THE DETERMINTS OF THE LENGTH OF CONTAINER SHIPS MOORING TIME OF PORTS KEELUNG AND TAICHUNG

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Abstract: For analyzing the determinants of the length of container ships mooring time on a berth of ports Keelung and Taichung, the time interval is firstly divided into three unfolded sub-periods：(1)preparation period, (2)container handling period, and (3)waiting for departure period. For each sub-period, an empirical model is estimated with a sample of size 77 ships observed from both ports. Factors of port and ship company are included in the models of preparation and waiting for departure sub-periods, and factors of port, berth assignment rules and quantity of containers handled are included in the model of container handling period. Some possible reasons why these factors are included in the models are also explained in the paper.

1. INTRODUCTION

The operational efficiency of a port can be measured by the time from the arrival of a ship at the port to its departure. For a container wharf, the shorter is the time a ship stays in this wharf, the better is the efficiency of the wharf operations, provided that the total quantity of containers handled by this ship at different wharves are equal. The time interval a ship stayed in port can be divided into two parts: mooring time and waiting time. The mooring time of a ship is the period from the arrival of a ship at the berth to its actual departure from this berth. The waiting time is the period of time that a ship stays in the port but not at the berth. The main purpose of a ship arriving at a port is to load or/and discharge cargoes in the berth. An efficient berth service system provides users the benefit of economizing the time required for berth occupancy. Hence, The length of mooring time is one of the most important indicators measuring the operations efficiency of a port.

The mooring time is a synthesis implemented by the various port operations participants. In comparison with the measures of different ports we can say that the performance of which port is better, but we do not see what causes the performance differences among these ports. And only performance indicators are not sufficient for port management although a lot of other operations performance indicators was proposed by several authors in the last two decades, such as Hoffman (1985) and Plumlee (1979) among others. For the purpose of port management not only the efficiency of activities should be measures, but also the factors influencing the activity efficiency should also be identified. This is the purpose of this study. We attempt to construct a model to investigate the factors contributing the length of container ships mooring time at ports Keelung(KL) and Taichung(TC), and then the efficiency of berth operations systems of these two ports will be explained and compared. The remainder of the paper is organized as follows. Section 2 analyzes the berth operations system, Section 3 constructs the model. Section 4 describes the data and the sample. Section 5 presents the empirical result, while Section 6 explains the results. Section 7 contains the summaries and conclusions of this paper.

2. BERTH OPERATIONS SYSTEM

The purpose of berth operations system is to provide the services of loading or discharging cargoes in a ship. When a containership just moors at a berth, the operations of container handling can not be started until all ropes are fastened, immigration inspections are implemented completely by customhouse officials, and all preparation works of handling containers are finished. On the other hand, the ship can not departure from the berth at the moment that the works of container handling are just finished unless activities, such as the maintenance of engines and equipment, the replenishment of stores, complement of crews and inspection of immigration. are accomplished. Taking this viewpoint, the period of containership mooring time can be separated into three unfolded sub-periods : (1)preparation period which is defined as the time interval from the throw down of the first rope to the beginning of the first movement of container loaded to or discharged from the ship; (2)container handling period which is defined as the time interval from the beginning of the first movement of the container to the end of the last movement of the containers that are loaded to or discharged from the ship, and (3)waiting for departure period which is defined as the time interval from the last movement of the container that are loaded to or discharged from the ship to the actual departure from the berth. The properties of works in these three sub-periods are different, it is doubt that the determinants of the three sub-periods of mooring time will be same, they should be analyzed separately, otherwise the important factors which might affect the length of containership's mooring time could not be discovered.

3. THE MODEL

In order to investigate the determinants of the containership, mooring time of ports KL and TC. Potential factors to be considered in this paper are (1) the port itself, (2) the berth assignment rules, (3) the shipping companies, and (4) the quantity of containers handled.

There are two meanings of variable "port" . On the one hand, it represents the environmental conditions of that port which includes the number of berths and its relevant facilities, the magnitude of backyard areas, and the congestion of traffic outside the harbor, etc., those conditions can not be controlled by port authorities. On the other hand, "port" also represents the management performance implemented by the port authority. We define port variable as:

$$x_1 = \begin{cases} 1 & \text{for port TC} \\ 0 & \text{for port KL} \end{cases}$$

The berth assignment rules represents the policy variable controlled by port authorities. There are three berth assignment rules used in three different berths of ports KL and TC. The first is the first come-first serve rule which is used on public berths. The second is a priority option. That is, port authority offers some preferential berths, if a shipping company bought the option, containerships of this company had the preferential right to moor at these preferential berths even if there was a ship without this right in the berth, they had to move out. The third is exclusive rule, that is, a shipping company can rent a berth for exclusive use from port authority, then this exclusive berth can not be moored by other company's ships without the permission of the company who rent this berth. Define two variables as

$$X_2 = \begin{cases} 1 & \text{for exclusive berth} \\ 0 & \text{o.w.,} \end{cases}$$

and

$$X_3 = \begin{cases} 1 & \text{for preferential berth} \\ 0 & \text{o.w.,} \end{cases}$$

to distinguish three kind of berths which represents the three berth assignment rules, respectively, and the negative coefficients of these two variables will be expected.

The length of mooring time might be affected by shipping companies. For example, the policy at which port to proceed these activities, such as engines maintenance, stores replenishments, crews complements, and the decision on which port their container yards or terminals build, etc., that are all controlled by shipping companies would influence the length of mooring time. There are many shipping companies having containerships arriving at ports KL and TC, companies Yangming(YM), EverGreen(EG), Uniglory(UG) and Wan Hai(WH) are the four biggest companies among others, the proportions of containerships arrived at ports KL and TC belonging to these four companies are 41% and 67%, respectively(Keelung Harbor Bureau 1977). Furthermore, we combine EG and UG to be the company "E&U" because these two companies belongs to same business conglomeration, their policies are very similar. Thus we use three dummy variables to denote the different companies. That is,

$$X_4 = \begin{cases} 1 & \text{if ship belongs to YM} \\ 0 & \text{o.w.,} \end{cases}$$

$$X_5 = \begin{cases} 1 & \text{if ship belongs to E \& U} \\ 0 & \text{o.w.,} \end{cases}$$

and

$$X_6 = \begin{cases} 1 & \text{if ship belongs to WH} \\ 0 & \text{o.w.,} \end{cases}$$

The function of container berth is to handle containers, hence, the quantity of containers handled by a ship should be an important factor to influence the mooring time of the ship. We use variable X_7 to represent the quantity of containers loaded and/or discharged by a ship. Some interaction effects of ports and other factors are expected to exist on the length of mooring time for various reasons. Hence, we define variables

$$X_k = X_1 * X_{k-6} \quad ,k = 8,9,\ldots,13$$

as interaction effect variables to test whether the interaction effects between ports and other variables exist.

In order to analyze the influent factors of three sub-periods of mooring times. We define three multiple regression models, with normal error terms, in terms of these 13 proxy variables as

$$T_{ij} = \beta_{i0} + \beta_{i1}X_{1j} + \ldots + \beta_{i13}X_{13j} + \varepsilon_{ij} \tag{1}$$

where β_{i0}, β_{i1},..., β_{i13} are regression coefficients which will be estimated in this paper,

ε_{ij} are independent N(0, σ_i^2), i=1,2,3; j=1,2,…,n; T_{ij} is the mooring time that the jth observed ship stays in the ith sub-period. The response functions for port KL and port TC in model (1) are:

$$E(T_i) = \beta_{i0} + \beta_{i2}x_2 + \beta_{i3}x_3 + \beta_{i4}x_4 + \beta_{i5}x_5 + \beta_{i6}x_6 + \beta_{i7}x_7 \tag{2}$$

and

$$\begin{aligned} E(Ti) = {} & (\beta_{i0} + \beta_{i1}) + (\beta_{i2} + \beta_{i8})x_2 + (\beta_{i3} + \beta_{i9})x_3 + (\beta_{i4} + \beta_{i10})x_4 \\ & + (\beta_{i5} + \beta_{i11})x_5 + (\beta_{i6} + \beta_{i12})x_6 + (\beta_{i7} + \beta_{i15})x_7, \end{aligned} \tag{3}$$

i=1,2,3;respectively.

Thus the interaction model (1) implies that each port model has its own regression line with different intercepts and slopes for the different port model. The objective of this paper is to build a model based on these 13 variables that could best explaine the variations of T_i, i=1,2,3.

4. THE SAMPLE

Because of no secondary data adequate to our study, 35 and 42 containerships arrived at ports KL and TC, respectively, from May 1 to July 30 of this year were observed directly and the relevant data were collected. Number of ships in terms of variables "ports", "berths", and "companies" are exhibited in Table1.

Table 1. The Sample

Port	Company / Berth	YM	E&U	WH	OT[a]	Total
KL	Public	0	0	0	4	4
	Preferential	9	12	10	0	31
	Sub-total	9	12	10	4	35
TC	Public	12	0	0	10	22
	Exclusive	0	10	10	0	20
	Sub-total	12	10	10	10	42
	Total	21	22	20	14	77

a OT = others

From this table one can see that in port KL ships belonging to YM, E&U, and WH moor at preferential berths only, and ships belonging to "others" moor at public berths. Similarly, in port TC ships of E&U and WH moor at exclusive berths, and ships of YM and "others" moor at public berths, so that there is neither ships of E&U and WH moored at public berths, nor is ships of others moored at preferential and exclusive berths. This fact causes the problem of multicollinearity in model building (Neter, J. *et al.* 1989). The correlation coefficients matrix of variables X_1 to X_7, and T_1, T_2, and T_3 are presented in Table 2. In fact, an exact linear relationship

$$X_{10} = -X_3 + X_4 + X_5 + X_6 - X_8 - X_9 \tag{4}$$

exists in the data set. Therefore, the variance inflation factor (vif) values are used to detect possible problems in the process of model selection.

There is a noticeable fact appeared in Table 2, that is, all of the correlation coefficients among variables T_1, T_2 and T_3 do not differ from zero at a 5% significant level.

Moreover, the hypothesis

$$H_0\text{: } R = \begin{bmatrix} 1 & 0 & 0 \\ & 1 & 0 \\ & & 1 \end{bmatrix} \tag{5}$$

is tested by the statistic

$$\chi^2 = -(N - 1 - \frac{2p = 5}{6}) \ln|R| \tag{6}$$

which is distributed as a Chi-square variate with 1/2p(p-1) degrees of freedom if H_0 is true where p is the number of variates and N is the number of observation vectors(Morrison 1990).
With

$$R = \begin{bmatrix} 1 & -0.090 & 0.147 \\ & 1 & 0.125 \\ & & 1 \end{bmatrix} \tag{7}$$

χ^2=3.36,we do not reject the hypothesis of H_0 at a 5% significant level. Therefore, based on the independent result, the three regression equations in (1) are estimated separately in the following sections.

"The average mooring times of three sub-periods and quantity of containers handled in term of companies and ports are summarized in Table 3. From this table one can also find that there exists a strong linear relationship between variables T_2 and X_7."

Table 2. Correlation Coefficients

	T_1	T_2	T_3	X_1	X_2	X_3	X_4	X_5	X_6	X_7
T_1	1.000	-0.090	0.147	-0.166	-0.215	0.144	-0.182	0.120	-0.087	-0.151
T_2		1.000	0.125	-0.392*	-0.182	0.095	0.116	-0.165	-0.202	0.951*
T_3			1.000	-0.414*	-0.276	0.426*	0.179	0.082	-0.204	0.032
X_1				1.000	0.524*	-0.897*	-0.008	-0.101	-0.040	-0.311*
X_2					1.000	-0.463*	-0.295**	0.250**	0.295**	-0.059
X_3						1.000	0.071	0.172	0.106	0.047
X_4							1.000	-0.375*	-0.351	0.136
X_5								1.000	-0.388*	-0.166
X_6									1.000	-0.180
X_7										1.000

* significant at level 1%

** significant at level 5%

Table 3. The Average Mooring Times of Three Sub-periods and Quantity of Containers Handled

Port	Company	T_1	T_2	T_3^{a}	X_7^{b}
KL	YM	46	996	129	718
	E&U	174	409	149	162
	HW	32	471	69	240
	OT	80	1636	78	1017
TC	YM	72	285	89	126
	E&U	23	457	25	316
	HW	63	311	42	199
	OT	264	430	69	227

a. in minutes

b. in units

5. MODEL ESTIMATION

For the choice of an optimal empirical model to analyze the lengths of mooring time the selection procedure is set as following stages：

1. listing all possible full rank models,
2. deleting models listed in the stage1 which have not hierarchically well-formulated(HWF)structure that contains all lower-order components (Neter, J. *et al.*1989),
3. selecting an initial model satisfying following criterion：

$$\max_{all\ HWF\ \text{models}} R^2$$
$$\text{sub. to}\quad \left|C_p-(p+1)\le 2\right| \tag{8}$$

where R^2 is the coefficient of determination of models, C_p is the Mallow's statistic and p is the number of variables in models.

4. diagnosising the initial model and remedying it, if any.

5.1 Preparation Period Model

Table 4 presents the estimated regression coefficients and related statistics for the preparation period model selected by the preceding procedure.

Table 4. Statistics Summary of The Preparation Period Initial Model

Variable	Intercept	Port	E&U	Port*E&U	R^2
Coefficient	58.08	16.05	71.42	-109.78	29.25%
t value	3.715*	0.862	2.820*	-3.351*	
VIF	0.000	1.476	2.259	2.321	

* significant at level 5%

This model contains three variables X_1, X_5 and X_{11} $(=X_1 * X_5)$. Due to the requirement of HWF, the variable X_1 is included in this model although its coefficient is not significant at level 5%. All vif values are less than 10.00 which indicates non-existence of severe linear relationship among variables in the model. The Shapiro-Wilk test statistic W=0.947 is not significant at level 5% which indicates that the normality assumption of error term is violated (Wethweill 1981). This violation is caused by an outlier whose residual is 1699.3 minutes, and cannot be remedied by reweighted least squares methods. This observation was observed from a ship whose crane was damaged, moored at a TC's public berth without crane, so the container handling operations of this ship could not be started until the damaged crane was fixed, this is the reason why the observation is so large. Because this case is not usually occurred, we delete this observation from data set and re-run the model. Table 5 shows the statistics of the re-run model.

Table 5. Statistics Summary of The Preparation Period Final Model

Variable	Intercept	Port	E&U	Port*E&U	R^2
Coefficient	56.2	11.49	72.88	-111.42	43.35%
t value	3.994*	0.673	3.173*	-3.540*	
VIF	0.000	1.476	2.23	2.32	

* significant at level 5%

On the comparison Table 4 and Table 5 the signs of coefficients are same, all the magnitude of differences between two estimated coefficients of the same variables are small. Shapiro-Wilk statistic W=0.967 is significant at level 5% which indicate the normality assumption of error term is appropriate. In order to test the constant variance assumption of error term, we divide the sample into four groups with the values of variables X_1 and X_5, and Bartlett testing statistic

$$B = 1 - \frac{1}{3(k-1)}\left(\sum_{i=1}^{k}\frac{1}{n_i} - \frac{1}{\sum_{i=1}^{k} n_i}\right)\left[\left(\sum_{i=1}^{k} n_i\right)\ln S - \sum_{i=1}^{k} n_i \ln S_i\right] \tag{9}$$

which is approximately distributed as a Chi-squared variate with degrees of freedom k-1 when the constant variance hypothesis $H_0 : \sigma_1^2 = \dots = \sigma_k^2$ is true(Morrison,1990) is used. The value of B calculated from the re-run model is 5.63 which do not reject the hypothesis at level 5%. Durbin-Watson statistic D_w=2.26 implies that the error term are not autocorrelated. Thus, the model whose estimated coefficients presented in Table 5 is the final preparation period model.

5.2 Container Handling Period Model

Table 6 summarizes the relevant statistics for the container handling period model.

Table 6. Statistics Summary of Containers Handling Period Model

Variable	Intercept	Port	Exclusive	Preferential	Container.	R^2
Coefficient	502.66	-330.78	-74.59	-285.33	1.11	93.36%
t value	6.621*	-4.518*	-2.213**	-4.235**	21.308	
VIF	0.000	9.125	1.418	7.514	1.648	

* significant at level 1%

** significant at level 5%

This model contains four variables X_1, X_2, X_3 and X_7. The t-value of the coefficient of X_7 is 21.308, which is the most significant. There is no multicollinearity problem because all values of vif are less than 10.0. The value of Modified Levene statistic calculated in term of variable X_7 is t_m=0.892, and W=0.975 verify the constant variance and normality assumptions of error terms are appropriate; D_W=1.746 do not reject the assumption of independent of error terms. Thus this model is to be considered as the final container handling period model. This model is powerful because of R^2=93.36% which is the proportion of variations of T_2 that can be explained by the model.

5.3 Waiting For Departure Period Model

Table 7 summarizes the relevant statistics for the initial waiting for departure period model.

Table 7. Statistics Summary of The Waiting For Departure Period Initial Model

Variable	Intercept	Port	E&U	WH	Port*E&U	R^2
Coefficient	111.55	-30.78	37.29	-40.66	-93.15	24.38%
t value	6.511*	-1.578	1.398	-2.033**	-2.584*	
VIF	0.000	1.45	2.23	1.18	2.25	

* significant at level 1%

** significant at level 5%

This model contains four variables X_1, X_5, X_6 and X_{11}, among which X_1 and X_5 are not significant at level 5%, they are included in the model because of X_{11}=X_1 $*$ X_5 included in. W=0.818 and t_m=3.89 imply that neither normality assumption nor constant variance are appropriate. In order to remedy these two problems simultaneously, Box-Cox transformation technique is applied to the initial model. Let

$$Y' = \begin{cases} Y^{\lambda} & \lambda \neq 0 \\ \log Y & \lambda = 0 \end{cases} \tag{10}$$

where λ is the transformation parameter. The Box-Cox transformation method is to find a λ which maximizes the likelihood function of normal distribution in terms of the transformed model

$$\begin{aligned} &E(Y_j^{\lambda}) = \beta_0' + \beta_1' X_{1j} + \beta_5' X_{5j} + \beta_6' X_{6j} + \beta_{11}' X_{11j}, \\ &Var(X_j^{\lambda}) = \sigma^2, \qquad \forall j, \end{aligned} \tag{11}$$

Since SAS package used by this study does not automatically provide the Box-Cox maximum likelihood estimate $\hat{\lambda}$ for the transformation. A simple procedure obtaining $\hat{\lambda}$ using standard regression software can be employed instead. This procedure involves a numerical search in a range of potential λ value. Table 8 contains the Box-Cox results for the initial model.

Selected values of λ, ranging from –1.0 to 1.0, were chosen, and for each chosen λ the transformation was made and the linear regression Y^{λ} on X_1, X_5, X_6 and X_{11} was fitted. For each fitted regression, two statistics, W and t_m, were calculated. Note from Table 8 that

Table 8. Box-Cox Results

λ	-1	-0.75	-0.5	-0.25	-0.1	0	0.1	0.25	0.5	0.75	1
W	0.949*	0.954*	0.971	0.977	0.972	0.965	0.955*	0.937*	0.901*	0.880*	0.818*
t_m	3.87	4.36	5.10	5.72	6.97	7.55	8.79*	9.23*	12.48*	19.28*	21.32*

*Hypothesis violation at level 5%

both hypotheses of normality and constant variance of error terms of transformed models are not rejected as values of λ ranging from –0.5 to 0. While the model of which λ= -0.25 seems the best one, the model with λ=0 is chosen as the final model of this period because the values of W as a function of λ are fairly stable in this range and also because of the ease of interpreting it. The statistics of this final model are shown in Table 9.

Table 9. Statistics Summary of The Final Waiting For Departure Period Model

Variable	Intercept	Port	E&U	WH	Port*E&U	R^2
Coefficient	4.543	-0.397	0.138	-0.430	-1.119	40.04%
T value	31.709*	2.432**	0.620	-2.569**	-3.713*	
VIF	0.000	1.449	2.230	1.181	2.59	

* significant at level 1%

** significant at level 5%

6. INTERPRETATION

6.1 Quantity Effect

Our result regarding the ability of the quantity of container units to explain T_2 is very much in line with our preceding prediction. In average, one unit increment in container handling will increase 1.11 minutes increment in mooring time of a containership in spite of how many container cranes has been used in the period. For the reduction of mooring time shipping companies should employ as many cranes as possible to handle their containers no matter what port or berth they used. In general, the more is the containers handled, the more is the cranes used. This is the reason why the quantity of containers handled can explain most of variations of T_2 without inclusion the number of cranes used in the model.

On the other hand, the significance of variable x_7 while variable X_{13} ($=X_1 * X_7$) is not significant implies that in a certain extent the efficiencies of container handling of dockers of two ports has no significant difference although the managerial systems of dockers of two ports are not same.

6.2 Port And Berth Assignment Rules Effect

Among all variables only port X_1 is included in all of the three equations. This means that port itself is an important factor influencing the length of mooring time. The differences of mooring times between two ports are presented in Table10. As the Table shown, The 11.49 minutes difference in T_1 between two ports is not significant at level 5%.

In the containers handling period, the differences of mooring times between two ports depend on which kind of berth is moored. For the public berths, the time that a ship stays in T_2 at port TC is 330.72 minutes less on an average than that of at port KL. Part of this huge difference is resulted from the worse environmental conditions of port KL. The long containers handling times may be caused by the congestion of traffic and narrow back yards of wharves of port KL. For an example, the area of container yard of port TC is 74 hectares, triple of port KL. And part of this difference be resulted from the inferior management, such as the high cranes damage rate and the loose relationship with a strong union of dockers, of KL port authority.

Table 10. The Comparison of The Mooring Time of Ports Keelung and Taichung

Period / Port	T_1	T_2			T_3	Total		
		Public Berth	Preferential Berth	Exclusive Berth		Public Berth	Preferential Berth	Exclusive Berth
Keelung	56.2	502.66	217.33		93.97	652.55	367.22	
Taichung	67.69	171.94		97.35		302.63		228.04
Difference	-11.49	330.72			30.69	349.92		

On the other hand, in contrast to mooring at a public berth, there is a 285.33 minutes short in time if the ship moors at a preferential berth of KL. Similarly, there is also a 74.59 minute shorter if a ship choose to moor at an exclusive berth than a public berth in port TC. These results imply that the berth assignment rules have a significant influence on the length of mooring time. It is an interesting finding because the effect of berth assignment rules on the time that a ship stays in a port seems to be known by most of port practicians and researchers, but there was still no concrete study result on the subject in the past. The original purposes of berth assignment rules is supposed to be designed to reduce the time that a ship has to wait for entering the harbor. While this direct effect of the berth assignment rules has not been studied; the effect on the mooring time reduction which may not suppose to be is observed in this paper. In view of shipping companies, the operational environment become more flexible when they can choose an appropriate berth assignment rule to fit their own needs. Those companies adopting preferential or exclusive berths will put more efforts to managing the relevant affairs when a ship arrive at the port, and these managerial efforts may cause the reduction of mooring time.

In the waiting for departure, the average mooring time of port KL and TC are 93.97 minutes and 63.18 minutes, respectively. There is a 30.69 minutes difference between ports KL and TC. This difference is significant at level 5%. A reason for this difference is resulted from the fact that, in comparison with port TC, there are more ships in port KL with a narrower water area. Hence, when the departure times of several ships are scheduled on several short time intervals, particular in 8:00~10:00 and 22:00~24:00, then the time waiting for departure will be large in port KL than in port TC in these intervals.

6.3 Company Effect

Table 11 presents the average mooring time for the different periods in terms of variables "port" and "companies". The difference in T_2 among average times of the companies are explained by the different berth assignment rules of which they employed and the different ports at which they moored. The incentive of employment of preferential or exclusive berths is the effect of economy of large scale. It is no wonder that all companies having busy voyages, like YM 、E&U and WH, employ the berth assignment rules to reduce the mooring times of their ships.

It is found, from Table 11, that the company effect is also significant T_1 and T_3. In the first place, one can see that, in these two periods, E&U has the longest average mooring times at port KL, But the shortest at port TC. The possible reasons for that of T_1 are (1) sometimes, the activities of containers handling can not be started even when all preliminary works have been done well at port KL because containers are crowded in the road between Taoyuan container terminal and port KL. And (2) the damages of aged cranes of preferential berths in the second container center of port KL employed by E&U often delay the start times of containers. For an example, in port KL, the average years of

Table 11. The Comparison of Company Effect (unit = minute)

Port	Company	T_1	T_2	T_3	Total
KL	YM	56.2	217.33	93.69	367.22
	E&U	129.08	217.33	107.55	453.96
	HW	56.2	217.33	61.13	334.66
	OT	56.2	502.66	93.69	652.55
TC	YM	67.69	171.94	63.00	302.63
	E&U	29.15	97.35	23.71	105.21
	HW	67.69	97.35	41.14	206.18
	OT	67.69	171.94	63.00	302.63

cranes used in the second container center is 12.3 years which is large than that of the first and the third container center whose average years of cranes are 11.9 years and 9.3 years, respectively. Furthermore the damage rate of the second container center of port KL is 3.92% of work hours which is significantly larger then that of the first and the third container centers whose damage rates are 2.01% and 2.38%, respectively (Keelung Harbor Bureau 1997).

The reasons for the longest T_3 of E&U at port KL can be explained as follows. (1) Because of the uncontrollable factor of traffic conditions, E&U usually plans a long T_2 for the ships at port KL, then there will appear a long T_3 if traffic and cranes are in good conditions. And (2) recently, most of E&U ships have begun to moor at port TC, the preferential priority of E&U to the berths in the second container center of port KL is beyond YM and WH. For keeping their subsequent ships being able to continuous moor at the berths for their own convenience, the existing ship in the berths will postpone the departure time tactically, this then makes a long T_3. The second, the shortest T_3 of E&U at port TC and the good performance in all periods of WH at both ports might be explained by the same reason, that is, the extra managerial efforts they made in all respects. The third, the average T_3 of YM at port KL is not shorter than OT might be explained by the fact that when a ship arrives at port KL, YM permit the crew of this ship to go and stay at home for a period.

7. CONCLUSION

For analyzing the determinants of the length of container ships mooring time on a berth of ports KL and TC, we divide the time interval into three unfolded periods: (1) preparation period, (2) container handling period and (3) waiting for departure period. For each period, an empirical model is estimated with a sample of size 77 ships observed from both ports. The results are summarized as follows:

(1) The lengths of time interval of the three periods are statistically independent. It is an interesting finding because the models of these three periods can be estimated separately and their determinants could be different.

(2) The three estimated regressions are:

$$\begin{aligned}\hat{T}_1 &= 56.2 + 11.49X_1 + 72.88X_5 - 111.42X_1 * X_5 \\ \hat{T}_2 &= 502.66 - 330.78X_1 - 74.59X_2 - 285.33X_3 + 1.11X_7 \\ \hat{T}_3 &= \exp(4.543 - 0.397X_1 + 0.138X_5 - 0.430X_6 - 1.119X_1 * X_5)\end{aligned} \tag{12}$$

where T_i, i=1, 2, 3, are the length of the i th period of mooring time, their proportion to the total mooring time are , on average, 10%, 78%, and 12%, respectively. The ratios of PRESS to SSE of the three models (Neter, J. *et al.* 1989), are 1.41, 1.03 and 1.37, respectively. The fact that all PRESS values do not differ to greatly from their corresponding SSE supports the fitted regression model.

(3) The coefficients of variable "port" are significantly on the models T_1, T_2 and T_3, this means that the efficiency of berth operations system of port TC is better then that of port KL because of the superior environment and also the superior management of port TC.

(4) In viewpoint of berth operational performance evaluation, the insignificance of the coefficient of interaction effect of variable "port" and variable "the quantity of containers handled" represents that the container handling efficiency of both ports have but little difference. With the exception of the quantity of containers, the coefficients of port and berth assignment rules of T_2, which represent the effort of port authority, are also significantly.

(5) The significance of interaction effect coefficients β_{11} in model T_1 and model T_3 demostrate that the E&U adapts different mooring policies to different ports and that the company effect on mooring time does exist although R^2 of model T_1 and of model T_3 are less than 50%.

(6) The effect of berth assignment rules has been discovered in T_2. There is, on average, a 285.33 minutes mooring time less in T_2 if a ship arriving at port KL moor at preferential berths instead of mooring at public berths. Similarly, the time less is 74.57 minutes in port TC.

(7) Due to her own policy, E&U has the longest T_1 and T_3 in port KL, but has the shortest T_1 and T_3 in port TC among three companies. On average WH's performance of managing container ship mooring time is superior to the other companies in both ports.

Our main objective in this paper is to shed some light on the issue of the determinants of container ships mooring time. Although 93% variation of container handling times can be explained, what we offer is not an exhaustive list of the factors that influence the first and the third sub-periods of the mooring times. It is our belief that apart from the factors examined in this paper, there are other factors, such as the liner routes, the pilot systems, etc., which may also affect the lengths of these two sub-periods of the mooring times. However, we believe that the findings of this paper may be useful to both the shipping companies and the port authorities in the sense that they provide a first insight to the four factors affecting the container ships mooring time.

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