A Study on Ship Planning System for Container Terminal Using Multi-Distributed Method

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ABSTRACT

Container vessels are becoming larger and faster in line with development of shipbuilding technology and rapid enlargement of world' economy and commerce. Now, the appearance of 15,000 TEU vessel is expected soon. In the northeast Asia, fierce competition is ongoing for securing leadership in logistics to cope with fast-changing logistics environment along with economy globalization. Meanwhile, major harbors are competing intensely to attract large chipping companies. Therefore, we are in need of the ways to quickly and precisely execute ship planning, and the existing ship planning systems need to be innovated proactively. In this study, in order to help improving the existing ship planning system, a multi-distributed ship planning system is proposed, where number of planners are used to implement loading and unloading plans in a more speedy and precise way, and the proposed system will contribute to improve ship planning by allowing the planners to share information. To verify the efficiency of the system, ARENA simulation has been conducted.

INTRODUCTION
In the world's economic development, container traffic of the world is increasing by 7% on average in each year and input of container vessels is increasing as well. Container vessels are becoming larger and faster in line with development of shipbuilding technology and rapid enlargement of world' economy and commerce. In the end of 1960, the first generation of container vessel with a size of 1,000 TEU was introduced and in 2006, 12,500 TEU vessel ordered by Maersk appeared. Now, the appearance of 15,000 TEU vessel is expected soon. According to CSC (Ocean Shipping Consultants), one of the companies engaging in marine transportation in England, 12,500 TEU vessels will be placed in commission in 2010 and it is expected that 20~24 12,000 TEU vessels will be placed in commission by 2008 and 54 by year 2012 (CSC, 2000) In the northeast Asia, fierce competition is ongoing for securing leadership in logistics to cope with fast-changing logistics environment along with economy globalization. Meanwhile, major harbors are competing intensely to attract large shipping companies. Therefore, we are in need of the ways to quickly and precisely execute ship planning and the existing ship planning systems need to be innovated proactively. Commonly, vessel planning has been carried out by one planner per one container vessel. Assuming container is 1,000 TEU, it takes about 5 hours for one planner to work on ship planning. In case of 6,000 TEU, it takes more than 10 hours. If ship planning for the container vessel takes a long time, the quality of the plan is degraded and rework of the container might be required. As a result, the overall productivity of the container terminal will get lower. Also, in terms of existing ship planning system's design structure, it used to be 20-Tier system. Such system, when working on a ship planning for a container vessel, requires a planner to download information of the container vessel from DB server and upload the plan to the DB server. However, using the 2-Tier system, the planner is unable to understand if there are any changes in the situation of container terminal for 5~6 hours when the ship planning is being worked out. Because of this, the planner might work on a ship planning based on the situation which is different from the current situation. In addition, in the past, each planner did not share information with one another while working on the ship planning. They couldn't understand the other planners' ship planning situation, which led them to merely depend on their experience not considering efficiency of equipment and yard causing equipment's lower rate of operation and complexity in yard. Moreover, if ultra large container vessels enter into and depart from the container terminal at the same time, it is more difficult and complicated to work on ship plannings of the container vessels, and it will worsen the above mentioned problems. Therefore, a system needs to be developed to support smooth ship plannings for all the container vessels entering into and departing from container terminal.

1. Objective and method of the study

In this study, two objectives have been set to solve existing problems of ship plannings. First, it is to shorten loading and unloading planning hours of container vessel by letting number of planners to carry out ship plannings simultaneously. Planners will be able to focus on their ship planning which in turn will improve quality of loading and unloading work plans. Second, it is to let each planner to share information while planning their loading and unloading works which will provide a solution for problems of low rate of operation and complexity in yards. In order to improve existing ship planning, a loading and unloading plan system using several planners will be executed. This study will propose a multi-distributed ship planning system for improving the quality of the plan system by letting planners to share information. In order to verify the efficiency of the proposed system, a simulation through ARENA will be carried out.

2. Related Research

2.1 Studies on the literatures of ship planning

Studies of shipping plan system can be divided into the studies of algorithm development for efficiently establishing the plan and the studies of design and embodiment of shipping plan system. As for the studies on algorithm development, there is a study on quantitative model of freight transportation and operation (2 other than Kim Gab Hwan, 1998) and a study on using genetic algorithm for establishing the best loading and unloading plans in a shortest time and for securing safe shipping service of vessels (2 other than Kim Gab Hwan, 1997). For determining the best lading position of containers with regard to safety of vessels, options were compared and analyzed by using a navigation technique combining simulation and MonteCarlo technique to gi. Also, there was a study proposing a mathematical model merely considering minimization of the line of flow in yard. (Cho Deok Woon, 1986) As for the study on design and embodiment of ship planning system, an attempt has been made to introduce a professional system using the actual working method of a terminal planner as a knowledge base to load planning (Dumbleton, J ,1990). And an automatic shipment decision support system was developed to propose practical requirements and efficient plans for domestic terminals (1 other than Shin Jae Yeong, 1995) which is a professional system combining mathematical model and a knowledge base established based in professionals’ knowledge, and it is suitable for practical working environment. Also, for efficient container terminal shipment planning, a system was designed for automatic shipment planning method using artificial intelligence and professional system and a part of the module was developed as a prototype. (2 other than Shin Jae Yeong, 1999) In addition, there was a study on a development of a system for establishing loading and unloading of container terminal and operation planning of yard all together in integrated environment.
These studies are about algorithms that suggest a solution for decision making problems occurring when operating container terminals, and they are showing good results in the field of planning related to decision making. However, there has been no study on the ways to improve ship planning system to make it more efficient.

2.2 Current ship planning system

In container terminals, planning systems are being adopted and operated for efficient ship planning. In domestic and international major container terminals, various ship planning systems are being used but in this study, N company from U. S. A and T and K companies from Korea that sell operational information systems to world's major container terminals were analyzed to understand the current status of ship planning system of container terminals. Ship planning system of container terminal consists of sub systems such as loading and unloading plans for scheduling working sequence and planning positions of loading and unloading containers in vessels and equipment assignment plan for planning allocation of cargo handling equipment in yard.

Planning tasks of container terminal require expertise. Therefore, they are performed with systems that best reflect the knowledge of professionals. By adding automatic planning system such as ship planning with optimization technique, yard planning and resource allocation planning to come up with more efficient system (3 other than Yang Chang Ho, 2006) In the course of transfer from manual planning to automatic planning with professional system, multi-level decision making is supported, and systems are being upgraded to be able to establish optimized planning based on conversation with users or automatic determination in case information is omitted or there is a lack of accuracy. Systems for ship planning of container terminal in each company are different but they are largely classified into 3 systems namely, planning, operation and support. Systems are changing constantly to increase productivity of terminal operation through work efficiency. Development of planning and operational management system is being carried out along with adoption of new IT technology where automatic planning and intelligent decision making are enabled to support manual ship planning in real-time. The tendency is toward establishing a web-based open integrated operation information system based on distributed processing type, cutting-edge integrated data receiving/transmitting network technology but none has been actually built yet and its efficiency has not been studied yet either.

3. Multi-distributed ship planning system

3.1 Concept and features

Multi-distributed ship planning system enables number of planners to share their work in loading and unloading planning of container vessels that enter into and depart from container terminal, and it consists of server system, client system and data base. The server system supports algorithm that allocates loading and unloading area for container vessels. It performs work planning of container vessels according to the orders of server system by connecting through communication network such as client system and network. It monitors situation of loading and unloading, and it supervises loading and unloading of container vessel based on client management feature. The client system consists of master planner's client system that receives and transmits data associated with loading and unloading and number of slave planners' client system. The data base division can store vessel information and the information of the planner who will perform work planning. As it can be seen above, multi-distributed ship planning system is constructed based on Multi-Tier (N-Tier) consisting of a master planner's client system that supervises loading and unloading planning and a slave planners' client system that is selected by the master planner. According to ship planning method using multi-distributed method proposed in this study, the master planner who leads the loading and unloading planning can select a slave planner who will help doing the planning job. Then work area of container vessel can be allocated and by checking the loading and unloading traffic, the master planner and the slave planner can perform the planning job together. In case some adjustment is required in loading and unloading plan, the master planner can adjust the job of each slave planner.

The below Fig. 2 shows a concept of multi-distributed planning system. The server system manages and operates loading and unloading planning of container vessels. It processes the information of the container vessels using ship cluster and determines job sequence of loading and unloading and the area. It also manages and supervises the whole process of loading and unloading planning such as collecting and verifying work results and storing it in date store module.
3.2 Design and structure of multi-distributed system

This section illustrates detailed block structure of the server system and the client system of multi-distributed ship planning system as shown in Fig. 5 and 6. We will look into the details of multi-distributed ship planning system. First of all, as shown in Fig. 5, the server system consists of divisions such as DB management, client version management, message management, shared object module, object synchronization, distributed work control and management, client processing management, lock manager, configuration manager, communication management and J2EE link.

The client system consists of a master planner's client system and number of slave planner's client system. They use the same client system individually and perform loading and unloading planning with the server system but it can be seen as one work group. In Fig 2, the server system consists of one client system used by the master planner but this is just to illustrate this study and many clients can be connected to the server system. In such system structure, the master planner can understand the loading and unloading traffic and decide if he will perform the job alone or number of planner will perform multi-distributed planning together. If multi-distributed planning is chosen, the master planner selects number of slave planners who will help him doing the planning job for the container vessel and allocate planning jobs to them. Then, the selected slave planners will perform the loading and unloading planning assigned to them and the planners can cross monitor other planners' planning in real-time through intelligent integrated monitoring system. The planner can understand the entire loading and unloading planning and they can perform efficient planning. The multi-distributed ship planning explained so far shows an example where it is applied to only one of the container vessels that enter into and depart from container terminal but it can be applied to many container vessels. Based on Multi-Tier structure, the master planner can carry out loading and unloading planning for number of container vessels and in this case, loading and unloading planning for each container vessel is performed by number of master planners and slave planners. The number of planners and the number of container vessels are in M:N relationship. In the past, loading and unloading planning for each of many container vessels was established individually but in this study, many planners can perform the planning for many container vessels simultaneously. By being able to carry out loading and unloading planning for many container vessels at the same time, work speed and convenience can be improved in terms of T/S work between different container vessels.
service can be supported, and it is in charge of session management, real-time monitoring and data synchronization in an unified mode at upper level.

Communication connection pool management can authorize or reject connection of clients and it is in charge of maintaining and monitoring sessions with the server system. Looking at the block composition of client system as shown in Fig. 6, just like the server system in Fig. 5, it consists of divisions such as DB management, message management, shared object module, object synchronization, work planning, version management, configuration manager and communication management. It also includes work area units such as Vessel, Berth, Yard, Equipment, Container and Job. Here, DB management, message management, shared object module, object synchronization and communication management are the same as those of the server system in Fig. 5.

Work planning division executes loading and unloading planning for the container vessels that enter into and depart from container terminals. It lets the slave planners selected by the master planner to execute loading and unloading planning or T/S planning between container vessels. Therefore, the work planning division consists of work unit selection module that checks the amount of loading and unloading traffic of the container vessel and selects single or distributed loading and unloading planning. It also consists of a planning control module that receives and synchronizes planner's work messages. There is also a planning data storing module that stores planner's loading and unloading planning data in the data base.

Client system sends and receives the information of current work situation of the planners with the server system. Ther server system manages data while sends the integrated data to the client system and synchronizes loading and unloading work situation. Therefore, all the planners who are involved in multi-distributed loading and unloading planning of the container vessel can cross monitor the current loading and unloading work situation in real-time.

4. Development of multi-distributed planning system

In this section, embodiment of the system that reflects the requirement found in this study will be explained and we will look into multi-distributed planning system from GUI's view point. Fig. 7 shows the main screen of multi-distributed ship planning system. Loading and unloading planning, direct T/S, berth planning, Q/C working summary can be compared and worked on the same screen simultaneously.

Fig. 7 Main screen

Fig. 8 illustrates the actual monitor screen showing the loading and unloading planning process of the allocated work area, where slave planners can be selected and the loading and unloading planning done by them through distributed planning can be monitored in real-time. For instance, a master planner "Hong Gil Dong" assigns a slave planner "Kim Chul Soo" to Work Area 1 and "Park Min Soo" to Work Area 2.

Fig. 8 Slave planner selecting screen

"Hong Gil Dong" checks the loading and unloading traffic and the work area of each slave planner through work area allocation algorithm. When necessary, as shown in Fig 9, he can select a slave planner, then select Bay to make adjustments.

Fig. 9 Work allocation

On the other hand, slave planners will carry out multi-distributed planning for the work area assigned to them, as shown in Fig 10.
Here, slave planners execute the loading and unloading planning only for the area assigned to them. Each of them sends the planning message produced from their planning to the server system. Distributed work control and management division of the server system verifies the contents of the planning message and stores the work result in the storage. Then, based on the work results of multi-distributed loading and unloading stored in the storage, the overall distributed loading and unloading planning of the container vessel will be performed. Finally, Fig. 11 shows the situation of multi-distributed loading and unloading planning of T/S container vessel. When executing T/S planning for T/S container vessel, the planning for both the loading container vessel and the unloading container vessel is executed simultaneously. This can also be done by either single planning or multi-distributed planning where a master planner and slave planners are involved.

5. System evaluation using simulation

5.1 Simulation model

The purpose of this simulation is to find out how much more efficient the system get when using multi-distributed ship planning system. Here, ARENA simulation tools were used for the verification. The scenario hypothesis of the simulation is as follows. Vessel stowage plan, BAPLIE for establishing loading and unloading plan is sent to the terminal in electronic document format within 10~12 hours (uniform distribution) on average before coming alongside the pier. Hypothetically, the vessel handled in the container terminal is above 12,000TEU and the amount is about 6,000TEU. 3 planners will be involved in loading and unloading planning, and the hours for establishing a plan for a ship in terminal A, in Busan is 10.8 seconds per 1 box and 7.8 seconds for checking the shipment traffic. In the existing planning system, only one planner can execute loading and unloading planning, which means, even when the planner is not working, the other planners cannot do their work. In multi-distributed ship planning system, all the planners that are not doing loading and unloading work can cooperate and work together.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAPLIE arrival time</td>
<td>10-12hrs</td>
</tr>
<tr>
<td>Vessel traffic amount</td>
<td>6,000TEU</td>
</tr>
<tr>
<td>No. of planners</td>
<td>3 persons</td>
</tr>
<tr>
<td>Time for establishing loading and</td>
<td>Time establishing</td>
</tr>
<tr>
<td>unloading plan</td>
<td>plans</td>
</tr>
<tr>
<td></td>
<td>10.8sec/BOX</td>
</tr>
<tr>
<td></td>
<td>Time for checking</td>
</tr>
<tr>
<td></td>
<td>traffic</td>
</tr>
<tr>
<td></td>
<td>7.8sec/BOX</td>
</tr>
</tbody>
</table>

And, after analyzing 1 year's berth schedule of terminal A, it was found that the intervals of ships' arrival was 5 hours and 3 minutes with 22 minutes of deviation. Fig.12 shows the model of existing ship planning system using area simulation tool. Based on Table 1, the arrival time of BAPLIE is set as 10 hours before coming alongside the pier and the traffic was set as 6,000TEU. The loading and unloading time per 1 box is based on the interview material obtained from terminal A.

5.2 Evaluation result

As shown in Fig. 12, 3 planners are waiting in simulation process and when BAPLIE arrives, shipment traffic is checked and loading and unloading planning is executed. Next, Fig. 13 shows the model of multi-distributed ship planning system where number of planners are executing loading and unloading plan in the same vessel by cooperating with each other.
In the above modeling, 3 planners are waiting in simulation process and when BAPLIE arrives, shipment traffic is checked and loading and unloading planning is executed. Here, the master planner and slave planners can execute the plan by cooperating with each other.

5.2 Simulation result
Through the simulation models, the result of the existing ship planning system was compared with the result of multi-distributed ship planning system. As a result of conducting a simulation using the existing ship planning system, the analysis was found as the below Fig. 14. 3 planners worked on the planning of 573 ships in one year and the working hour of each planner is as follows.

![Fig. 14 Time consumption analysis(existing)](image)

As a result of conducting a simulation using multi-distributed planning system, the analysis was found as the below Fig. 15. The working hour of each planner is as follows.

![Fig. 15 Time consumption analysis(multi-distributed)](image)

As shown in the result of the simulations, in multi-distributed ship planning system, the time consumption was shorten by 24.5% compared to the existing ship planning system.

![Table 2 Simulation result(planners' working hours)](image)

<table>
<thead>
<tr>
<th>Item</th>
<th>Total hours (hr)</th>
<th>Hours of per one planner(hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing ship planning system</td>
<td>20,177</td>
<td>6725.7</td>
</tr>
<tr>
<td>Multi-distributed</td>
<td>15,278</td>
<td>5092.7</td>
</tr>
</tbody>
</table>

As a result of analyzing the operating ratio of 3 planners in the two systems, as shown in Fig. 16, it was found that in the existing ship planning system, the work load was mostly imposed to the planner 1.

![Fig. 16 operating ratio in the existing system](image)

On the other hand, in multi-distributed ship planning system, as shown in Fig. 17, the 3 planners' operating ratio was 41% on average.

![Fig. 17 Planners' operating ratio in multi-distributing](image)

<table>
<thead>
<tr>
<th>Item</th>
<th>Planners' operating ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td></td>
</tr>
<tr>
<td>Planner 1</td>
<td>58% average</td>
</tr>
<tr>
<td>Planner 2</td>
<td>35% average</td>
</tr>
<tr>
<td>Planner 3</td>
<td>22% average</td>
</tr>
<tr>
<td>Multi-distributed</td>
<td>3 planners 41% average</td>
</tr>
</tbody>
</table>

In multi-distributed ship planning system, planners' operating ratio was higher and more evenly distributed compared to the existing system. As a result of analyzing ship waiting hours, it was found that average plan establishing hours and waiting hours per one vessel was consumed as shown in Table 4. In the existing ship planning system, 17 hours and 52 minutes on average was required when processing 6,000TEU. And when the information for establishing the plans
was received, the planning could only take place after 49 minutes on average. On the other hand, when multi-distributed ship planning system was used, 5 hours and 58 minutes was required when establishing plans for 1 vessel and there was almost no waiting time required.

<table>
<thead>
<tr>
<th>Item</th>
<th>Existing ship planning system</th>
<th>Multi-distributed ship planning system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average waiting time for establishing plans</td>
<td>49 minutes</td>
<td>1 minute</td>
</tr>
<tr>
<td>Hours for establishing plans per one vessel</td>
<td>17 hours 52 minutes</td>
<td>5 hours 58 minutes</td>
</tr>
<tr>
<td>Total hours</td>
<td>18 hours 41 minutes</td>
<td>5 hours 59 minutes</td>
</tr>
</tbody>
</table>

It was found that, when multi-distributed planning system is used, the operating ratio of planners can be increased and the average hours for establishing plans per one vessel can be shorten. Also, these are the hours required in establishing plans for ultra-large vessels and it can prevent delays occurred in ship planning.

CONCLUSION

The system proposed in this system, enables users to chose single loading and unloading planning or multi-distributed loading and unloading planning depending on the loading and unloading traffic of container vessels. In multi-distributed loading and unloading planing, the master planner can assign number of slave planners to their work areas and let them execute the loading and unloading planning simultaneously, which shorts the working hours and the effect will be bigger with larger vessels. By allowing the planners to share information, the result of the finished planning can be collected and verified. Through simulation, this can be applied to the working plan again in consideration of interference of equipment and complexity of yard, which will result in quality and highly efficient loading and unloading planning. In turn, the overall productivity of the container terminal will be improved. As shown in the result of simulations, when multi-distributed ship planning system is used, the overall hours of ship planning can be shortened. In the future, a study proving the effect of multi-distributed ship planning system on productivity improvement could be carried out in order to prove more practical improvement effects, which will contribute to improve the productivity in establishing loading and unloading planning.

ACKNOWLEDGEMENTS

This work was supported by the grant No. B0009720 from the Regional Technology Innovation Program of the Ministry of Knowledge Economy(MKE).

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