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The body can be viewed from the next page.

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Coastwise Transportation Planning and Administration System*

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Synopsis:

Kawasaki Steel has developed the coastwise transportation planning and administration system, aiming at efficiency in transportation by sea that takes a leading part in steel products distribution. This system is connected to personal computers equipped on ships on-line and collects the result and plan information changing constantly in real-time, and enables the nationwide sections concerned to see the information at the same time. An expert system technology was applied to develop the subsystem providing transportation schedules by ship, which hitherto has been planned based on the judgement of a single person in charge. Although this subsystem is very large, it can make schedules for one day in about 20 min, and has began to produce a good effect.

1 Introduction

Marine transportation plays a very important role in the distribution of steel products. However, the steel industry has been backward in computer application in this field. Ship transportation planning, which is an especially important task, has been limited to partial optimization based on the judgment of a single person in charge.

Considering that the development of software linked with various investments in hardware is necessary for substantially reducing the cost of marine transportation, Kawasaki Steel has recently developed an integrated coastwise transportation planning and administration system and started the full-scale operation of this system.

The word "integrated" here suggests that the loading port, unloading port, and cargo boat, which are the three principal elements of coastwise transportation, are integrated; at the same time, it suggests that the planning function and execution function are integrated in this system. The company developed software for realizing this integration and substantially reformed the existing systems including organizations.

This report describes the purpose and aim of the development and the details of the wide-area distributed processing system and ship transportation planning subsystem which are the features of this coastwise transportation planning and administration system.

2 Outline of Material Distribution by Coastwise Transportation

2.1 Features and Actual Condition of Material Distribution by Coastwise Transportation

The features and actual condition of coastwise transportation are briefly described below.

The ratios of transportation methods by works and the proportion of companywide coastwise transportation by works are shown in **Figs. 1** and **2**, respectively. It is apparent that in particular, the coastwise transportation at Mizushima Works is important and that Mizushima Works plays a critical role in coastwise transportation at Kawasaki Steel.

Ships called "regular cargo boats" play a major role in coastwise transportation. Regular cargo boats are about 100 ships that transport, as a rule, only Kawasaki Steel's steel products. Plans are formed on the basis of regular cargo boats.

Ships will repeat transportation under a 24-hour-a-day system. However, the actual ship employment efficiency

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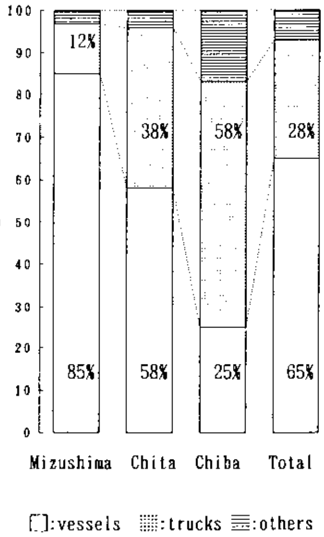

Fig. 1 Ratio of transportation methods

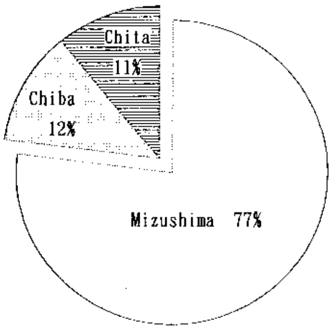

Fig. 2 Inter-plant ratio of shipment vessele

is very low and lay days exceed half the hours under way. The improvement of this low efficiency is an urgent problem, which will be described in detail later.

The control affairs of coastwise transportation are broadly divided into three areas: information gathering, planning, and plan adjustment.

First, information gathering involves the collection of wide-ranging and vast information on ships, cargo handling at the loading ports, cargo handling at more than 100 unloading ports, cargoes, warehouses at the unloading ports, etc. Because the greater part of information gathering work has so far been the input of information into computers after manual operation, such problems as delays in timing and unshared information have developed.

Second, planning greatly influences ship transportation efficiency, which is determined by many factors at loading ports, in ships, and at unloading ports. For example, if there is no berth or personnel for cargo handling at a loading port where there are both a ship and a cargo, the ship does not function in the least. Conversely, even if loading work is carried out smoothly, a ship that calls at an unloading port simultaneously with other vessels must wait, and efficiency is low. Planning involves the design of work at loading ports, in ships, and at unloading ports by ensuring a good balance among these many factors. However, because conventional planning has relied entirely upon manual operation, it has been physically impossible to give adequate consideration to the vast amount of information described above, and ships have been requested from loading ports as a realistic method. For this reason, the consideration given to the factors at unloading ports has been inadequate and ships usually have had to wait at unloading ports.

Lastly, plan adjustment involves measuring the difference between plans and results and correcting it to a desirable state; this is important work that greatly influences the ship transportation efficiency, as with planning. However, conventional plan adjustment work has been limited to individual adjustments, partly because of the nonexistence of a clear organization for conducting this work.

2.2 Examination of Problems

The greatest problem against this background is many lay days at unloading ports, in particular the long waiting time for unloading and, hence, low ship transportation efficiency. The transportation time of one voyage is shown in **Fig. 3**. Lay days account for 56% of the transportation time of 105 hours, and in particular, the waiting time for unloading is 24 hours, which is abnormally long. The shortening of the waiting time for unloading is therefore an urgent problem.

Why is the waiting time for unloading long? We divided the causes of this long waiting time into the following four factors and concluded that they are all ascribable to the lack of consideration of factors at unloading ports:

(1) Arrival at ports on holidays—Because work is stopped on Sundays at most unloading ports, the waiting time for unloading is long when a ship arrives at a port in the afternoon of Saturday and on

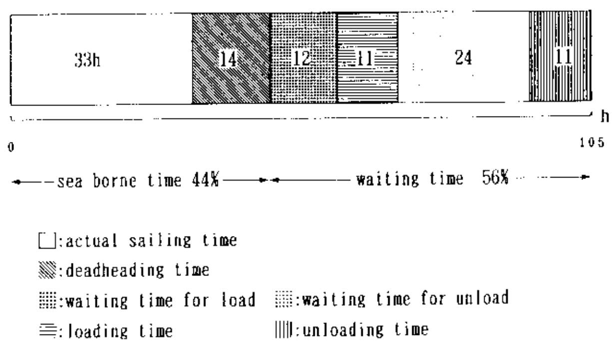

Fig. 3 Transportation time

Sunday.

(2) Improper time of arrival — Because most unloading ports work only during the daytime, the waiting time for unloading is long when a ship arrives at a port in the afternoon or during the nighttime.

(3) Overlap of ships — When a succeeding ship arrives at an unloading port where a preceding ship has already called, this condition is called an overlap of ships. An overlap of ships occurs due to insufficient coordination among plants, and hence the waiting time for unloading becomes long.

(4) Unloading at multiple ports — When cargoes would be insufficient if unloaded at one port only, they are unloaded at multiple ports. Because most unloading ports work only during the daytime on weekdays, waiting till the morning of the next day occurs at the second and later ports, and the waiting time for unloading becomes long.

Furthermore, the following factors are conceivable as problems in the system that create this situation:

(1) Lack of information — Improper planning and delays in adjustment occur due to the lack of necessary information and delays in timing.

(2) Limits of manual work — Work from the entry of information to all judgment tasks is completely conducted manually, and there is no further room for improvement.

(3) Limits of the system of requests from loading ports — In the present system, ships are requested from loading ports. Therefore, loading ports are "stronger" than unloading ports, and it is difficult to aim at optimization of the whole.

3 Outline and Features of the System

3.1 Aim and Target of Development

As mentioned above, there are many problems in the computer system, system of tasks, etc., of coastwise transportation. To solve these problems and maximize ship transportation efficiency, we carried out the following development and reforms:

(1) Improvement of Information Gathering Capacity
Information gathering capacity is improved substantially by establishing on-line communication between land and sea, which is accomplished by installing onboard terminals in all regular cargo boats; expanding an on-line networks to cover small-scale unloading ports; visualizing and sharing of unloading information, which is accomplished by introducing workstations for plan adjustment; expressing warehouse information in quantities and numerical values, etc. The foundation of the whole system is made positive by this substantial improvement.

(2) Establishment of System for Forming Ship Transportation Plans
A system for forming ship transportation plans is established. In this system, planning is conducted by using gathered information and synthetically judging the factors of loading ports, ships, and unloading ports. This system enables the factors of unloading ports to be considered and provides the basis for realizing the shortening of the waiting time for unloading. Furthermore, the conventional system of requests from loading ports is replaced with the system of supply of plans from the Head Office, aiming at optimization of the whole system.

(3) Improvement of Plan Adjustment Capacity
A Coastwise Transportation Control Center for Kawasaki Steel Group Companies has been organized in the Head Office of Kawasaki Steel as a new organization, and the total control function from planning to plan adjustment is centralized in this center. The system of work is such that implementation can always be based on plans, and problems are made clear.

The above three are the pillars supporting this system, and they enable desirable plans to be formed and the capacity to carry out the plans to be provided. It is finally planed to shorten the total lay days by an average of 10.5 hours, the greater part of which will be accomplished by shortening the waiting time for unloading.

The realization of wide-area distributed processing for improving the information gathering capacity and the system for forming ship transportation plans, which are the essence of this system, will be described below in more detail, in addition to the configuration of this system.

3.2 Configuration and Features of the System[1)]

The features of this system are the realization of wide-area distributed processing, that connects information generated at a very large number of points, and the establishment of a large-scale ship transportation planning system by an expert system.

The configuration of this system is shown in **Fig. 4**. The "ship transportation planning subsystem" in which expert-system techniques are adopted forms the nucleus of the whole system. In addition to this subsystem, the whole system is composed of the "information tracking subsystem" for gathering the latest information for planning, the "plan execution subsystem" for carrying out various kinds of work on the basis of plans, the "plan adjustment subsystem" for adjusting ship transportation plans to suit the constantly changing situation, and the "logging/analysis subsystem."

The configuration of the computer equipment and network of this system are shown in **Fig. 5**. The host computers of the company are supplied by multiple vendors; an IBM computer is used at the Head Office and Fujitsu computers are used at the Works. As the work stations of this system, IBM products are used for planning and Sun Microsystems products are used for plan adjustment. Therefore, to realize linked processing among dif-

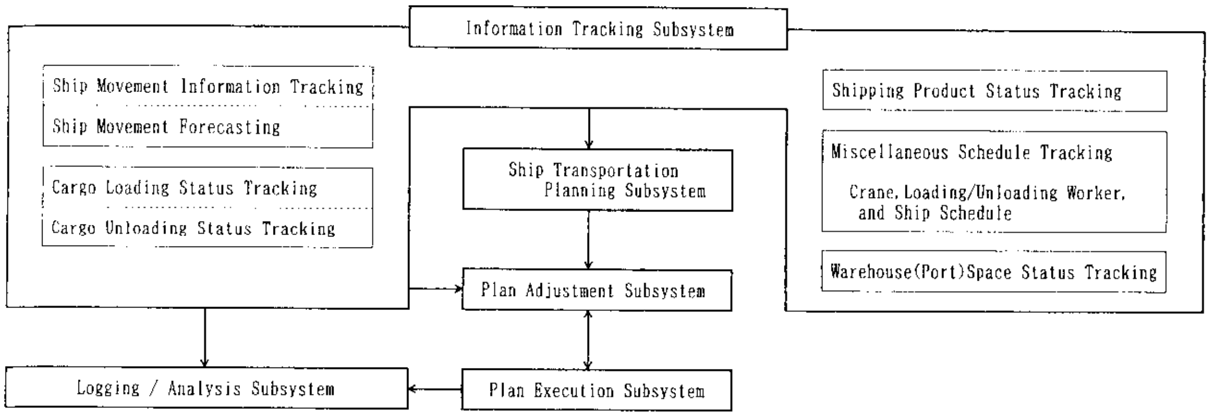

Fig. 4 System configuration

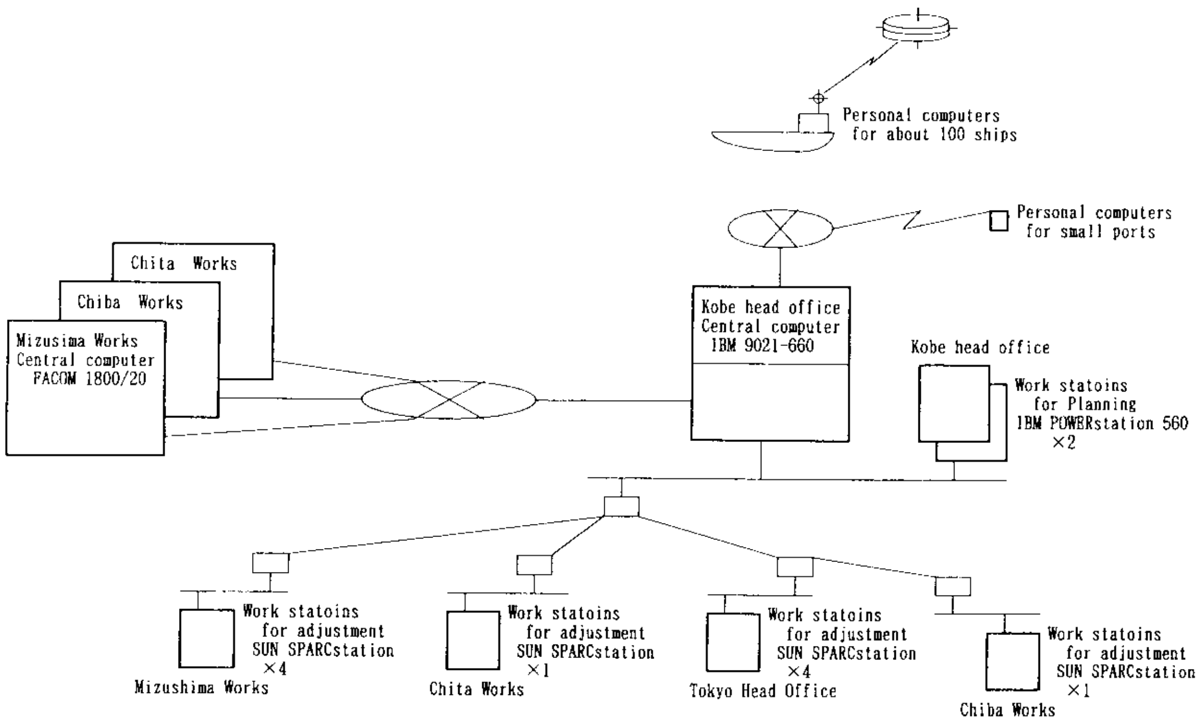

Fig. 5 Computer configuration

ferent types of computers in remote locations was a great problem for system technology.

The following description gives an outline of the information tracking subsystem in which wide-area distributed processing was realized and the method for using the newly introduced work stations.

3.2.1 Outline of information tracking subsystem

The basic feature of this subsystem involves real-time gathering of information distributed throughout Japan—at over 100 unloading ports, at all Works, and at over 100 ships—and integrated control of this information by the host computers. For this purpose, the following functions were incorporated in this subsystem:

(1) Gathering Information on the Situation of Ships

Jointly with NTT, Kawasaki Steel developed for this system a function for automatically gathering information on the situation of ships. Notebook-type personal computers equipped with a GPS (global positioning system) are installed in about 100 regular cargo boats. The notebook-type personal computers are connected to the Head Office host computer as shown in Fig. 5 via multi-adapters attached to the personal computers. This makes the operations so far conducted using a ship-phone circuit unnecessary, and has permitted automatic real-time gathering of information on the present position of ships, arrivals at and departures from ports, sheltering, etc.

(2) Gathering Information on the Cargo-Handling Condition at Loading Ports
The information on the cargo-handling situation at loading ports that is input to the works systems at any time (such as the scheduled and actual start time of loading and scheduled and actual completion time of loading, etc.) is communicated between the Works host computers and the Head Office host computer using the support system for the processing of asynchronous communication among the applications belonging to the different types of computers (KISS), developed by Kawasaki Steel Systems R&D Corp. This has enabled information on cargo-handling condition to be gathered without load and in real-time at the Head Office.

(3) Gathering Information on the Cargo-Handling Condition at Unloading Ports
At small-scale unloading ports so far excluded from the conventional Head Office network, inexpensive personal computers are installed and connected to the Head Office host computer via the public telephone network and simple gateways. This has permitted timely gathering of information on the unloading condition at small-scale unloading ports. The on-line network can now cover almost 90% of all unloading ports.

3.2.2 Method of using work stations

Information on the condition of loading ports, ships, and unloading ports controlled in an integrated manner by the information tracking subsystem on the host computers is downloaded on the work stations for planning, and ship transportation plans are formed using expert system. The information on formed plans is stored in the host computers and can be visually referenced from the work stations for execution installed in each district; therefore, the plans can be easily changed according to variations in the execution stage. In this system, distributed processing by work stations is applied in the two aspects of the formation of ship transportation plans by expert processing and the reference/updating of plan information. The technical features of this subsystem are as follows:

(1) Preparation of Ship Transportation Plans (Integrated Plans)
Various kinds of up-to-date information in the host computers can be easily downloaded at any time by the work stations for planning using the file transfer support function (OPENWAY-FT) developed by Kawasaki Steel Systems R&D Corp., and expert processing can be started at any time. The details of planning will be described in detail later.

(2) Adjustment of Integrated Plans
The function of referring to and updating the plan information at the host computers at any time from the work stations for adjustment installed in each district was realized by applying the function of real-time synchronous communication among the applications belonging to the different types of computers on the basis of socket interfaces. GUI (graphical user interface) processing at the work stations for adjustment is conducted by making the most of mouse and windows, enabling berth plans to be easily displayed/corrected. The information on the ships arriving at and leaving berths is visually displayed on berth plans, and the information displayed on berth plans, such as the number of cranes, can be arbitrarily selected by operators, improving the man-machine interface.

3.3 Ship Transportation Planning Subsystem

3.3.1 Outline of functions

The ship transportation planning subsystem is aimed at efficiently forming ship transportation plans. Concretely, the minimization of the waiting time for unloading at unloading ports is the greatest aim of this subsystem[2,3].

Ship transportation planning involves forming the following four small plans:

(1) Composition of Transporting Lots
Shipments are grouped in one transporting lot for loading on one ship (one lot per ship).

(2) Assignment of Ships
Ships are allocated to transporting lots, and the loads and destinations of the ships are determined.

(3) Making of Loading Berth Plans
The plan of cranes used for loading at the loading port quay is determined.

(4) Making of Unloading Berth Plans
The plan of cranes used for unloading at the unloading port quay is determined.

In all of these plans, there are various constraints, and the knowledge and experience of persons in charge who are well acquainted with their tasks are required to solve problems. It is not easy to solve these problems, even if they are independent ones. In reality, however, the problems are closely related to each other and efficient schedules cannot be obtained if they are handled individually. Concretely, in considering how to form transporting lots, it is necessary to take into consideration not only the delivery dates and loading rate of shipments, but also the number, size, and arrival-time distribution of ships arriving at a loading port, the operating condition of the cranes in the loading port, the working condition at an unloading port, the space available in the warehouses at the unloading prot, etc. Even if transport lots of 1 600 t, for example, are usually desirable for a certain unloading port and kind of product, it may sometimes be more efficient to reduce the lot size to 700 t and to combine other unloading ports and kinds of products.

Furthermore, the data used for planning covers more than 2 000 shipments at all Works, about 100 cargo boats, and more than 100 unloading ports throughout Japan, and is enormous.

Computers were applied by using expert system to cope with such a large quantity of data, wide range of functions, and difficult problems.

3.3.2 Method for solving problems

This subsystem forms four days of plans for a period two days to five days in advance, as viewed from the loading port. This is conducted by repeating four times the preparation of one day of plans at the loading port. Plans are rolled day by day by performing this operation every day. The composition of the inference portion is shown in **Fig. 6**.

(1) Composition of Transport Lots

Items to be determined in the composition of transporting lots are the unloading port, kind of product, and weight of shipments that composes the transporting lots, ship size, etc. In many cases, various combinations are possible for the same shipment by unloading at multiple ports, loading of various kinds of products, and ship size. As mentioned above, however, it is impossible to determined which is desirable unless other problems are considered. Therefore, as many candidates for transporting lots as possible are taken into consideration in the composition of transporting lots.

Next, each of the candidates for transporting lots thus formed is estimated as to the waiting time for unloading at unloading ports.

As mentioned above, there are several causes of

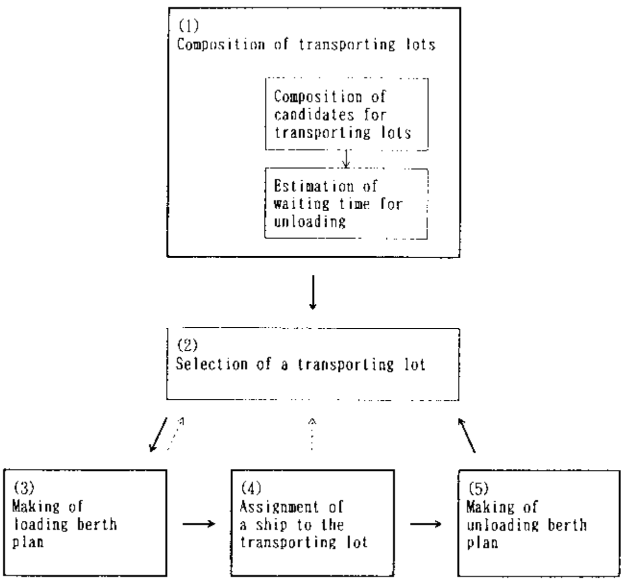

Fig. 6 Inference procedure of the ship transportation planning subsystem

waiting at unloading at unloading ports, such as the arrival at ports on holidays and overlap of ships. However, it is impossible to know the actual waiting time unless unloading berth plans are made. Therefore, waiting time is estimated by finding the day of arrival at an unloading port by rough calculation and judging the optimal time of arrival at the unloading port and, at the same time, conducting almost the same check as in the making of unloading berth plans. The optimal time of departure from a loading port is calculated by reverse calculation from the optimal time of arrival at the unloading port.

A desirable transporting lot can be selected from the candidates for transporting lots by using the waiting time found here as an index. However, whether or not planning as estimated here is possible depends on the unloading berth plans and the condition of ships. Therefore, transporting lots are selected one by one and plans are made in sequence depending on these conditions.

(2) Selection of Transporting Lots

One lot is first selected according to priority from the candidates for transporting lots. The first priority is given to transporting lots with severe delivery date requirements, and the second to transporting lots with a short waiting time for unloading at the unloading ports, as found in (1) above. Therefore, plans are formed first from transporting lots with a short waiting time for unloading at unloading ports, from the viewpoint of meeting delivery dates.

(3) Making of Loading Berth Plan

A loading berth plan is formed for the transporting lot selected in (2) above. In making this loading berth plan, the cargo-handling crane and the start and completion time of cargo handling are determined after meeting constraints, such as cranes capable of being used for cargo handling and the number of cranes in operation. Furthermore, the completion time of cargo handling must be made close to the optimal time of departure from the loading port found in (1) above. If this cannot be met, the procedure is returned to (2), and another transporting lot is selected.

The optimal time of departure from a loading port is the departure time that minimizes the waiting time for unloading at the unloading port. It is possible to minimize the waiting time for unloading at the unloading port by meeting this condition.

(4) Assignment of Ship

A ship that arrives at a port in time for the start of cargo handling and meets the constraints of cargoes, voyagable zone, etc., is assigned to the transporting lot for which a loading berth plan was prepared in (3) above.

(5) Making of Unloading Berth Plan

The transporting time to the unloading port is calculated for the above transporting lot and the cargo-

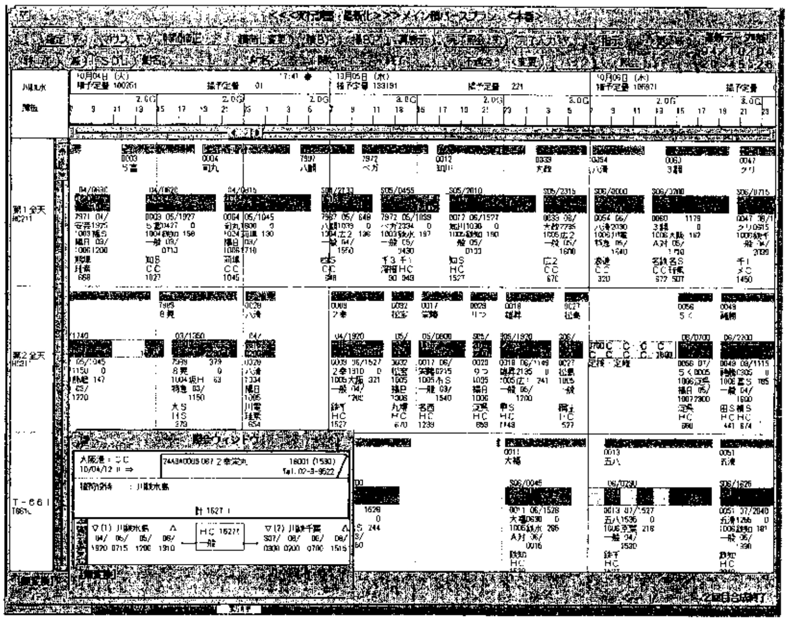

Fig. 7 An example of loading berth plan made by the ship transportation planning subsystem

handling crane at the unloading port and the start and completion time of cargo handling are determined. If the waiting time for unloading at the unloading port is equal to or less than the time determined in (1) above, a berth plan holds true. Otherwise (due to the competition with other transporting lots, etc.), the plans for this transporting lot are canceled, the procedure is returned to (2), and another transporting lot is selected.

The steps (2) to (5) are repeated until there is no space in the berth at the loading port. Because the second best transporting lot is selected one after another, even if a selected transporting lot cannot be planned, it is possible to form a plan which minimizes the waiting time at unloading ports. An example of a loading berth plan formed using the expert system is shown in **Fig. 7**. K Engine[4)] developed by Kawasaki Steel as a support tool for building the expert system is used in this subsystem. The scale of K Engine is about 410 rules and about 95 K steps in the portion other than the rules (mainly, C language). It is possible to make one day of plans at a loading port in a processing time of about 20 min.

4 Evaluation

4.1 Operating Condition and Achieved Results

This system has many functions including information gathering and planning, and the gathered information covers a wide range of items, including many ships that are not handled by usual computer systems.

For this reason, the system was carefully brought into full-scale operation. In particular, it took a considerable time to offer training in operation and application to ships and to verify the appropriateness of the results of planning by the planning subsystem. As a result, it took about ten months to shift the operation status from test runs to full-scale operation, and the full-scale use of this system, including the planning function, was started in December 1993.

Owing to these careful measures, this large-scale system has been operating smoothly without major trouble in the computers since start-up, and good results are being achieved steadily.

The greatest effect expected from this system is the shortening of the waiting time for unloading. The waiting time for unloading around 1990, when the examination of this shortening was started, was about 24 hours. Afterward, this time was shortened to about 20 hours in the first half of 1993, just before the start-up of this system, because of a great decrease in the transportation volume. However, the waiting time for unloading was still long.

The waiting time for unloading has been reduced steadily since December 1993 when the full-scale operation of this system was started, and is now about 16 hours. The present aim is to shorten the waiting time for unloading to 15.5 hours, and this has almost been achieved.

However, there are still many problems. No remarkable improvement has been made in the reduction in the arrival at ports on holidays or the optimization of the time of arrival at ports considered to be the means of shortening the waiting time for unloading in the design stage. Furthermore, there are still many corrections by operators to the plans prepared by computers. In addition, the capacity to carry out cargo handling at loading ports according to plan is not yet adequate.

Although there are problems to be solved, the actual condition of ship transportation at Kawasaki Steel has begun to be steadily improved, mainly by this system. We intend to realize more desirable ship transportation administration by knowing the actual condition accurately and improving the system and its operation.

4.2 Evaluation of the System

As mentioned above, this is an epoch-making system that provides a great innovation in business and is characterized by the adoption of new techniques for computer application.

First, many different computers and terminals perform interlocking operation, and centralized data management has practically been realized. This point is highly evaluated. Because distributed processing is expected to expand in the future, OPENWAY-FT, which has made possible the interlocking operation of the work stations with the host computers, will become increasingly important.

Second, the development of a large-scale planning system in terms of function and the volume of data processed is highly evaluated. The tasks of composition of transporting lots and making of berth plans covered by the functions of this system have so far been carried out by separate persons in charge at loading and unloading ports, and there has been no true expert acquainted with the whole process of these tasks. It was possible to adopt expert-system techniques based on the concept of making plans that are efficient in a companywide manner, and efficiency was substantially improved. There is no other ship transportation planning system of a larger scale than this system and one day of plans can be formed in 20 min without narrowing the search range of combinations. This point should also be highly evaluated.

5 Conclusions

The concept of a coastwise transportation planning and administration system aimed at substantially raising marine transportation efficiency was described. The following effects were obtained from this system, which has the three main functions of information gathering, ship transportation planning, and plan adjustment:

(1) The waiting time for unloading was substantially shortened, and ship transportation efficiency was improved.
(2) As a result, a desirable condition took the place of an undesirable one; that is, ships wait at loading ports instead of waiting at unloading ports.
(3) The loading ratio was improved and ship transportation efficiency was also improved in this respect.

Thus, this system is manifesting its expected effects steadily. We intend to improve this system and its operation and make efforts so that the system can produce better effects.

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