A Research on the Improvement Strategy on the Operation Performance of Container Terminal

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Abstract: This research intends to carry out study on the strategy of improving the operating performance of container terminal from the software aspect through quantitative simulation model. Shipping strategic alliance is popular in recent years and it is anticipated to base on the improvement strategy on berth to enhance the operating performance of container terminal. This research applies three evaluation indicators (average waiting time, waiting time factor and the author create indicator) to evaluate the operating performance with three different schemes (berth charter, berth exchange and common berth). The research results show that no matter which type of the above evaluation methods is adopted and according to the research on the sample cases of shipping companies the operation performance of the scheme of common berth is most significant.

Key Words: *Simulation model, evaluation indicator, operation performance, strategic alliance*

1. INTRODUCTION

Sea transportation business is an industry with high investment, low profit and long recovery period. Ship owner has to put in a lot of capital. However, very often the rate of return on investment is not as high as expected and the operating risk is high. Nevertheless to a certain extent the development of strategy alliance can reduce risk. On one hand, strategic alliance can avoid excessive idling of berth or a lot of rental. On the other hand, it can reduce the number of competitors and the level of competition. The rationalization of utilization of resource integration is one of the main purposes of enterprise operation and management. Through alliance, shipping companies can enhance their competitive strength and can compete with liner companies without strategic alliance.

No matter how the sea transportation market and the international situation will change. In order to satisfy requirement of consignees and to provide high quality service and sustainable operation of the company, shipping companies should continue to search for new operating method and strategy. 「Strategic alliance」 is the feasible route for operators at present. This is because strategic alliance can expand the market share of shipping companies, reduce risk and operating cost, generate economy of scale and sharing of new technology.

International sea transportation company should include 「sea transportation strategic alliance development」 in the strategy of operating development, apply limited source of the fleet efficiently, maintain low cost advantage and enhance service standard and strengthen competitive advantage so as to survive and develop in this market with fierce competition. In recent years, ship tonnage is developed towards economy of scale that means towards large scale. However, for ship owner of a single large container ship, how to satisfy the condition that if its ship has suitable berth? In addition, during leasing or building berth, consideration has to be given to the berth length, water depth, deployment of gantry crane and the area of the backline stacking site etc. Through the alliance method of berth charter, berth exchange and common berth, the excessive idling of berth and consumption of resource can be reduced so as to avoid malignant competition in the sea transportation market.

According to the definition on strategic alliance by many scholars including (Eelmuti and Kathawala, 2001; Breucellaria, 1997; Das and Teng, 1999)，strategic alliance can be defined as: in order to achieve specific strategic goals and to reach the specific market objectives, two or more enterprises will exchange or provide resource of each other so as to enhance the competitive advantage and competitive strength of the enterprise. Based on the definition in the Weber Dictionary, strategic is "important", alliance is "associations to further the common interests of the members". Therefore strategic alliance can be defined as 「an important combination in order to achieve the common benefit of each other.」

The operation with strategic alliance method by shipping companies are very successful, for example, the CKYH alliance (COSCO/K Line/Yang Ming/Hanjin), New World Alliance (APL/MOL/Hyunadai) that can effectively improve the operation efficiency and competitive strength and can also greatly reduce cost and improve the loading and unloading operation efficiency. There are already many relevant researches on this aspect including study conducted by (Cullinance and Khanna, 2002; Pierre, 2002; Midoro and Pitto, 2000; Heaver et al., 2000; Midoro, et al., 2005; Acosta, et al., 2007; Huang, et al., 2007; Petering et al., 2009). Although there are many literatures on the strategic alliance on shipping line, yet quantitative literature on the study on improvement strategy of container terminal management is quite in shortage. Except Dong et. al, (2000) who points out those shipping companies with neighboring port can conduct alliance operation and its berth, crane and equipment, human resource and information can be utilized mutually. The rest of the literatures on improvement strategy for container terminal operation management are not too many.

In the liner market, the implementation of strategic alliance has been popular for many years including Ship-owners' Association, Shipping Conference, Rate stabilization agreement, Ship pooling agreement, Slot charter and Slot exchange etc. Ports leased by many shipping companies in Kaohsiung Port are in different container center and integration is not easy for the Port Authority. For example, ***Y*** Ocean Carrier of Kaohsiung Port leases #70 berth in T3 Container Center and #120 berth in T4 Container Center, respectively. Transportation in different container center will generate problem of entry and exit control station, customs escort in transportation, increase of transportation cost and low efficiency in loading and unloading operation. In addition, due to the uncertain sea transportation market, the special port of the shipping company cannot cope with the requirement resulting in frequent idling in the nearby port very often. Moreover, due to the development trend of large ship, problems like length of the special wharf, berth quantity, draft depth, operation crane and wharf backline stacking site become more serious. In order to handle the above problems, this research conducts study on shipping companies of neighboring berth utilizing improvement strategy of slot charter, slot exchange or common slot to enhance the operation performance of the container base.

2. EVALUATION INDEXES RELATED TO COST FUNCTION

Plumlee (1966) and Nicolau (1967) utilized the minimized berth waiting cost and berth idling cost as their target function. Wanhill (1974) took the cost of the ship's operating time into account. Schonfeld and Sharafedien (1985) also took the cargo storage costs of the yards into account. Yoshikawa (1987) took even more loading and unloading costs into consideration. This paper sums the cost functions presented by various documents since 1960 into three main categories. Initially, Plumlee (1966) utilized the minimized ship waiting cost (SWC) and berth waiting cost (BWC).

Nicolau (1967) then considered the BWC and service cost in respect of berth (BSC). Considering just the ship, the SWC was calculated. Noritake and Kimura (1990) added the cost of the ship service time in port (SSC) and formed the cost function which is now widely used by the various shipping sectors.

Talley (1994) offered that performance standards are the values of the performance indicators that optimize the port's objective(s), i.e., if these standards are achieved, the port would be effective and efficient.

For a approximate solution of the queuing system and whether or not there is change in the berth service rate (ρ), there are still many places that are not stringent enough. So, this paper considers the non-dimensional evaluation indicator (UC) presented by Huang et al. (1995) as the basis on which to evaluate the deployment of the berths and cranes, and the performance of the terminal.

The total cost of the ship in port can be divided into two large items: the ship and cargo cost (C_1) and the port service cost (C_2). C_1 is the cost incurred by the port user (ocean carrier etc.), it includes: the cost of building, maintenance and repair, and operations management the ship, known as the ship cost C_s. The cost of the cargo carried on the ship and the related interest costs are defined as C_{cg}.

$$C_1 = C_s + C_{cg} \text{ (\$.ship/hr)} \tag{1}$$

Furthermore, C_2 includes the cost of the following items: construction of the port facilities, maintenance and repair and operational management, crane handling and related activities, and cargo storage.

$$C_2 = C_{pf} + C_{po} + C_{bf} + C_{bo} + C_{cm} + C_{co} + C_{yd} \text{ (\$.ship/hr)} \tag{2}$$

Where this equation,

C_{pf}: construction costs of port facilities except for that of the berth,
C_{po}: port operation costs except for that of the berth,
C_{bf}: construction costs of the berth facilities,
C_{bo}: berth operation costs,
C_{cm}: cost of crane and its handling and maintenance costs,
C_{co}: working costs of operators using crane,
C_{yd}: costs of the storage yard.

The above equation (1) and (2) include the queuing mode characteristics and various port costs for ship. Therefore, various costs can be formulistic and separated in detail as follows:

(1) C_s and C_{cg}

According to the queuing theory $M/E_K/N$ model, the anticipated number of ship (L) of the port system can be written as:

$$L = \lambda/\mu + L_q \tag{3}$$

L_q : Waiting line average numbers of ship (ships)

Therefore, assuming that the unit time cost of one ship at the port is U_s (NT$/time per ship), then the unit time cost of ship in the port shall be:

$$C_s = U_s \cdot (\lambda/\mu + L_q) \tag{4}$$

λ: Ship arrival rate (ship/hour), $1/\mu$: Ship average service time

Moreover, assuming that the unit cargo (tons, TEUs), unit time of cargo and the interest cost of its related outfit is U_{cg} (NT$/hour. Ton), then the unit time cargo on the ship and the cost of related outfit C_{cg} shall be:

$$C_{cg} = U_{cg} \cdot \chi \cdot (\lambda / \mu + L_q) \tag{5}$$

χ : Average carrying cargo volume of ship (TEUs)

(2) C_{pf}, C_{po}, C_{bf} and C_{bo}

Whereas when the four items including port construction cost beyond the berth (C_{pf}) and its operation management cost (C_{po}), berth construction cost (C_{bf}) and its operation management cost (C_{bo}) are all calculated based on the unit time cost of one berth, then its unit cost shall be U_{pf}, U_{po}, U_{bf} and U_{bo} respectively. Then this is multiplied by the number of berth N respectively and the port facilities and its related cost can all be obtained as follows:

$$C_{pf} = U_{pf} \cdot N \qquad C_{po} = U_{po} \cdot N$$
$$C_{bf} = U_{bf} \cdot N \qquad C_{bo} = U_{bo} \cdot N \tag{6}$$

(3) C_{cm} and C_{co}

Assuming that the average number of installation handling crane in a berth is AC, And supposing that there are N berths at a port; U_{cm} is the cost of a machine per crane hour; U_{co} is the cost of operation per crane hour and then C_{cm} and C_{co} can be obtained respectively as follows:

$$C_{cm} = U_{cm} \cdot N \cdot AC \tag{7}$$
$$C_{co} = U_{co} \cdot AC \cdot T \cdot \lambda \tag{8}$$

AC: the average number of gantry cranes deployed in a berth
$T = V / (AC^f \cdot \gamma)$: the average operation time per ship per hour
V : Average loading and unloading volume per ship at port (tons or TEUs)
f : Interruption coefficient during operation of one set or more loading and unloading crane in one berth
γ : Operation efficiency of loading and unloading crane (TEUs/hour)

(4) C_{yd}

If the storage cost of the unit time of unit cargo (tons, TEUs) is expressed with U_{yd}, then the cost of the cargo storage yard shall be:

$$C_{yd} = U_{yd} \cdot V \cdot H \cdot \lambda \tag{9}$$

H : Unit cargo average storage time (hours/TEU)

By substituting the above E_q. (3) ~ (9) into (1) and (2), then the total cost of ship at port can be expressed as:

$$\begin{aligned} TC &= C_1 + C_2 \\ &= (U_s + U_{cg} \cdot \chi)(\lambda/\mu + L_q) + (U_{pf} + U_{po} + U_{bf} + U_{bo}) \cdot N + U_{cm} \cdot N \cdot AC \\ &\quad + U_{co} \cdot AC \cdot T \cdot \lambda + U_{yd} \cdot V \cdot H \cdot \lambda \end{aligned} \tag{10}$$

Therefore, this paper defines the total cost at the port of the unit cargo (ton, TEU) and unit time (Hour) as follows:

$$UC = TC／(\lambda \cdot U_s \cdot V)$$
$$= [(1+R_{cg})\ (1/\mu+W_q) + (R_{pf}+R_{po}+R_{bf}+R_{bo})\ \times N/\lambda + R_{cm}\ (N\times AC)\ /\ \lambda + R_{co}\times AC\times T + R_{yd}\times V\times H\ ]／V \tag{11}$$

R_{cg}, R_{pf}, R_{po}, R_{bf}, R_{bo}, R_{cm}, R_{co}, R_{yd} are, respectively, the ratio of $U_{cg}\cdot\chi$, U_{pf}, U_{po}, U_{bf}, U_{bo}, U_{cm}, U_{co}, U_{yd} and U_s.

The dimensional analysis of UC in equation (11) is as follows:

$$UC = \frac{TC}{\lambda \cdot V \cdot U_s} = \frac{\$/(hr \cdot TEU)}{ship/hr \cdot TEU/ship \cdot \$/(hr \cdot ship)} = \frac{\$/(TEU)^2}{\$/(hr \cdot ship)} \tag{12}$$

Namely the ration of unit cargo in port total cost and the cost of ship unit time, owing to numerator and denominator are unit of money, so the UC unit is an no dimensional.

In order to consider the cost items for the demand user (ocean carrier) and supplier (port authority), this research uses the UC evaluation indicator to evaluate various schemes. Further details on the UC indicator can be found elsewhere (Huang, 1990; Lu, 1991). The parameters have been updated and the relevant numbers are given in Table 1.

Table 1 UC evaluation indicator setting value

parameter	parameter illustrate	Huang (1990)	Lu (1991)	This study
AC	the average numbers of handling crane	1~5	1~5	1~5
R_{cg}	the ratios of interest cost of its relevant equipment	0.25~1.5	0.375	0.126
R_{pf}	the ratios of construction costs of port facilities except for that of the berth cost	(0~5)×R_{bf}	3.9*R_{bf}	1.62*R_{bf}
R_{po}	the ratios of port operation cost except for that of the berth cost	(0.05~0.2)×R_{pf}	0.13* R_{pf}	0.2* R_{pf}
R_{bf}	the ratios of construction costs of berth facilities	0.1~1.0	0.232	0.494
R_{bo}	the ratios of berth operation cost	(0.1~0.2)×R_{bf}	0.13* R_{bf}	0.2* R_{bf}
R_{cm}	the ratios of cost of handling crane and its maintenance costs	0.01~0.2	0.11	0.2
R_{co}	the ratios of working costs of operators using crane	(0.5~1.5)×R_{cm}	0.13* R_{cm}	0.357
R_{yd}	the ratios of the storage yard costs	0~6×10^{-5}	0.00014	0.00009

The judgment of whether or not a reasonable evaluation criterion can be achieved is established from the definition of the UC. If can obtain the minimum UC value with simulation, show that has already reached the rational evaluation value. The lower the value of the UC indicator, the lower is the total cost of the unit cargo. In other words, the port will be performing more effectively and efficiently. Longer service times for the ships result in longer waiting times when the port has insufficient equipments and irrational management.

3. MODEL FORMULATION

3.1 Design simulation program

The logic of the simulation program of this research is established according to the actual condition of the Kaohsiung Port Container Terminal. FORTRAN programming language was adopted instead of present general packaged software. In order to save computer execution time, event scanning method is adopted. Moreover, input information adopted in the simulation cannot conform to the distribution theory completely. Therefore, in order to ensure that the actual condition can be conformed to, the cumulative probability distribution of the present information is adopted as a substitute. However, the service time is decided according to the crane function and volume generated from the cumulative probability. For each simulation, the previous 1000 hours is set as the stability period and the simulated ship information is only collected after 1000 hours in order to avoid that the stability is not yet reached because the system is just activated thereby resulting error. The detailed simulation flow is as indicated in Fig. 1.

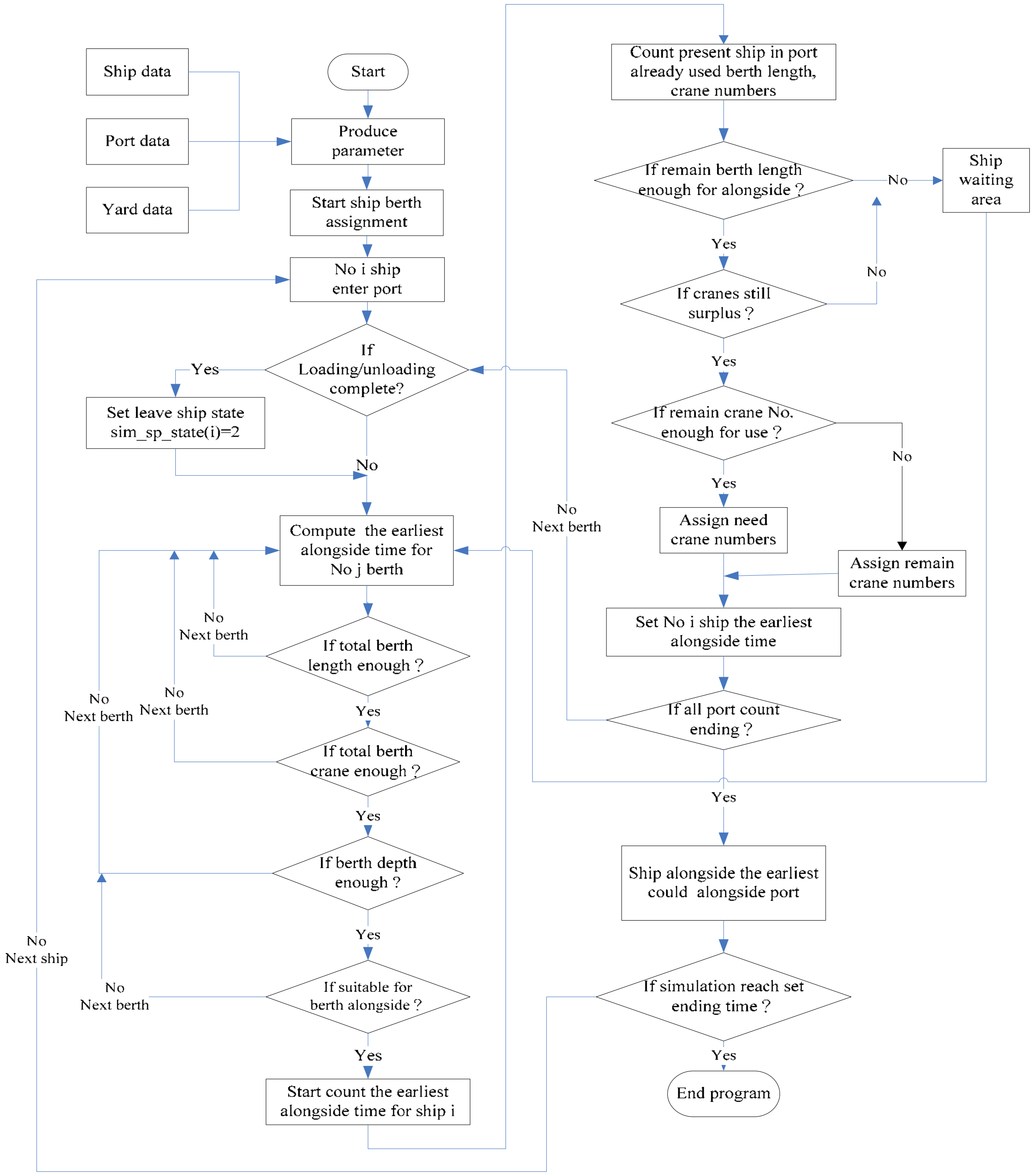

Figure 1 Port system simulation flow chart

According to the program design content, its steps are explained as follows:

1. Setting of the starting value.
2. Ship parameter establishment.
3. Ship arrival.
4. Looking for the wharf that can be berthed as early as possible.
5. Set the berthing time and calculate the loading and unloading operation time.
6. Judge whether the system set time is reached.
7. Collectively sort the statistical information and simulation result.

3.2 Input data

The simulation model input data produced by way of the accumulated probability table was not used for the theory formula. The input data for the simulation were real ship arrivals at the Kaohsiung port for a period of one year. The input items consist of:

- The cumulative probability table of the ship interval-arrival time: According to past research reports the ship interval-arrival distribution of Kaohsiung Port is close to Erlang distribution. In order to enable that the simulation results to match the real world condition and as this research has complete data of ship arriving in port.
- The cumulative probability table of ship length and draft, and load/unload container volumes: in order to enhance the accuracy of the simulation, this research employs length of actual different forms of ship, draft and the load/unload volumes of ship arriving as the basic data of the behavior of ships arriving to establish the simulation model.
- The cumulative probability table of the load/unload container volumes and number of crane utilized: based on the loading and unloading container volumes of each arriving ship. The expected number of crane to be deployed for each ship is produced to operate. In the simulation process, if the port is equipped with less than the required cranes, we set the required cranes number to the equipped with crane number. Similarly, if the required cranes are less than the port is equipped with, we assign the cranes number to the required cranes number. If the port is equipped with more cranes than the required cranes, but some of the cranes are used for another ship and the remaining cranes are less than the required cranes, we assign the crane number to the remaining cranes number.
- The cumulative probability table of the number of crane and the loading and unloading efficiency: the efficiencies of the cranes were one hour one crane could operate number of containers (average). The loaded/ unloaded container volume is estimated according to the probability table.
- The berth condition: the information of simulation is set according to the actual condition of berth including: berth number, berth length, depth and width, number of crane deployed and number of berth leased by the ocean carrier etc.
- The time of the simulation: The simulation time was set as one year.

3.3 Model Verification and Validation

Law and Kelton (1991) define the verification and validation in the classic simulation textbook as "Verification is determining that a simulation computer program performances as intended, i.e., Debugging the computer program....Validation is concerned with determining whether the conceptual simulation model (as opposed to the computer program) is an accurate representation of the system under study".

Jack (1995) infers that validation cannot be assumed to result in a perfect model, since the perfect model would be the real system itself. To obtain a valid model, we try to measure the inputs and outputs of the real container terminal, and the attributes of intermediate variable. Since it is not easy to obtain actual relevant data, we use the data sources from the Kaohsiung harbor bureau file of ship movements and the file of harbor work records.

Most past studies address that the container ship arrival time interval distribution is Erlang-k in nature. We use the data about the arrival ship of ocean carrier to execute the K-S test of arrival interval pattern. The ship arrival interval pattern of Kaohsiung container port shows an approximate Erlang distribution listed in Table 2, and does not match completely with past research. In order to let simulation result match with the real situation, we decide to take the accumulated probability table for simulation.

Table 2 Ship arrival time interval distribution KS-Test result

No.	Ocean carrier	Berth No.	Ship No.	AVG	Std. error	$\hat{K}$	Maximum probability error K=						significance level =		
							1	2	3	4	5	6	0.10	0.05	0.01
1	Y	2	863	0.42	0.38	1.233	0.052^	0.132	0.195	0.240	0.270	0.292	0.04155	0.04632	0.05552
2	A	2	570	0.65	0.55	1.424	0.089	0.083^	0.149	0.192	0.221	0.242	0.05119	0.05706	0.06839
3	N	1	391	0.93	0.96	0.927	0.042^	0.172	0.225	0.267	0.295	0.318	0.00767	0.06878	0.08243

︿：Approximate distribution

Upon completing the Kaohsiung Port simulation model, it needs to be verified. The main aim was to compare the difference in the actual values measured at the port and the output given by the simulation model. From this, the differences between the constructed model and the actual system can be judged in order to establish whether or not the simulation model is adequate to represent the real system. Table 3 shows the coefficient of variation (cv) that used to check the deviation of variables. Those of all not have apparently changed.

Table 3 Test the significance of the variables for ocean carriers

	variables	Wq	λ	1/μ	ρ
Y Carrier	ϕ	0.2061	0.0009	0.0953	0.0010
	$\underline{s}_d$	0.7001	0.0334	0.2821	0.0048
	cv=	0.1622	0.0334	0.0112	0.0211
	α=0.05	2.0452	2.0452	2.0452	2.0452
	T=	1.6122	1.4126	1.8507	1.1141
	P value=	0.1178	0.1684	0.0744	0.2744
A Carrier	ϕ	0.0131	-0.0003	0.0609	0.0017
	$\underline{s}_d$	0.4431	0.0446	0.2745	0.0052
	cv=	0.2730	0.0446	0.0172	0.0172
	α=0.05	2.0452	2.0452	2.0452	2.0452
	T=	0.1623	-0.6070	1.2147	1.7800
	P value=	0.8722	0.5486	0.2343	0.0856
N Carrier	ϕ	0.0612	0.0007	0.0612	0.0002
	$\underline{s}_d$	0.3995	0.0614	0.3995	0.0100
	cv=	0.0262	0.0614	0.0262	0.0262
	α=0.05	2.0452	2.0452	2.0452	2.0452
	T=	0.8395	1.4549	0.8395	0.1027
	P value=	0.4080	0.1564	0.4080	0.9189

We also use mathematical statistics to obtain quantitative data about the quality of the simulation model. The four variables (W_q, λ, 1/μ and ρ) have been used to check. Let $\underline{w}_i$ and $\underline{v}_i$ denote the average parameter on run i in the simulation and real system, respectively. Suppose that n runs are simulated and observed in reality, so i=1… n, set n=30. Those were calculated form the individual parameters of all ships arrived at the port. Statistically, this trace-driven simulation means that there are n paired differences $\underline{d}_i = \underline{w}_i - \underline{v}_i$, which are identically and independently distributed (i.i.d.).

Then the t statistic is

$$\underline{t}_{n-1} = \frac{\overline{\underline{d}} - \phi}{\underline{s}_d / \sqrt{n}} \tag{13}$$

Where $\overline{\underline{d}}$ denotes the average of the n pair of $\underline{d}$'s, φ is the expected values of $\underline{d}$, and $\underline{s}_d$

represents the estimated standard deviation of $\underline{d}$. Suppose that the null-hypothesis is H_0: $\varphi=0$, and Eq.(13) gives a value $\underline{t}_{n-1}$ that is significant $(|\underline{t}_{n-1}| > t_{n-1;\alpha/2})$. From Table 8, the three ocean carriers (Y, M and E) and the four variables, when n=30 and take α=0.05, the all of $(|\underline{t}_{n-1}| < t_{n-1;\alpha/2})$ and p value $>\alpha$=0.05, then the simulation model is not reject, since the model gives average variables per run that doesn't deviate significantly from reality.

When the Kaohsiung Port simulation model had been completed, it needed to be verified. The main aim was to compare the difference in the actual values measured at the port and the output given by the simulation model. From this, the differences between the constructed model and the actual system can be judged in order to establish whether or not the simulation model is adequate to represent the real system (see Table 4).

This paper explores a credible simulation model of the container terminal in Kaohsiung, Taiwan. The Kaohsiung harbor bureau data of ship movements and the data of harbor work records were the main input data sources. The input data were very detail and complete, consist of time of ship's arrival, ship's waiting time (ships waiting to alongside the berth and access port equipment), time alongside the berth (service begins), service time (loading/unloading time), ship's idle time and departure time (service ends). So we have well and detail input data result in good model. The performance criteria and the model parameters to propose an operational orientation that promotes port effectiveness.

Table 4 Comparison of the actual values and simulated values for Kaohsiung Port

Ocean carrier / variable	***Y***			***A***			***N***		
	Actual value (A)	Simulation value (B)	Error percentage (A-B)÷A	Actual value (A)	Simulation value (B)	Error percentage (A-B)÷A	Actual value (A)	Simulation value (B)	Error percentage (A-B)÷A
W_q(hours/ship)	4.11	4.316	**4.77%**	1.61	1.623	0.81%	4.35	4.38	0.78%
λ(ships/hour)	0.0999	0.0991	-0.86%	0.065	0.0646	-0.49%	0.045 0	0.0457	1.63%
1/μ(hours/ship)	25.15	25.245	0.38%	16.04	15.949	-0.57%	15.30	15.239	-0.40%
ρ(ships/hour)	0.226	0.227	0.43%	0.30	0.301	0.56%	0.38	0.379	-0.05%
Berth No. (Terminal No.)	# 70 (T3) # 120 (T4)			# 68-69 (T3)			#121(T4)		

This also can be seen that just in W_q, the error percentages of ocean carrier ***Y*** are slightly higher, when n=30 that error percentage is 4.77%. However, when they are converted to actual error time they are only 0.2061 hours. But for rest of all are below within ±2%. Therefore shows that the difference between the model established by this research and the actual conditions is extremely small. Thus, this simulation model can be utilized to execute a reasonable evaluation of the operation of the container terminal at Kaohsiung Port.

4. APPLICATION OF PORT TRANSPORTATION SYSTEM SIMULATION MODEL

4.1 Port transportation system simulation scheme

This research intends to base on two ocean carriers ***Y*** and ***A*** in the T3 Container Center in Kaohsiung Port as the case study analysis. Its port area position is as shown in Fig. 2.

Y ocean carrier at present that leases #70 berth in the T3 container center and #120 berth in the T4 container center, respectively. The berth length of the #70 berth is 320.57 meters and is deployed with four sets of cranes. In addition, ***A*** ocean carrier leases #68-69 berth that total berth length is 752.16 meters and is deployed with seven sets of cranes. The basic information of the berth and the statistics number of ships berthed are as shown in Table 5. Coping with the trend of large ship, very often the berth of ocean carrier ***Y*** is not enough for use. In order to enhance the utilization rate of berth and the operation performance, this research formulates two more feasible substantial schemes through operation management method to conduct comparison and evaluation on these schemes.

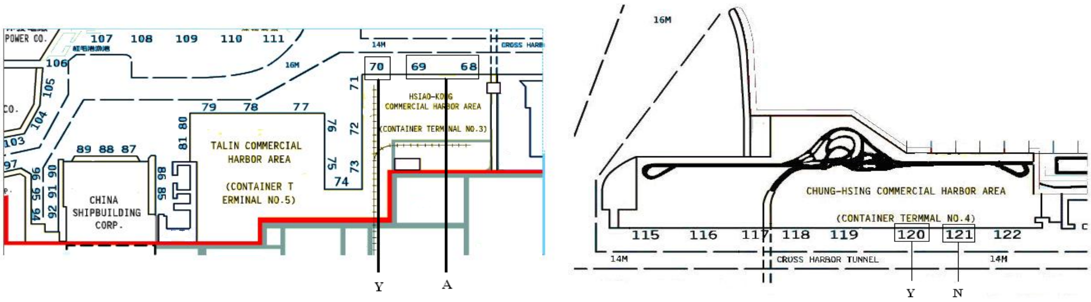

Figure 2 Kaohsiung Port T3 and T4 container center plane position diagram
Information source: Kaohsiung Port Authority, 2008

Table 5 Kaohsiung Port container terminal basic information and statistical compilation on number of ships

Ocean Carrier	Berth number	Container terminal	Berth length (Meter)	Berth draft (Meter)	Number of crane deployed	Number of ship berthed/year
A	# 68	T3	432.16	14.0	3	301
	# 69		320.00	14.0	4	269
Y	# 70	T3	320.57	14.0	4	412
	# 120	T4	320.00	14.0	3	451
N	# 121	T4	320.00	14.0	3	391

During the formulation of feasible comparative scheme, the principles of consideration are as follows:

1. For a terminal with a linear type berth, its berth length and crane numbers will be combined for the calculation. Except the total number of variable crane (C_No) and when the total number of crane is fixed, the crane combination will be varied so as to judge on what kind of total number of crane and crane combination deployment will generate better performance.
2. In order to conform to the present operation, the principle is based on deployment of one crane for each 80~100 meters on the average.
3. ***Y*** ocean carrier leases #69 berth of ***A*** ocean carrier. The principle of its utilization is when the berth of ***A*** ocean carrier is idle, ship of ***Y*** ocean carrier can berth and can also use its crane and this is scheme 1.（For berth charter, the expenses of leasing the berth and crane shall not be considered temporarily）.
4. Berth leased by ***Y*** ocean carrier and ***N*** ocean carrier shall conduct mutual exchange and this is scheme 2. (Berth exchange).
5. All ships of ***Y*** and ***A*** ocean carrier can berth all in the three berths #68-70 and this is scheme 3. (Berth common)

4.2 Port transportation system simulation result

4.2.1 *Y* ocean carrier

From the simulation result in Table 6, it can clearly judge that at present ***Y*** ocean carrier leases berth in #70(T3) and #120 (T4) respectively and when the number of ship arriving in port each year (SHIP_NO) is 863 and the total number of crane is 6 sets and the crane combination is C_SET=(3,3), that means during deployment of 3 sets of cranes for #70 and #120 respectively, this is the most reasonable deployment. For the present crane combination deployment C_SET=(4,3), although the average waiting time can be slightly reduced, yet when the number of ship arriving in port is 863, this is not the most reasonable performance. If consideration is given to reducing the waiting time cost and the intention is to increase the number of crane to 7, the present crane combination is a reasonable deployment.

Table 6 Comparative analysis at present crane combination deployment of ***Y*** ocean carrier

C_No (sets)	C_SET	W_q (hr)	$1/\mu$ (hr)	AWT/AST	ρ	UC	remarks
6	**(3, 3)**	4.37	25.08	0.174	0.67	**0.0979**	※
	(4, 2)	7.52	26.99	0.279	0.78	0.1073	
	(2, 4)	8.68	27.11	0.320	0.32	0.1099	
7	**(4, 3)**	4.31	25.24	0.171	0.67	**0.1011**	&
	(3, 4)	4.23	24.93	0.170	0.67	0.1019	
	(5, 2)	7.52	26.99	0.279	0.78	0.1120	
8	(4, 4)	3.46	23.75	0.146	0.65	0.1030	
	(5, 3)	3.86	24.38	0.158	0.66	0.1049	
	(3, 5)	4.18	24.79	0.169	0.67	0.1062	

Notes: 1. &: Present deploy, ※ : The lowest UC value, V(units/ship)=655, SHIP_NO(ships/year)=863
2. C_No: total crane number, C_SET (4,3) : #70 set 4 cranes and #120 set 3 cranes, λ=0.0991(ships/hrs)
3. AWT/AST= $W_q /(1/\mu) = W_q \cdot \mu$

If discussion is only conducted on #70 berth of ***Y*** carrier, the number of ship arriving in port each year (SHIP_NO) is 412 and the number of crane deployed is 4. In order to understand whether its crane deployment is reasonable, the simulation result of total crane number after variation is as shown in Table 7. From Table 7, it can be clearly seen that when the total crane number is 4 sets, its UC value will vary gradually and when it varies to the lowest point, it can reach the most reasonable performance. At this time the UC value is 0.0943, the average waiting time is 4.61 hours and the berth utilization rate (ρ) is 0.78. From this simulation analysis result, it can clearly judge that the present crane deployment is reasonable. However, its loading and unloading service time is as high as 27.65 hours and obviously improvement on the service quality is required.

Table 7 Simulation result of the total number of varied deployed crane for ***Y*** ocean carrier

C_No (sets)	W_q (hr)	$1/\mu$ (hr)	AWT/AST	ρ	UC	remarks
3	7.00	30.53	0.229	0.87	0.1011	
4	4.61	27.65	0.167	0.78	**0.0943**	※
5	4.38	27.53	0.159	0.78	0.0987	
6	4.23	27.23	0.155	0.77	0.1032	

Notes: ※ : The lowest UC value, V(units/ship)=757, SHIP_NO(ships/year)=412, λ=0.047(ships/hrs)

In order to compare with scheme 3, this must be established on similar comparison level. Therefore the berth simulation condition of scheme 1 is changed as 3 seats of berths, the berth length is 1072.73 meters and number of crane deployed is 11 sets and the number of ship arriving in port each year is 982 ships (the simulation scenario of ship is similar to berthing in #70 berth). The simulation results under this scenario are as shown in Table 8.

Table 8 Simulation results of ***Y*** ocean carrier under the scenario of scheme 3

C_No (sets)	W_q (hr)	$1/\mu$ (hr)	AWT/AST	ρ	UC	remarks
11	2.15	18.07	0.117	0.68	0.1353	A1B1

Notes: SHIP_NO (ships/year) =982

4.2.2 *A* ocean carrier

At present, an ocean carrier leases two berths (#68-69) in T3 container center and the total length of berth is 752.16 meters. As two berths are collinear, its deployed crane can be used jointly and this will enable the cranes to bring its function into full utility. What Table 9 shows is the simulation result of varied crane number and this can be easily seen that when the number of ship arriving in port(SHIP_NO= 570 ships) and the total number of crane is 6 sets, its UC value=0.1032 is the most minimum and reach the reasonable deployment.

Table 9 Simulation result of varied crane number for ***A*** ocean carrier

C_No (sets)	W_q (hr)	$1/\mu$ (hr)	AWT/AST	ρ	**UC**	remarks
5	4.47	20.16	0.222	0.38	0.1064	
6	**2.49**	**17.58**	**0.141**	**0.33**	**0.1032**	※
7	1.62	15.95	0.102	0.30	0.1045	
8	1.14	15.49	0.073	0.29	0.1083	
9	0.69	15.54	0.044	0.29	0.1132	

Notes: ※ : The lowest UC value, V(units/ship)=1087, SHIP_NO(ships/year)=570, λ=0.065(ships/hrs)

This represents what ***A*** ocean carrier emphasizes on is efficiency. So even due to increase of one crane, it will increase the cost and the UC value will increase slightly by 1.26%. However, this will enable its average waiting time to reduce by 0.85 hours in order to enhance the turning rate of berth. Nevertheless, this is not the most reasonable performance for the overall operation.

4.2.3 Strategic alliance of *Y&A* ocean carrier

As mentioned above, two berths leased by ***Y*** ocean carrier are distributed in T3 and T4 container center. The #70 berth leased in the T3 container center is the headquarters of ***Y*** ocean carrier in Taiwan. In the stacking site on the back line yard, that ocean carrier is deployed with the latest four rail mounted type of gantry cranes as in that container center, just only one berth is not enough for operation.

This research formulates similar sea transportation strategic alliance and brings up three improvement schemes:

1. Scheme 1: Y ocean carrier can only berth under the premise that Y ocean carrier will not obstruct the berthing of ships owned by A ocean carrier, which means when the berth space leased to A ocean carrier is idle. Scheme 1 causes the minimal hindrance to A ocean carrier and brings rentals to A ocean carrier. As to Y ocean carrier, when Scheme 1 is applied, the rent to be paid is the lowest.
2. Scheme 2: Berth swap will be made between Y ocean carrier and N ocean carrier, which leases #121 berth in T4 terminal. After berth switch, #120~121 shall be leased to Y ocean carrier in T4 terminal. The berth length is 640 meters and 6 sets of crane are deployed. If Scheme 2 is applied, not only berths can be jointly used the cranes and can also be used jointly as support by coping with large scale ship, which enhances the overall loading and unloading rate of the berth as shown in Table 10.

Table 10 Berth exchange improvement scheme_A

Ocean carrier	Present condition of berth number	Berth number after adjust operation	Berth length (Meter)	Number of crane deployed
Y	#70(T3)、#120(T4)	#120-121(T4)	640	6
N	#121(T4)	#70(T3)	320.57	4

After the improvement brought by berth switch with N ocean carrier, the number of crane is changed and the simulation results are shown in Table 11. It has shown that when the number of carne is 6 sets, the minimum UC value of 0.0957 can be obtained, which means that 6 sets of crane is a reasonable deployment and this deployment can yield the maximum benefits.

3. Scheme 3: Y ocean carrier and A ocean carrier jointly lease 3 seats of berths (#68~70). The total berth length is 1072.73 meters and the 11 sets of crane separately deployed by 2

ocean carriers can also be utilized mutually. The SHIP_NO is equal to 982 (570 of A carrier and 412 of Y carrier) ships.

Table 11 Analysis on the improvement scheme after berth exchange by ***Y*** ocean carriers

C_No (sets)	W_q (hr)	$1/\mu$ (hr)	AWT/AST	ρ	**UC**	remarks
5	4.80	26.93	0.179	0.76	**0.0967**	
6	3.23	25.33	0.128	0.75	**0.0957**	※
7	**2.33**	24.70	0.095	0.74	0.0974	
8	2.14	24.11	0.089	0.72	0.1007	

Notes: ※ : The lowest UC value, V(units/ship)=613, SHIP_NO(ships/year)=863, λ=0.098(ships/hrs)

The simulation results of the three aforementioned Schemes have been summarized in Table 12. Upon comparative analysis of various improvement schemes and their simulation results, the result is shown in Table 13.

Table 12 Improvement scheme simulation result

Scheme	No.	W_q	$1/\mu$	AWT/AST	ρ	UC	Crane_No	Berth_No	SHIP_NO	remarks
Present	A1	4.61	27.65	0.167	0.87	0.0943	4	1	412	Y(#70)
	B1	1.62	15.95	0.102	0.30	0.1045	7	2	570	A(#68-69)
	C1	4.31	25.24	0.171	0.67	**0.1011**	7	2	863	Y(#70, #120)
1	A2	3.96	24.81	0.160	0.84	0.0940	4	1	396	Co-Y(#70)
	B2	2.19	17.58	0.125	0.38	0.1089	7	2	586	Co-A(#68-69)
2	C2	3.23	25.33	0.128	0.75	**0.0957**	6	2	863	Adj.-Y(#120-121)
3	A2B2	1.73	15.48	0.112	0.58	0.1335	11	3	982	Y-A(#68-70)

1. Scheme 1: Since Y ocean carrier can only berth when the berth space leased to A ocean carrier is idle, consideration must be made regarding whether the length of the remaining berth is enough. As a result, only 16 ships can berth during the entire year, which consequently decreases the average waiting time of #70 by 14.1% to 3.96 hours. In addition, the variation percentage of waiting time factor and UC is slightly reduced. As paying the rent is necessary, the reasonable berth rental price can be measured based on the variation percentage. Although A ocean carrier utilizes the idling time of berth, the overall deployment operation of the berth is still affected, which results in the a slight increase in the average waiting time to 2.19 hours. Correspondingly, such results can also lead to a consideration on how much rent should be collected.

2. Scheme 2: The Scheme is on the premise that both Y ocean carrier and N ocean carrier agree to switch berths with each other. If the assumption is made true, berth owned by Y ocean carrier can form a so-called linear berth, which makes simultaneous use of berth and crane possible. It is shown in Table 13 that the average waiting time slightly drops by 25.06% to 3.23 hours when the number of crane utilized is 6 sets. If the number of crane is added to equal the current crane number, 7 sets, the average waiting time can be reduced to 2.33 hours (see Table 11) and its loading and unloading efficiency can be enhanced. As the number of berthing ships of Y ocean carrier is 863 per year, it is evident that the 2 currently-leased berths are no longer sufficient. As a result, it is strongly suggested that Y ocean carrier should lease one more berth in Kaohsiung Port.

3. Scheme 3: As Y ocean carrier and A ocean carrier jointly lease three berths (#68~70), not only the leasing expenses can be more favorable, the berth and crane can also be used mutually. In response to the trend of large scale ships, the linear berth can bring its functions into full play. Although the rental Y ocean carrier needs to pay is 0.5 berths more than the present condition in T3 terminal, the average waiting time can still be

greatly reduced to 1.73 hours since Y ocean carrier can jointly use 3 berths with A ocean carrier. As to A ocean carrier, although the average waiting time is slightly increased by 0.13 hours, the rent to be paid for 0.5 berths can be saved. The reduced cost can enhance the competitive strength of the overall operation. This research is based on A1B1 scenario (If Y ocean carrier lease three berths (#68~70), 982 ships belong to Y ocean carrier, so SHIP_NO=982) to make comparisons. Judging from Table 13, the variation percentage of the three evaluation indicators of A2B2 scenario (Y ocean carrier and A ocean carrier jointly lease three berths (#68~70), 412 ships belong to Y ocean carrier and 570 ships belong to A ocean carrier, so the total SHIP_NO=982) drops slightly. A reasonable inference can be drawn that it might be due to the fact that the operation system of A ocean carrier is superior to that of Y ocean carrier, which improves the operation performance of Y ocean carrier when the berths are shared by the two ocean carriers.

Table 13 Improvement scheme comparative analysis

Scheme_No	W_q	AWT/AST	UC	SHIP_NO	remarks
A1	4.61	0.167	0.0943	412	Y(#70)
A2	3.96	0.160	0.0940	396	Co-Y(#70)
(A2-A1)/A1 Change percentage	-14.10%	-4.19%	-0.32%	-3.88%	***Scheme 1***
B1	1.62	0.102	0.1045	570	A(#68-69)
B2	2.19	0.125	0.1089	586	Co-A(#68-69)
(B2-B1)/B1 Change percentage	35.19%	22.55%	4.21%	2.81%	***Scheme 1***
C1	4.31	0.171	0.1011	863	Y(#70, #120)
C2	**3.23**	0.128	0.0957	863	Y(#120-121)
(C2-C1)/C1 Change percentage	**-25.06**%	-25.15%	-5.34%	0.00%	***Scheme 2***
A1B1	2.15	0.117	0.1353	982	Y(#68-70)
A2B2	1.73	0.112	0.1335	982	Y-A(#68-70)
(A2B2-A1B1)/A 1B1 Change percentage	-19.53%	-4.27%	-1.33%	0.00%	***Scheme 3***

5. CONCLUSION

Since the beginning of containerization transportation in the market in 1956, this had completely overthrown the traditional sea transportation mold. After close to fifty plus years of development, sea containerization transportation has been transformed into liner shipping mode. The operation of container liner ocean carrier responds with re-adjustment by following the step of time and develops towards the trend of large scale ship, globalize transportation, ship route axis, ocean carrier alliance and globalize logistics etc. The four motives of adopting the strategic alliance competitive strategy by liner shipping companies are: 1. expand the original or enter into new operating ship route based on this and increase competitive strength, 2. complementary resource and professional specialty is exchanged between each other, 3. reduce cost and share risk, 4. satisfy customer requirement, enhance market occupy.

Three schemes studied in this research provide significant improvement on ***Y*** ocean carrier. However, for Scheme 1, rental has to be paid to ***A*** ocean carrier resulting decrease of W_q by 14%. In addition, there is a certain degree of effect on the berth operation of ***A*** ocean carrier

(W_q increased by 35%). Therefore whether it is necessary to lease berth will depend on the operating goal of ***A*** ocean carrier. Scheme 2 is a comparative feasible alternative as by comparing with the present situation and in respect of W_q 25% improvement can be achieved. If permitted in the contract, berth change may not result in increase of berth rental. If there is increase in cost, a certain level of preferential treatment on rental can be obtained through port authority. This can greatly enhance the competitive strength of port resulting in winning for three sides. In addition, if this scheme is adopted, the result of this research shows that 3 berths and 6 cranes is a reasonable deployment. However, for container ship the average service time of ship (25.33 hours) is still too high. It is suggested that ***Y*** ocean carrier should add one machine in Kaohsiung Port or lease one berth in the neighboring berth so as to improve the operating performance. Scheme 3 is the scheme with largest improvement in operating performance. Table 13 shows the scale of improvement under similar criterion. If comparison is conducted with the present A1 scenario and even if additional rental for 0.5 berths is required, yet the W_q can obtain an improvement as high as 62%. By spending minimum cost, a maximum improvement benefit can be obtained and this is the operation management strategy worth to be promoted.

The operation mode of Kaohsiung Port is 「lease with exclusive use」. Mostly wharfs are leased by ocean carriers that will mainly serve their own company fleet. When there is extra capacity in berth or backline yard, it capable of serving ship and container of other company in order to create operating income of the wharf. The case study presented by this research is: as ***Y*** ocean carrier only leases one berth in T3 Container Center and the number of ships berthed per year is 412, therefore the time of ship in port is too long and the berth usage rate is too high. Berths leased by ***Y*** ocean carrier and ***A*** ocean carrier are all in T3 Container Center and these are neighboring berths. If the two ocean carriers can adopt the management method of strategic alliance and transform from 「lease with exclusive use」 into 「lease with common use」, this is a flexible berth deployment and utilization that can assist ocean carriers who lease the berth to integrate dispersed container yards and can bring maximum utilization benefit of port resource into full play. Not only the resource of berth can complement each other and the professional skill of each other can be exchanged, also the berth rental cost can be reduced , the risk can be shared, idling of berth can be reduced, the time of staying in the port can be reduced, the requirement of consignees can be satisfied, the market share can be enhanced, liner shipper can really reach the service mold of fixed port, fixed ship, fixed time and fixed route and this can adequate develop the sea transportation.

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