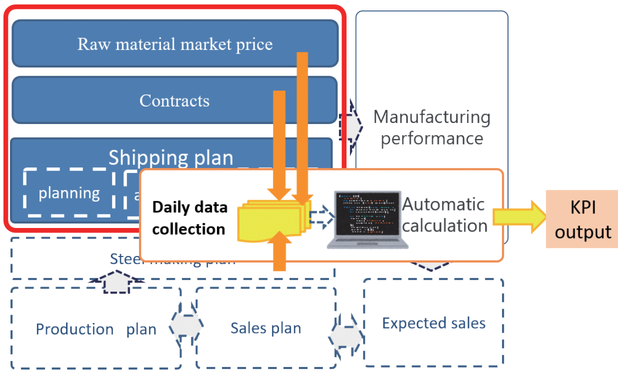

Fig. 13　Overview of data linkage and rapid output of evaluation KPIs

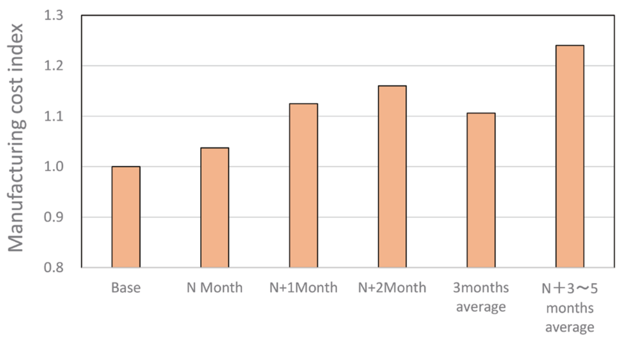

Fig. 14　Forecast transition of manufacturing cost index

5. Conclusion

Thus our initiative for business reform and DX in raw material procurement has been described. We are promoting business reform and DX with the intention of strengthening our response capabilities to changes by frequently linking the valuable data assets within and outside the company, and by rapidly promoting visualization and optimization. Hereafter as well, we will promote DX, and further promote the optimization of supply chain control.

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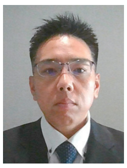

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