

Maritime Transportation Planning Support System for a Car Shipping Company

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Abstract : *In order to achieve a sustainable competitive advantage in the expanding maritime transportation market, most shipping companies are making every effort to reduce transportation costs. Likewise, the car shipping companies, which carry more than 80% of total car import and export logistics volume, also do their utmost for transportation cost saving. Until now many researches have been made for efficient maritime transportation, but studies for car shipping companies have rarely been made. For this reason, this study has tried to develop a maritime transportation planning support system which can help to save logistics costs and increase a competitive power of car shipping companies. To this end, instead of manual effort to solve the routing problem of car carrier vessels, this study has used an integer programming model to make an optimal transportation planning at the minimum cost. Also in response to the frequent changes both in the car production schedule and ship's arrival schedule after the completion of transportation planning, this research has developed a decision support system of maritime transportation, so that users can easily modify their existing plans.*

Key words : *Car shipping company, Optimal transportation planning, Routing problem, Integer programming, Decision support system*

1. Introduction

Owing to the ongoing activities of WTO (world trade organization) and increasing FTA (Free Trade Agreement), world trade volume is expected to increase continually. As of 2006, international trade volume stands at about US\$ 24.4 trillion. It has doubled compared with US\$ 11.2 trillion in 1997. In case of the maritime transportation that is in charge of the majority of global logistics volume, world logistics volume in 2005 was about US\$ 5 trillion (6.66 billion tons). This means that world logistic volume has increased on the average 9.5% (4.8% in terms of weight) a year from 1947 to 2005 (Mitsui, 2007). Thanks to its steady expansion of a global logistics market, more and more people have participated in the logistics market, eventually deepening market competition. Because of this trend, logistics service providers have to steadily increase their competitiveness in terms of price and quality by way of improving efficiency and productivity. Meanwhile, many researches have been made in order to deal with these kinds of logistics problems. In particular, in case of maritime transportation, because of its huge weight in the global logistics volume, much more researches have been made in comparison of other transportation fields. But in case of a car carrier vessel still having a relatively small market, much study has not

been made yet.

However, now car export volume is steadily increasing in proportion to rapid car production expansion. In 2006, car carrier vessels have carried about 12 million cars in the international maritime transportation market. As global auto markets are steadily expanding, the car import and export logistics volume is also increasing on an ongoing basis. Therefore, car shipping companies are required to expand their capacity including the enlargement of a car carrier vessel in order to handle increasing car logistics volume. But the car carrier vessels' capacity is not enough to meet car export volume and so the tonnage of car carrier vessel is still in shortage. Because of this, most car shipping companies are making every effort to make a more efficient transportation plan in order to carry more cars at a lower cost. But until now, most maritime transportation planning has been made manually based on worker's experiences and the process of planning, evaluation and follow-up management has been inefficient and time consuming. Even worse, in case that there are many changes happening in terms of car production date, production volume and ship's arrival date, it causes many difficulties in the revision of the existing plans. Also, it has to be pointed out that high priority is given to a shipper's cargo transportation instead of a shipping company's profitability. Because of this, profitability

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improvement is badly needed for a car shipping company.

In short, to seek more efficient and systematic maritime transportation, an optimal transportation planning has to be made based on reliable and accurate information and at the same time has to be updated on a real time basis in response to the continually changing basic information. But researches have not made enough to solve these problems. In an effort to cope with these problems, this study has tried to suggest an optimal maritime transportation planning support system enabling a car shipping company to gain a maximum profit, while making it possible to update the existing plan according to the changes in basic information on a real time basis. For this purpose, this study develops an integer programming model as well as planning support system with user interface for easy updating.

2. Literature review

An efficient maritime transportation planning makes it possible to allocate the maximum cargo volume to the least number of vessels, use the shortest route and return to the depot. Therefore, this is similar to a VRP (vehicle routing problem), which seeks the most efficient routes with the lowest cost, while satisfying all customers. VRP is a NP-hard problem, thus taking a long computing time in finding out an optimal solution (Lenstra and Kan, 1981). For the solution of VRP, the following approaches have been used: diverse heuristic approaches (Laporte, *et al.*, 2000; Pisinger and Ropke, 2007), genetic algorithm (Baker and Ayechev, 2003), tabu search (Gendreau and Hertz, 1994), simulated annealing (Osman, 1993) and ant colony optimization (Bell and McMullen, 2004). Like this, many researches have been made on the vehicle routing and scheduling problem, but little research has been made on ship routing and scheduling.

Generally, shipping operation can be grouped into three: liner, tramp and industrial (Lawrence, 1972). Liners and tramp vessels have much difference in routing and in scheduling. And until now researchers have paid more attention to tramp ship routing than liner ship routing (Fagerholt, 1999). Likewise, the problem of a car shipping company in this study belongs to the tramp vessel ship routing. Concerning a tramp vessel ship routing problem, many researches have been made on the scheduling of a vessel fleet considering the ship's capacity and the time window. Ronen (1986) proposed three different algorithms for scheduling problem of the shipment of bulk or semi-bulk products from one depot to many destination

ports. In the paper, vessels had different capacities and returned back to the depot and also any time window constraints were not considered. Brown *et al.* (1987) addressed the routing and scheduling problem of several crude oil tankers of similar size to ship crude oil from the Middle East to Europe and North America. A vessel had a single loading port and discharging port. The paper considered time window constraints on loading and discharging duration. They used a set-partitioning approach for the problem.

Fagerholt and Christiansen (2000) addressed a dry bulk ship scheduling problem that is a combined multi-ship pickup and delivery problem with time window and multi-allocation problem. Each ship in the fleet is equipped with a flexible cargo hold that can be partitioned into several smaller holds. They proposed a set partitioning approach consisting of two phases for the combined ship scheduling and allocation problem. Jetlund and Karimi (2004) presented a mixed-integer linear programming model and a heuristic decomposition algorithm for the maximum-profit scheduling of a fleet of multi-parcel tankers engaged in shipping bulk liquid chemicals. Each product with time window needed to be delivered from the pick-up port to the discharge port under given shipment schedule. Al-Khayyal and Hwang (2007) developed a mathematical optimization model to determine a minimum cost routing schedule for a heterogeneous fleet of ships engaged in pickup and delivery of various liquid bulk products. In this paper, the inventory level of each port was considered to order to determine what amount of products has to be delivered from a supply port to a demand port. Brønmo *et al.* (2007) proposed a multi-start local search heuristic for a tramp ship scheduling problem. Also, Fagerholt (2001) proposed an approach based on a set partitioning formulation to solve a multi-ship pickup and delivery problem with soft time window.

These diverse researches have not been applied effectively to the fieldwork. The reason comes from the shipping industry's conservative way of thinking and practice that are reluctant to absorb new ideas (Ronen, 1993). Even today, most shipping companies are manually making a plan based on their experiences (Fagerholt, 2004). In an effort to break through the traditional ways of problem solution, efforts for the development of optimization-based DSS (Decision Support System) have been made, so that vessel fleet routing and scheduling has been made possible by using an advanced computer technology. Kim and Lee (1997) developed a prototype

optimization-based decision support system for the ship scheduling problem in bulk trade. Fagerholt (2004) developed TurboRouter, a decision support system for vessel fleet scheduling to handle the tramp and industrial shipping. This DSS has been used by several shipping companies as commercial software. They used two different heuristic algorithms of the insertion heuristic and hybrid local search algorithm for the vessel fleet scheduling.

The existing VRP is based on the assumption that all the input data must be known in advance and not be changed before determining a car route. But in order to apply it to reality, these assumptions should be changed and more flexible like TurboRouter. In reality, the vehicle's moving hours and customer's order can be changed frequently. Recently more attention is being paid to the dynamic VRP (Du *et al.*, 2005; Haghani and Jung, 2005). This study has tried to address the real problems. The main point in the dynamic VRP is to make a plan again and again in response to the changing input data. To this end, both a new algorithm to make a new plan and a new system to show the results of new planning as well as collecting changed data are necessary. Ruiz *et al.* (2004) developed a DSS tool for more effective decision making in solving a real routing problem in a real life company producing various livestock feed compounder. This paper has much in common in the sense that the paper of Fagerholt (2004) and Ruiz *et al.* (2004) are tackling the real problems.

3. The routing problem of a car shipping company

3.1 Definition of the routing problem

The routing problem of car carrier vessels is to find out the minimum cost route in which car carrier vessels have to carry many cars with different destinations from one depot to many destination ports and then return its departure port. Each vessel needs to have an optimal allocation of cars and a voyage route. All cars have their own destinations and each ship's destination is determined according to the destination of allocated car groups. It means that a determination of the car allocation and voyage has to be made simultaneously at the lowest cost.

The routing problem of car carrier vessels is similar to a VRP. Generally, the VRP has a short planning horizon and all vehicles and served products to customers are

prepared at the time of planning. Also, every customer is only served once by a vehicle. But in case of a car carrier vessel, it has a long planning horizon because a ship has longer duration of sailing than a vehicle. And the available date of each ship is different in planning horizon and the cars produced on a daily basis have different destinations. Many cars with the same destination are being produced on a daily basis. And the operation cost of a ship is very high, ship's unnecessary waiting time at a port increases the operation cost greatly. Also, in order not to cause the shortage of vessel in the next planning horizon, it has become a general rule not to wait at a port. This is the reason why the destinations are visited by several vessels.

The routing problem of car carrier vessels is based on the ship's available date and car's production schedule within the planning horizon. But each ship's available date, capacity and speed within the same planning horizon are different. Also, due to the feature of car carrier vessels, the pick-up and delivery of cars cannot be handled simultaneously at the same port and cars have no time window constraint. Also, all the vessels within the same planning horizon don't visit the depot again. For these reasons, the routing problem of car carrier vessel can be called an extended and complex VRP. Furthermore, owing to the frequent changing information such as car production schedule and vessel's arrival schedule within the long-range planning horizon, it has to be approached by way of the dynamic VRP. In other words, it has to be quickly updated based on the changing information. In order to tackle this problem, this study has developed a DSS system.

3.2 Maritime transportation planning process of a car shipping company

For the solution of the routing problem of car carrier vessels, first of all, we have to understand the features of delivered cars. Each car has its own number at the time of production and also exported cars have their own information on their destinations. Because of this, even though some cars belong to the same car category and model, they have to be transported according to their unique number. Also, gaps between a production plan and an actual production can occasionally take place, so the car manufacturer's production plan and real production volume have to be checked all the time. If there is a gap, the existing plan has to be modified.

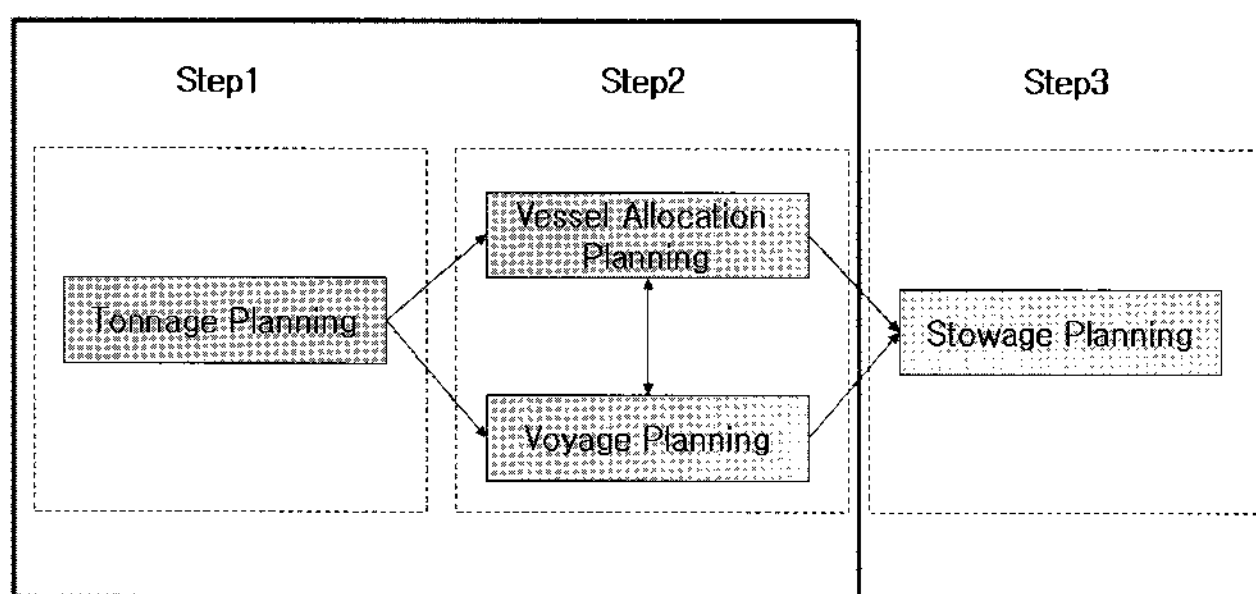


Fig. 1 Maritime transportation planning of a car shipping company

The maritime transportation planning of a car shipping company can be divided into four: tonnage planning, voyage planning, vessel allocation and stowage planning. The process of planning includes three steps like Fig. 1. The tonnage planning is to obtain, maintain and manage tonnage in order to keep balance between transportation volume and required tonnage during a certain period from the mid and long-term standpoint. It is badly needed to manage tonnage steadily before making a plan for vessel allocation and voyage. The reason is that it needs enough time to obtain necessary vessels in advance. The tonnage plan is to be made based on the information of yearly production schedule and then based on more recent information of the next three month from the time of planning. The one-year tonnage plan will be updated every month. After that, the vessel allocation and voyage planning will be made for the cargo volume to be handled this month, based on the tonnage planning. Voyage is the visitation order of each ship's destination and vessel allocation is what cargo to be loaded and how much to be loaded. Since each cargo (cars) has its own number and destination, a car carrier vessel's destination depends on what cargo is loaded on it. Also, as the visitation order of destination has a significant effect on the voyage cost, vessel allocation planning and voyage planning are being conducted simultaneously. In this study, the routing problem of car carrier vessels is the vessel allocation and voyage planning determined simultaneously. Table 1 shows what data is needed for each stage of the planning.

Owing to the occasional gaps between a shipper's (auto manufacturer) production schedule and actual production volume, the routing problem of a car carrier vessel needs to be solved on a short-term basis. For more accuracy, one month-based transportation planning is made based on the short-term cargo information including car categories and exported countries. Accordingly, the routing problem of car carrier vessels is solved by a month.

Table 1 Data needed in the maritime transportation planning

Section	Necessary data	Data contents and size	Data collection period	Data provider
Tonnage planning	Annual production plan	Monthly total production volume (by the year)	At the end of November of the previous year	Shipper
	Monthly production plan	Monthly total production volume (by the quarter)	At the end of the previous month	
Vessel allocation & Voyage planning	Production volume by exported country	Car category, cargo volume by exported country (by the month)	At the end of the previous month	
	Daily production volume	Car category, exported country, daily production volume (by the month)	Everyday	

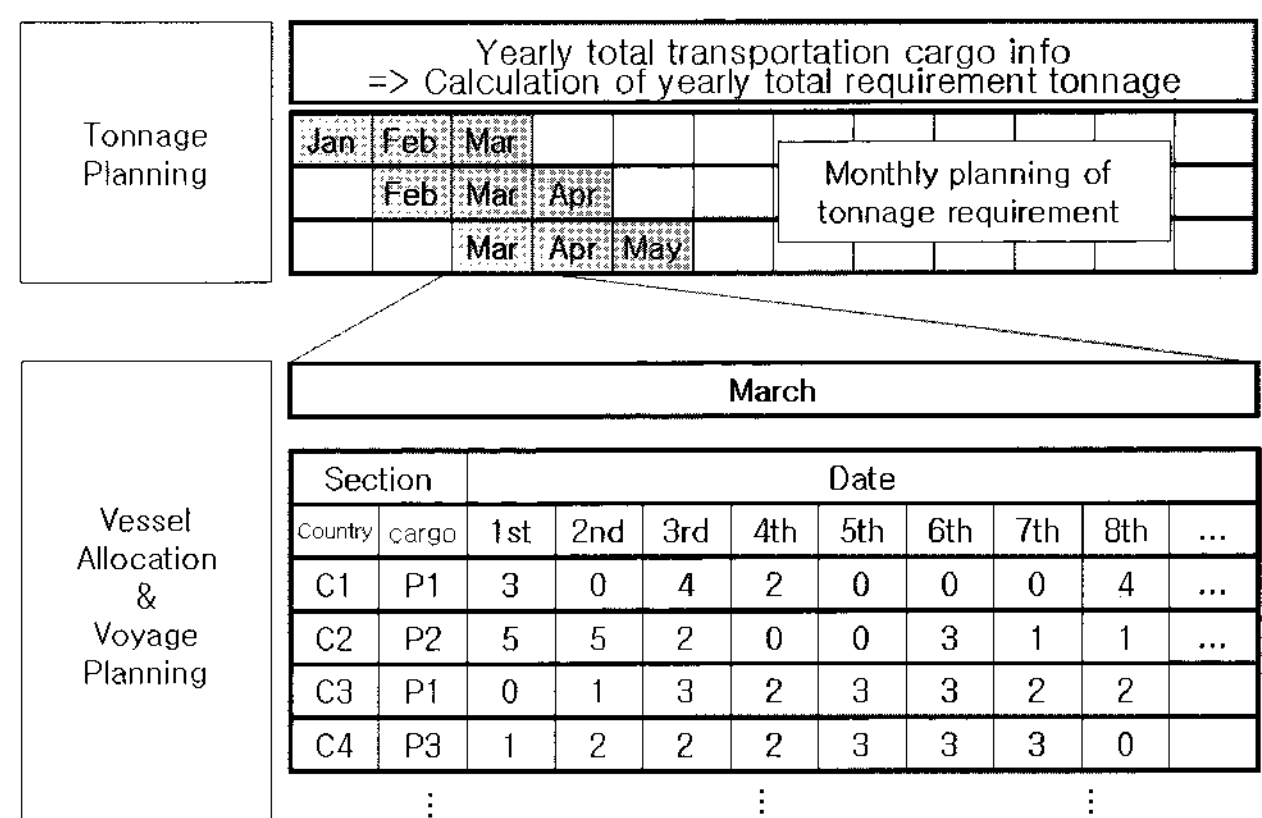


Fig. 2 Routing problem of car carrier vessels

Vessel allocation addresses the problem of what cars and how much has to be allocated to which ship. For this each ship's capacity and arrival schedule should be considered and then cars having a similar production date have to be grouped according to their destination and allocated to each vessel (see Fig. 2). It is needed because the cars to be carried are produced on a daily basis and the daily production volume for a certain destination is not enough for the available tonnage of each vessel. Also as it matters to the voyage cost how to group cars with destination and the daily production volume, voyage cost has to be considered in the vessel allocation.

3.3 Integer programming model

The routing problem of car carrier vessels is to address the vessel allocation and voyage in which each vessel starts from the depot, delivers cargo to the destinations in sequence and returns again to the departure port, while all

these processes being conducted at the lowest cost and in the least number of vessels. The basic assumption and IP (integer programming) model in this study are as follows:

- The number of cars to be delivered and their destination within the planning horizon are known in advance.
- Car production schedule and vessel arrival schedule are already known.
- The number of vessels to deliver cars and vessel's capacity are known in advance.
- As each vessel has the different capacity and speed of its own, their cost structures (including fixed cost) are also different with each other.
- Each port has a different stevedoring charge.
- The cars that can not be delivered within the planned period are carried over to next month.

Indices

i = node (destination)	$(i = 0, 1, 2, \dots, N)$
j = node (destination)	$(j = 0, 1, 2, \dots, N)$
※ 0 is depot	
k = date in a planning period	$(k = 0, 1, 2, \dots, K)$
s = the number of vessel	$(s = 0, 1, 2, \dots, S)$

Parameters

TP_{ijs} = the voyage cost of vessel s from node i to node j
DC_{sj} = the stevedoring charge of vessel s at the node j
PQ_{jk} = the number of cars produced at the k date having a destination j
PS_{jk} = the production date of cars produced at the k date having a destination j
AL_s = the arrival date of vessel s at the depot
CP_s = the capacity of vessel s
CO_{jk} = the penalty cost caused by carrying over to the next month the cars produced at the k date having the destination j

Variables

$$x_{ijs} = \begin{cases} 1, & \text{if vessel } s \text{ goes on a voyage from node } i \text{ to node } j \\ 0, & \text{otherwise} \end{cases}$$

$$y_{sjk} = \begin{cases} 1, & \text{if vessel } s \text{ loads the cars produced at the } k \text{ date} \\ & \text{having destination } j \\ 0, & \text{otherwise} \end{cases}$$

$$y_{sj} = \begin{cases} 1, & \text{if vessel } s \text{ visit the destination } j \\ 0, & \text{otherwise} \end{cases}$$

$$Z_{jk} = \text{Min} \sum_{i=0}^N \sum_{j=0, j \neq i}^N \sum_{s=1}^S TP_{ijs} \cdot x_{ijs} + \sum_{s=1}^S \sum_{j=0}^N DC_{sj} \cdot y_{sj} + \sum_{j=1}^N \sum_{k=1}^K CO_{jk} \cdot z_{jk} \quad (1)$$

subject to

$$\sum_{s=1}^S \sum_{j=1}^N \sum_{k=1}^K PQ_{jk} \cdot y_{sjk} + \sum_{j=1}^N \sum_{k=1}^K PQ_{jk} \cdot z_{jk} = \sum_{j=1}^N \sum_{k=1}^K PQ_{jk} \quad (2)$$

$$\sum_{k=1}^K y_{sjk} - M \cdot y_{sj} \leq 0 \quad \text{for all } s, j=1, \dots, N \quad (3)$$

$$\sum_{j=1}^N y_{sj} - M \cdot y_{s0} \leq 0 \quad \text{for all } s \quad (4)$$

$$\sum_{i=0, i \neq j}^N x_{ijs} = y_{sj} \quad \text{for all } s, j \quad (5)$$

$$\sum_{i=0, i \neq j}^N x_{jis} = y_{sj} \quad \text{for all } s, j \quad (6)$$

$$\sum_{i \in T} \sum_{j \in T} x_{ijs} \leq |T| - 1 \quad \text{for all } s, |T| \neq 0, (i \neq j) \quad (7)$$

$$\sum_{s=1}^S y_{sjk} + z_{jk} = 1 \quad \text{for all } k, j=1, \dots, N \quad (8)$$

$$\sum_{s=1}^S PS_{jk} \cdot y_{sjk} - \sum_{s=1}^S AL_s \cdot y_{sjk} \leq 0 \quad \text{for all } j, k \quad (9)$$

$$\sum_{j=1}^N \sum_{k=1}^K PQ_{jk} \cdot y_{sjk} \leq CP_s \quad \text{for all } s \quad (10)$$

$$x_{ijs}, y_{sjk}, y_{sj}, z_{jk} = \{0, 1\} \quad \text{for all } s, i, j, k$$

M = big number

T = every possible subset of a destination

Objective function formula (1) minimizes the total costs of transportation cost, stevedoring cost and carry-over cost that are caused by vessel voyage after car allocation to the vessel. Formula (2) enables the total number of car production within the planning period to be equal to the cars to be delivered plus the cars to be carried over next month. Formula (3) makes the y_{sj} value of vessel s "1" when the cars produced at the k date with destination j

were loaded on the vessel s . It also makes the vessel s visit the destination j only once even if cars produced at the couple of k date with destination j have been loaded on it. In case that the cars bound for destination j have not been loaded on the vessel s , it makes the y_{sj} value of the vessel s "0". Formula (4) makes all the vessels departed with cars loaded on it return to the depot. It also makes the y_{s0} value "1" if vessel s once visits a destination. Formula (5) and (6) makes a vessel visit a destination only once. Also, it provides the vessel s with a continuing route, so that it may go on a voyage from a visited destination to the next. Formula (7) eliminates the sub-tours coming from the voyage route of vessel s . Formula (8) makes the cars produced at the k date for destination j are loaded on the same vessel. The cars produced on a daily basis are to be grouped and loaded at the same vessel. Formula (9) allows the cars for destination j to be loaded on the vessel s only in case that the car production schedule is earlier than the vessels' arrival date or the same. In order to save vessel's waiting costs at a port, vessels are departed the very next day. At this formula, the waiting day of a vessel is controllable. Formula (10) does not allow the total number of cars loaded on vessel s to exceed the capacity of a

vessel.

Table 2 The basic data of vessels

Vessel name	Capacity	Available date	Fuel efficiency (l/mile)	Speed (knot)
0	3,200	2008.01.12	22.6	16
1	3,000	2008.01.09	20.0	18
2	2,700	2008.01.31	23.8	16
3	2,900	2008.01.25	23.9	17
4	2,700	2008.01.20	21.4	16
5	3,300	2008.01.11	22.2	18
6	3,400	2008.01.15	23.4	18

3.4 An example of maritime transportation planning through IP model

In order to show how the vessel allocation and voyage plan of a car carrier has been made through IP model, here is a simplified example. Table 2 shows available vessels' name and available capacity, available date (the arrival date at the departure port), fuel efficiency of each vessel for one month. The fuel efficiency of each ship is included in shipping costs.

Table 3 Daily production output of cars to be shipped to each destination port

Destination port	Daily cargo																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
B	70	60	75	80	75	80	80	95	85	95	65	60	80	85	70	85	95	60	60	90	55	75	75	50	60	95	95	65	50	60	80
C	60	55	70	85	60	85	55	90	90	55	95	75	80	75	55	50	90	95	80	85	50	85	90	65	55	80	85	75	75	95	60
D	85	50	75	75	95	85	55	60	70	55	60	50	85	50	50	85	80	50	65	95	85	70	85	50	55	65	70	55	80	80	90
E	70	60	55	60	80	70	95	95	80	70	80	75	50	95	75	65	60	75	75	55	55	65	85	85	95	55	90	55	70	70	85
F	65	80	55	50	70	85	80	50	80	60	70	60	80	60	80	85	85	50	90	70	60	55	65	70	60	75	70	85	70	95	90
G	95	85	70	65	95	60	70	75	85	70	55	50	55	90	50	75	90	50	50	65	65	50	95	95	50	95	75	95	55	60	65
H	65	90	55	95	60	90	85	55	95	85	55	50	65	85	90	80	60	60	65	70	95	85	75	80	80	70	60	90	50	90	60

Table 4 The distance between each port (mile)

	A	B	C	D	E	F	G	H
A	0	244.38	496.16	272.92	530.52	295.91	418.90	297.41
B	244.38	0	252.17	255.63	305.68	149.35	260.10	420.40
C	496.16	252.17	0	436.21	176.92	293.47	302.23	635.74
D	272.92	255.63	436.21	0	374.00	142.76	202.03	207.54
E	530.52	305.68	176.92	374.00	0	251.27	184.36	581.17
F	295.91	149.35	293.47	142.76	251.27	0	126.57	345.03
G	418.90	260.10	302.23	202.03	184.36	126.57	0	404.43
H	297.41	420.4	635.74	207.54	581.17	345.03	404.43	0

Table 3 shows the total number of cars produced in order to ship from depot to each destination port in the order of calendar date of January. The total number of cars was obtained including the weights for the size of each car. Table 4 is the distance between each visiting port and table 5 shows the stevedoring (per car) and anchorage fee at each visiting port.

Table 5 The stevedoring and anchorage fee (US \$)

Port	Stevedoring fee	Anchorage fee
A	9	351
B	7	401
C	9	443
D	7	407
E	9	477
F	8	469
G	9	401
H	7	489

Table 6 and table 7 show the results of handling these data through the IP model. Table 6 shows the results of vessel allocation per each day, that is, what and how many cargoes have been allocated to which ship. X implies that it is carried over to the next month. The figures in each cell refer to the ship. Table 7 presents the

Table 6 The results of vessel allocation per each day

Port	Daily cargo																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
B	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	4	4	4	4	4	3	3	3	3	3	2	X	2	2	2	2
C	5	5	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4	3	3	3	3	3	3	2	2	2	2	X	2	
D	1	1	1	1	1	1	1	1	1	6	6	6	6	6	6	4	4	4	4	4	3	3	3	3	3	2	X	2	2	2	2
E	5	5	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4	4	3	3	3	3	3	2	2	2	2	2	X	2
F	5	5	5	5	5	5	5	5	5	5	6	6	6	6	4	4	4	4	4	3	3	3	3	3	2	2	2	2	X	2	
G	6	6	6	6	6	6	6	6	6	6	6	6	6	6	4	4	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2
H	6	6	6	6	6	6	6	6	6	6	6	6	6	6	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2

Table 7 The results of voyage plan

Vessel name	Routes								
	Depot	1st	2nd	3rd	4th	5th	6th	7th	8th
0									
1	A	D	A						
2	A	B	C	E	G	F	D	H	A
3	A	B	C	E	G	F	D	H	A
4	A	B	C	E	G	F	D	A	
5	A	B	C	E	F	A			
6	A	H	D	G	F	B	A		

results of voyage plan showing the route of each ship, i.e. the routes of each ship that returns to the depot after visiting many ports. Total operating costs (the value of objective function) were US \$239,631. By using the computer of CPU 2.0GHz and Ram 512MB and ILOG CPLEX 10.0, the results have been computed in 297 seconds. These results are easily available by ship or by date in the maritime transportation support system. The bigger problems than this example take long computational time. It causes us limit maximum computation time in 2 days and the results were used for the problems of big size.

4. Maritime transportation planning support system for a car shipping company

The routing problem of car carrier vessels has generally a long planning horizon and the basic data for MTP (maritime transportation planning) can be changed frequently. For example, due to a process trouble or a strike, the production schedule can be changed, consequently changing the cargo volume to be delivered. Owing to the foul weather that causes a voyage delay or vessel failure, the vessel cannot be available at the scheduled time. Because of this, even if the MTP has been made based on the initial data, but cannot respond

to the changing factors, the planning becomes useless. Therefore, the changes in the basic data have to be managed systematically and used in modifying the initial plan. IP model can be used for making a plan again.

But sometimes, the use of IP model is rather inconvenient than a user himself revises it. For example, in case that the cargo loading is imminent or the changes in the cargo volume are so trivial, it can be more efficient if a user directly revises the original plan. In this case, the system should be able to help the user revise the plan. Also, it should help the user monitor various data related to the transportation planning. The system should support information of current state for each vessel, so that the user can control that no error or trouble may take place in the vessel's arrival schedule. For easy monitoring and smooth modification of an existing plan, this study has developed a RIA (Rich Internet Application) based user interface, which facilitates the mutual operation between a user and a system. The user interface of this study is developed on FLEX 2.0.

The function of MTP support system can be divided into two as demonstrated in fig. 3: one is a basic information management function and the other is a planning and management function. The basic information management performs the function of managing various data needed for planning. That is, it inputs, revises and refers to the various information including cargo, tonnage and tariff. The planning and management performs the function of making a plan based on the basic information and monitoring the changes of the basic information and then modify the existing plan in response to the changes.

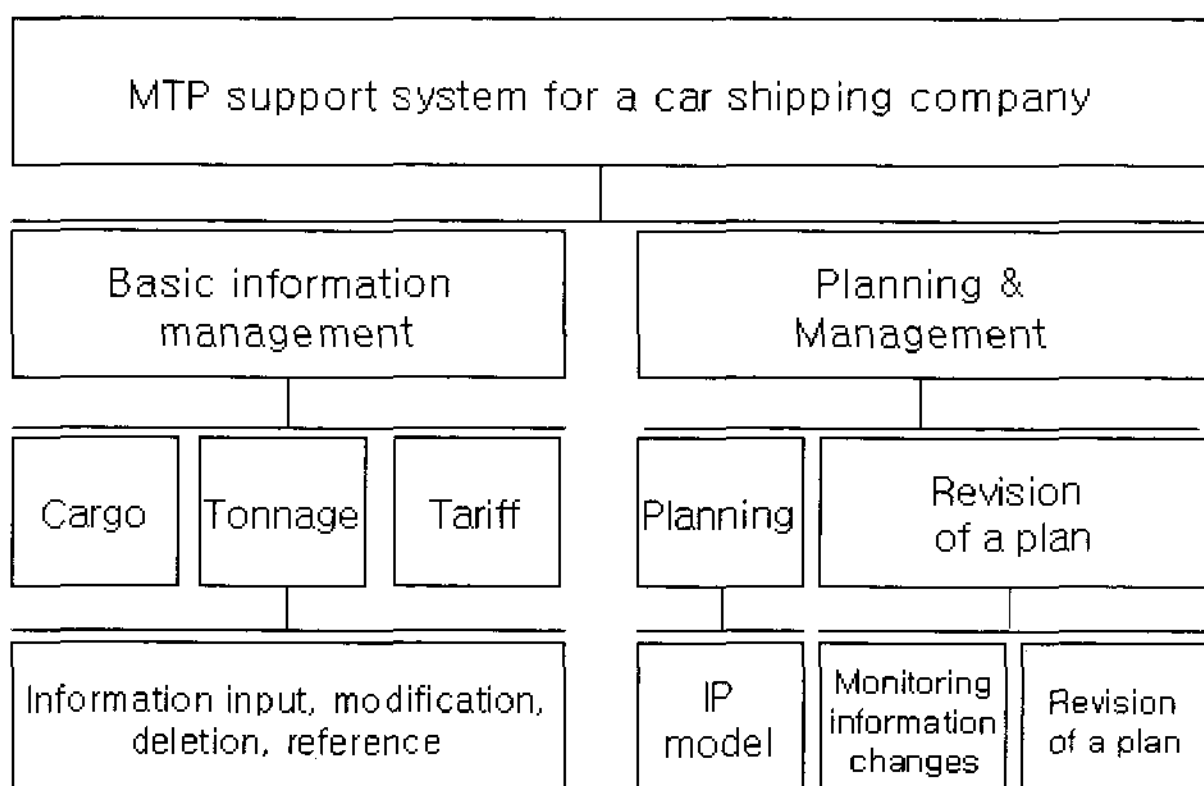


Fig. 3 Function of the MTP support system

The basic data such as cargo, tonnage and tariff has to be inputted in advance for MTP. In particular, the latest data has to be used for MTP. Meanwhile, if changes take place in the car production schedule or in the vessel's arrival schedule after MTP has been made, the decision

maker should be able to modify the initial plan based on the new information. Therefore, a MTP support system has to be able to update all the necessary information. Fig. 4 shows a screen of the system that inputs, modifies and refers to the basic data needed for MTP. There is another screen that manages freight, tariff and the basic information related to vessel operation.

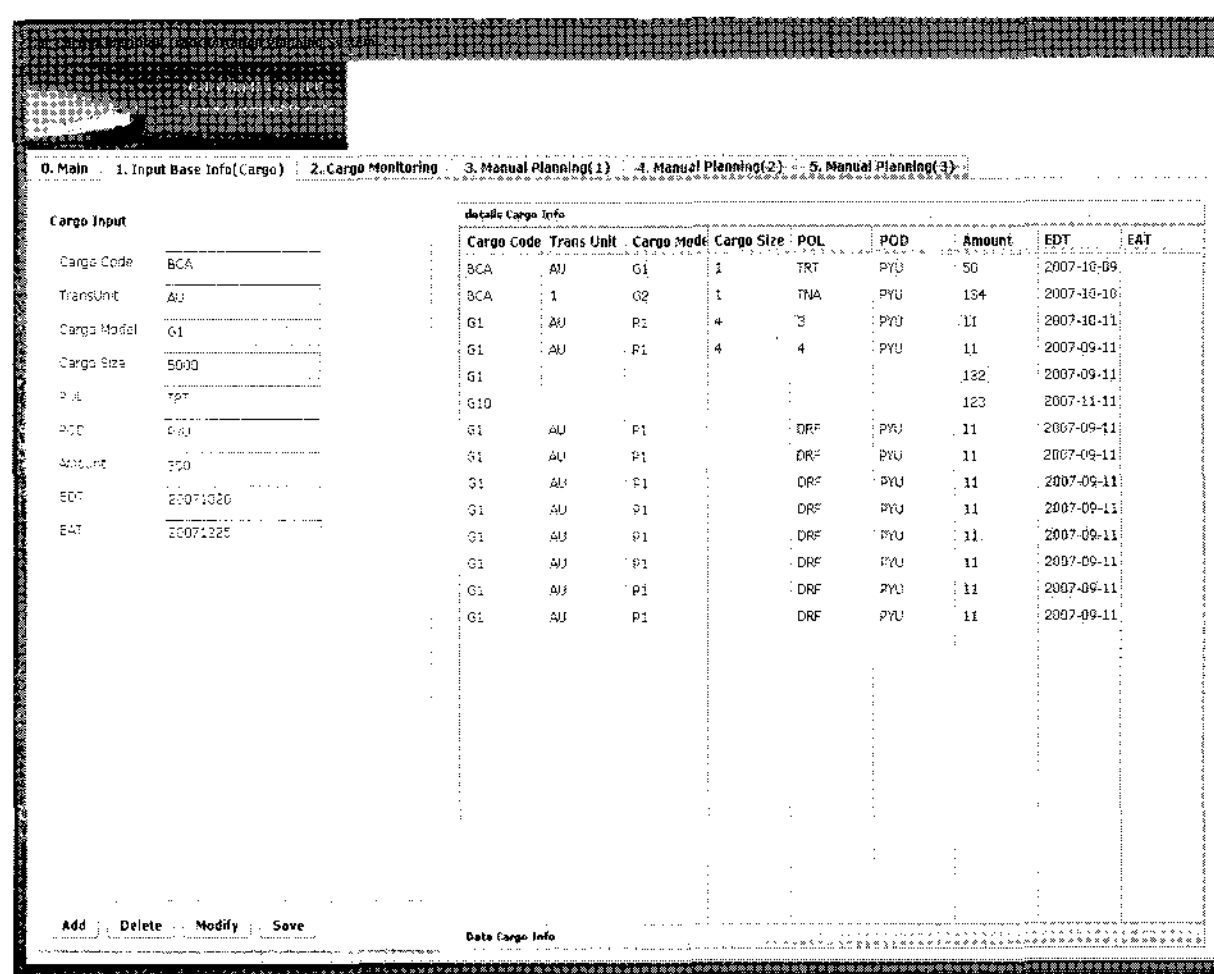


Fig. 4 Cargo information management for MTP of a car shipping company

Fig. 5 shows a screen that includes the vessel allocation and voyage of each vessel, which can be made by the solution of routing problem of car carrier vessels. The upper side of the screen provides a user with an optimal solution generated by IP model. The optimal solution was generated through CPLEX 10.0 of ILOG.

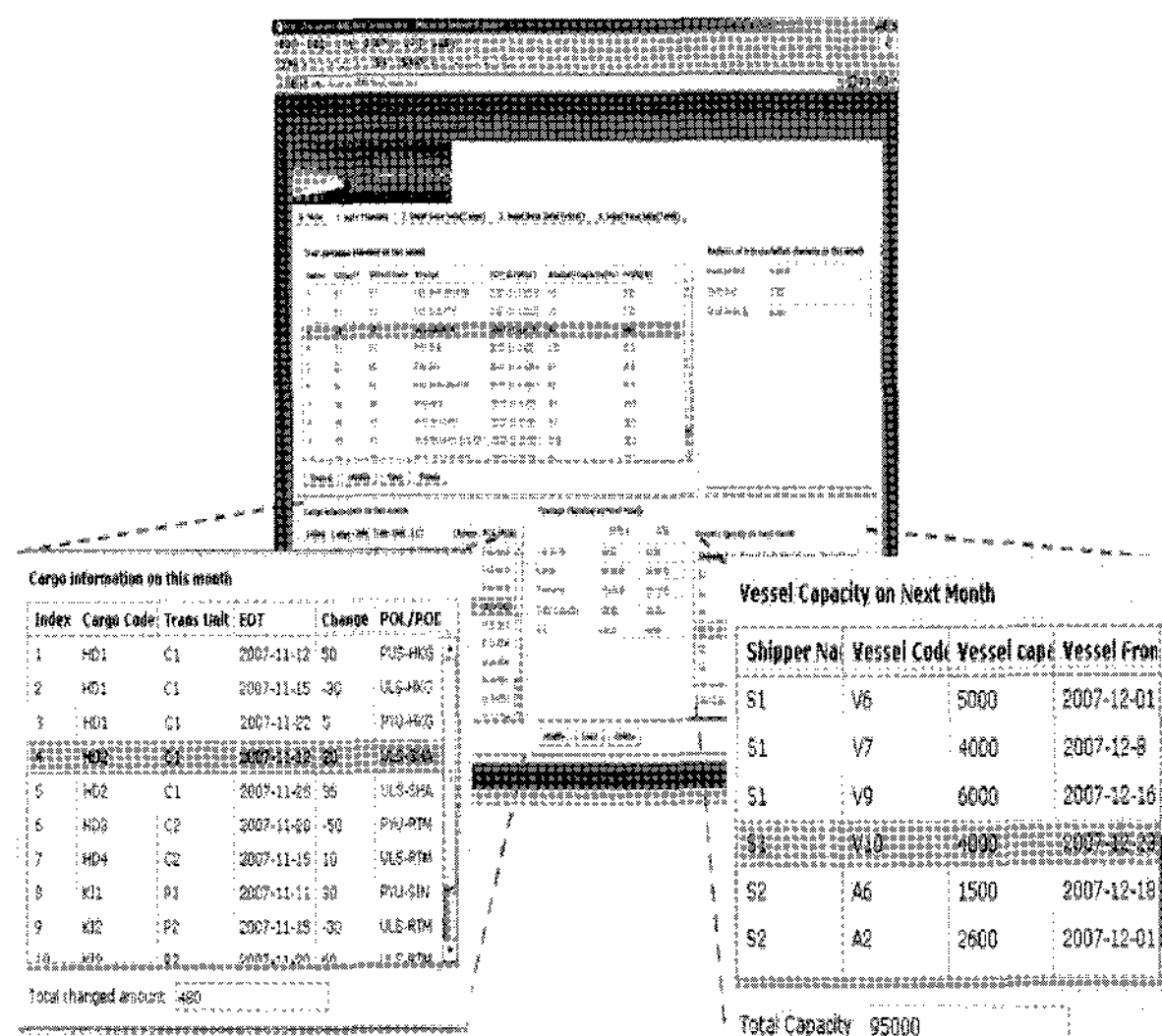


Fig. 5 A screenshot of MTP support system

The output screen includes such information as vessel's voyage route, ship's available capacity, loaded cargo

volume and profits. Meanwhile, the lower left side of the screen shows cargo information changes that have taken place after planning. Here, a user can modify the existing plan by the drag & drop a cell. If the new plan for this month is completed, it provides the carry-over cargo information that will have an effect on the tonnage planning of the next month. Therefore, the user can check how much tonnage is additionally needed for the next month (or after that). This is shown in the lower right side of the screen.

The MTP support system of this study automatically suggests to the users the results of MTP with the lowest cost, by using an IP model. Also, whenever changes take place in the basic information, it can again generate an optimal solution by using the IP model. But when cargo loading is so imminent, or when changes are trivial - in other words when there is no time to use the IP model, this MTP support system makes it possible for users to respond to the changes by modifying the existing plan directly. Also all the information needed for decision-making is shown on a screen, thus improving user's decision-making ability. This MTP support system was developed for a car shipping company in Korea. Efficient MTP leads to the profitability improvement of car shipping companies, making it possible to provide a better and cheaper service to the shippers, consequently making a contribution to reducing the logistics cost of auto makers.

5. Conclusion

For efficient maritime transportation planning for a shipping company, this study developed a MTP support system. By using an IP model, we have transformed the traditional manual planning method into an automated planning system, while providing users with an optimal solution at the viewpoint of cost. In addition, in response to the dynamic changes in the basic information taking place after planning, this system has made it possible for users to speedily modify the existing plan manually. That is, this study has tried to solve within the system all the problems coming from dynamic changes in the real world. However, the problem is very complicated because the planning horizon of the routing problem is long. The time required for an optimal solution increases exponentially according to problem size. Therefore, in an effort to cope with this difficult situation, much more efforts should be made together with heuristic approaches. Also, the MTP support system of this study can be further improved by

forecasting the delivered cars volume in a long-term viewpoint and by supplementing current tonnage management.

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