Journal of Port and Harbor Research. RIPAH
Korea Maritime University Vol. 8. pp. 1~11. 1997.

論 文

Mid-Term Container Forecast for Pusan Port

*J. Y. Gu**

부산항 컨테이너 물동량의 중간예측

구 자 영

Key Word : Mid-Term Container Forecast(컨테이너물동량중간예측), Regression Method (회기분석법), Multiple Regression Curved Surface(MRCS: 다변량 회기곡면), Port Information (항만정보), Non-linear Relationship(비선형관계), Competitive Ports(경쟁항만)

Abstract

The conventional methods of container forecasting is done through regression methods based on GNP growth trends and by other forecasting methods proposed by several authors. However these efforts prove to be inadequate with visible weakness and a more reasonable approach need to be determined. The succeeding sections elaborate the methodology and approach adopted. The results are then compared through a case study involving the forecast figures derived by the Pusan Port Authority and the values obtained by MRCS model introduced in this paper.

1. Introduction

1.1 Background

Ports, handling the majority of external trade act as the trade gateway and highly dependent on the economic growth of a country and in essence a terminal of seaborne cargo transit area. Stiff competition among neighbouring ports also warrants the approach towards port planning and development(such as expansion of port size, increase in the number of berths, freight flow trend and restructuring of port information system) to be scrutinized. Adequate and efficient port facilities and cargo transshipment route promotes

* 해양경찰청 전산소 개발계장

further international trade transaction. In addition, due to the separation of economic circle, competitiveness of inter-port is more serious now and accelerated the concept of open port system.

Thus, in the earlier studies, port facilities are decided by two dimensional relationship producing a less accurate freight demand forecasting. These seem to be one sided analysis causing the unbalance problem between container freight and port facilities. Comprehensive analysis between the relationship between port information (facility level, port service level) and container freight flow in the region need to be integrated.

1.2 Objectives

Taking the above factors into perspective and consolidating Korea's interest in the E/SE Asia region for containerized commodity, the objectives of this paper can be outlined as follow: To obtain a more reasonable forecasting method which is very detrimental to container freight flow analysis for port development purpose, Multiple Regression Curved Surface (MRCS hereafter) is introduced. Conventional methods proves to be inaccurate because no comprehensive analysis on the relationships between several port factors (total traffic volume) were done which are significant to the fluctuation of freight flow generated among inter-competitive hub-ports.

2. Comparative Analysis Among Major Hub-Ports

The dynamics of a port and the function it serves need to be comparatively analyze which leads to the individual port competitiveness in terms of containerization. In this analysis the ports in the region of E/SE Asia region were studied upon. The hub-ports compared are Hong Kong, Singapore, Kaoshiung, Pusan, Kobe, and Yokohama. There are many criteria for evaluating port competitiveness, but this paper selected only 2 main determinants; port facility and service level. Fig. 2.1 shows the scope of analysis performed.

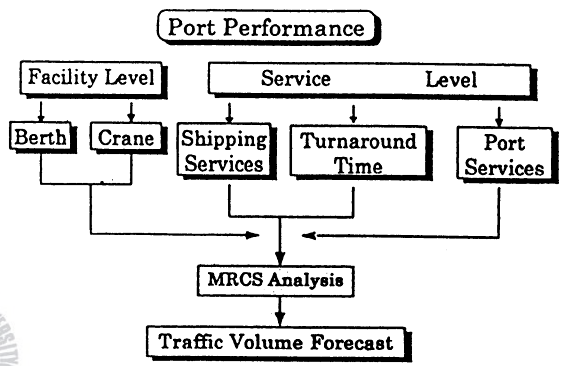

Fig. 2.1 Comparative analysis flowchart

3. Analysis of Port Information Variables

3.1 Methodology

In order to estimate the volume of container freight flow within any origin/ destination (called as O/D hereafter) in a transportation network, it is necessary to analyze the relationship between trade value and container freight volume of a country. The said relationship is further used in the analysis of container freight flow on sea routes followed by container volume forecasting and applying moving average method. Finally, using multiple regression curved surface (hereafter MRCS) model to ascertain the non-linear relationship between traffic volume, transportation fare, and port charges in order to analyze container among competitive ports.

3.2 Development of MRCS

1) Relationship between Transportation Fare and Distance

The reason for the MRCS model in inducing exponential function in its algorithm formulation can be explained as follows.

Table 3.1 Relationship between inland transportation fare and distance, lot size

Unit:US$

Fare	Distance (km)	Fare/ km	Fare	Lot size (ton)	Fare/ ton
300	15	20.0	13.9	1	13.9
205	15	13.7	15.9	2	8.0
1075	120	9.0	17.3	3	5.8
1265	180	7.0	19.0	4	4.8
1170	140	8.4	21.1	5	4.2
1410	190	7.4	23.0	6	3.8
1455	200	7.3	25.7	8	3.2
1505	207	6.8	29.3	10	2.9
1695	250	5.9	30.3	12	2.5
2100	356	5.6	34.0	14	2.4

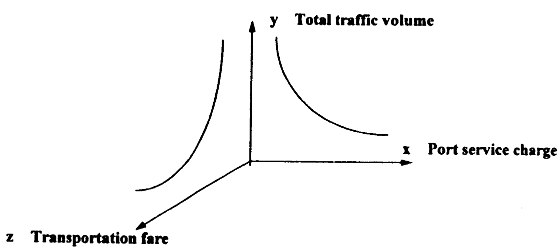

Fig. 3.2(a) Relationship between sea transportation fare and distance

According to the results of the various relationship analysis between transportation fare and distance, and lot size, the relationships follow an exponential curve pattern. This is expressed by Table 3.1 and Fig. 3.2(a).

2) Traffic volume, transportation fare (involving frequency, ship size, and distance) and port charges (involving number of cranes, number of berths) are port variables selected and presented in the 3D figure as shown by Fig. 3.2(b).

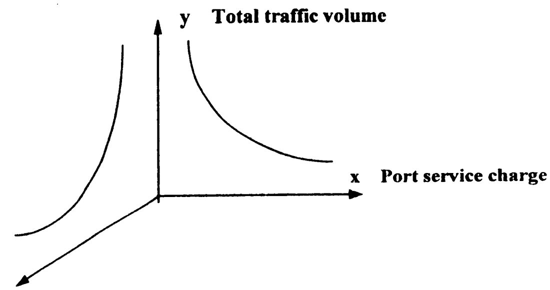

Fig. 3.2(b) Relationships between total traffic volume and port variables.

(1) Transportation Fare

It is the total fare from/to a port by route. Port handling volume depend greatly on the transportation fare (economic benefit) from/to a port which is influenced by several fluctuating factors. In this study, the route is categorized into 4 areas; Europe (Rotterdam), North America (Los Angeles), South East Asia (Singapore), and North East Asia(Shanghai). Naturally shippers and carriers route choice would be that of minimum transportation cost[10]. In the selection, however, the domestic transportation fare(truck) normally has not been considered since it is not related in measuring port total traffic volume. Inclusion of domestic transportation fare(truck) is explained in the succeeding section.

(2) Port Service Charge

Similar to (1) above, it plays an important role in deciding port handling volume. As port facilities changes, port service charge also changes. This variable determines the competitiveness power of a port and a key factor in the selection by shipper and shipping company. The curved regression lines as presented in the figure above can be expressed as in the equations below:

$$Y = f(x,z) \Rightarrow \partial f/\partial x = \alpha h(z), \partial f/\partial z = \gamma g(x) \quad \text{..(3-1)}$$

$$y = g(x) = \alpha\, e^{-\beta x}, y = h(z) = \gamma\, e^{-\delta z} \quad \text{..........(3-2)}$$

where α, β, γ are parameters determined by regression analysis.

(3) Plotting the MRCS

To plot a three dimension[3] multiple regression curved surface (MRCS), as depicted by Fig. 3.3, the three axes, x, y, and z are cut at any value by each axis, then shifted a parallel move from two to three dimensions curve of each axis matching point. In this space of three dimensions, the demand function can be drawn as the surface plane shown in the figure. The MRCS equation can be given by:

$$F = g(x) \cdot h(z) = \alpha e^{-\beta x} \cdot \gamma e^{-\delta z} \quad \text{...................(3-3)}$$

and the parameters can be determined by regression analysis. The container traffic volume demand decreases with increasing transportation fare, as would be expected, and also with increasing time on the level of port service charge axis, indicating that high transportation fare have increasing disutility.

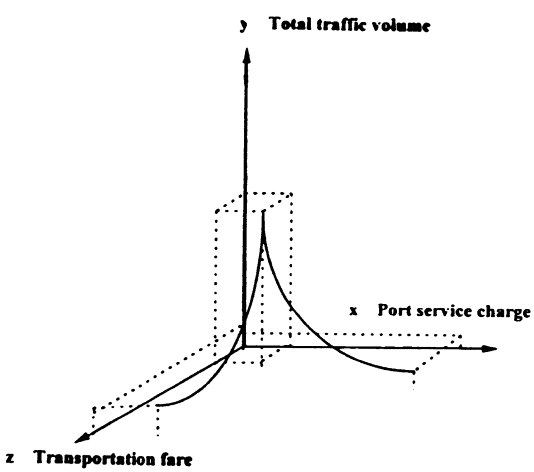

Fig. 3.3 Multiple-regression curved surface (MRCS)

The underlying choices made by the management of the facility and service charge which lead to this function are quite complex. In general, given the particular technology or production function, they will result in a unique cost and unique level of port service charge for each volume of traffic.

The MRCS carried the assumptions that the volume is the total available container with fixed volume between any O/D, and that the ship size is classified by route as given in the Table 3.2. In order to calculate total transportation fare and service charge, equations using simple algorithm are provided in the succeeding sub-chapter.

Table 3.2 Distribution of ship size by route

Unit: number of ship and TEU

Route /Size	-1000	-2000	-3000	-4000	-5000-	Average (TEU)
USWC	12	22	95	49	44	2888.6
UKCS	0	10	75	77	45	3298.3
SEAS	272	88	7	0	0	745
NEAS	8	-	-	-	-	748
KOCH	28	-	-	-	-	345
JPCH	118	-	-	-	-	405
KOJP	59	-	-	-	-	169

Data source: International Transportation Handbook 1996. Route: USWC-West Coast of North America, UKCS-United Kingdom, Continent and Scandinavia, SEAS-Inter Southeast Asia, NEAS-Inter Northeast Asia, KOCH-Korea and China, JPCH-Japan and China, KOJP-Korea and Japan.

3.3 Relationship Analysis of the Port Information Factors

1) Transportation Fare

The components of transportation fare can be illustrated by the Fig. 3.4 and represented by equation 3-4.

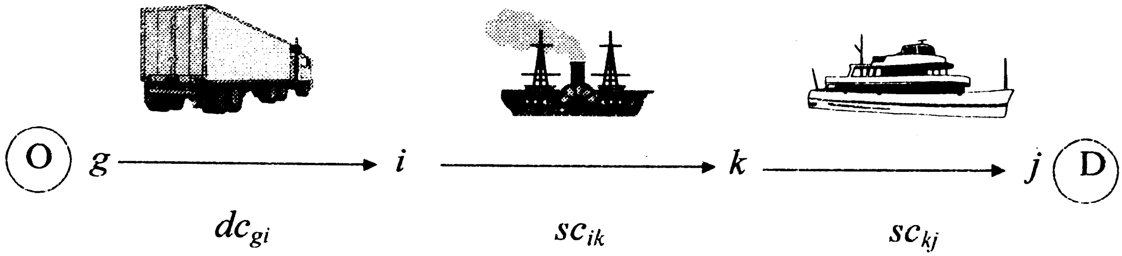

Fig. 3.4 Distinction of variables by route

$TF_{gj}=dc_{gi}+sc_{ik}+sc_{kj}$ .... (3-4)

where, TF_{gj}; total fare of container freight 1 unit from supply point g via i, k port to demand port j

dc_{gi}; fare of domestic transportation from supply point g to supply port i

sc_{ik}; tariff of freight transportation from supply port i to via port k

sc_{kj}; tariff of freight transportation from supply port k to demand port j

2) Port Service Charge at a Calling Port

Port service charges consist of ship-based charges and handling charges for container freight. The ship-based charges include tonnage dues, berth hire, pilotage, towage, mooring /unmooring charges et cetera. Fig 3.5 illustrates the variables for a given route and the port service charge is given as:

$PC_{i,k}=(sb_i+sb_k+hc_i+hc_k)$ .... (3-5)

where, $PC_{i,k}$; total port service charge at calling port i, k

sb_i; ship-base charge at supply port i

sb_k; ship-base charge at via port j

hc_i; fare of freight handling at supply port i

hc_k; fare of freight handling at via port k

In Fig. 3.5, two of the four factors areconsidered constant since the charges incurred are related to own port. In this case, the solution in handling cost and ship-base charges at hub-port is as follows:

$$PC_k = y_4\, e^{-(\alpha_4 nb + \beta_4 nc + \gamma_4 hv + \delta_4 wr)} \quad \text{........ (3-6)}$$

where, pc_k: port service charge at a calling port k

nb: number of berth,

nc: number of crane,

hv: total handling volume of container

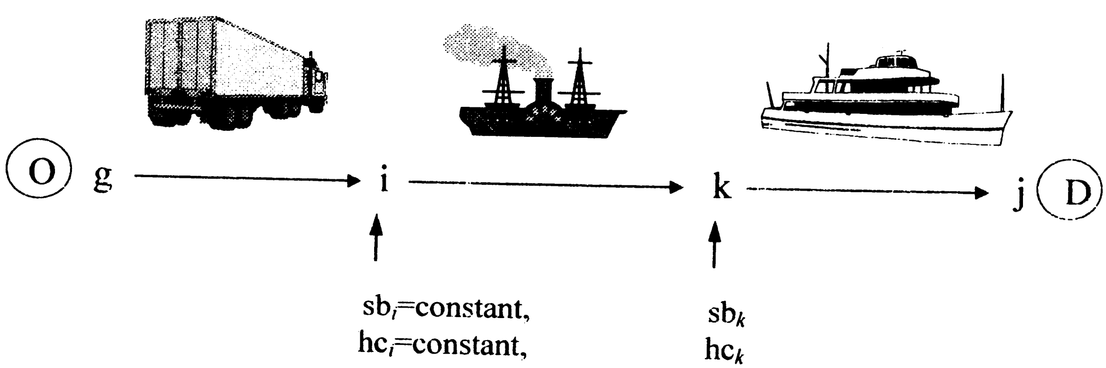

Fig. 3.5 Distinction of variables by via port

freight

wr: wage rate, y_4: unknown constant.

3) Relationship between Transportation Fare and Traffic Volume

The relationship between transportation fare and traffic volume is given by equation(3-7). In addition, taking account frequency as the main factor in transportation fare, the frequency at a calling port in relation to traffic volume is expressed by equation(3-8).

$$TV = y_5\, e^{-\alpha_5 TF} \quad \text{(3-7)}$$

here, TV: total traffic volume,

TF: total transportation fare by route.

$$TV = y_6\, e^{\alpha_6 Fq} \quad \text{(3-8)}$$

where, *Fq*: frequency (full container & semi-container) for a port per year

4) Relationship between Traffic Volume and Port Service Charge

Equation 3-9 and equation 3-10 expressed the relationships between traffic volume and port service charge, and between traffic volume and the number of berth and crane respectively.

$$TV = y_7\, e^{-\alpha_7 PC} \quad \text{(3-9)}$$

where, TV: total traffic volume,

PC: total port service charge a port.

$$TV = y_8\, e^{(-\alpha_8 nb + \beta_8 nc)} \quad \text{(3-10)}$$

where, *nb*; number of berth at a port

nc; number of crane at a port

5) Relationship between Transportation Fare and Port Service Charge

At present the analysis between the relationship of transportation fare (*frequency*), and port service charge (*nb, nc*) were done individually. By considering them simultaneously, their relationship are as follows:

$$e^{PC} = y_9 + \alpha_9\, e^{TF} \quad \text{(3-11)}$$

where, *PC*: total port service charge,

TF: total transportation fare by route.

$$Fq = y_{10}\, e^{(-\alpha_{10} nb + \beta_{10} nc)} \quad \text{(3-12)}$$

where, *Fq*: frequency(full container & semi-container) of a port/year

nb: number of berth,

nc: number of crane

6) Traffic Volume, Transportation Fare and Port Service Charge

By integrating all the port variables as stated in the preceding sub-chapters, the equation formulated is given by equation 3-13.

$$TV = y_{11}\, e^{[\alpha_{11}(TF) + \beta_{11}(PC)]} \quad \text{(3-13)}$$

By considering equations (3-2) and (3-4), the following equation is obtained.

$$TV_k = \alpha\, e^{-\beta(TF_{gi})}$$
$$= \alpha\, e^{-\beta y_1[(\alpha_1 d) + (1 - \beta_1 l)] + y_2\, e^{-(\alpha_2 d + \beta_2 sv)} + y_3\, e^{-(\alpha_3 d + \beta_3 f_{ki})}} \quad \text{(3-14)}$$

Also, from equations (3-2) and (3-4), port service charge can be computed as:

$$y = h(z) = \gamma e^{-\delta z} \Rightarrow TV_k = \gamma e^{-\delta x}$$

$$TV_k = \gamma e^{-\delta(PC_{ik})} \quad \text{(3-15)}$$

From equation (3-3):

$$TV_k = \theta e^{-\beta TF_{gi}} \cdot e^{-\delta PC_k} \quad \text{(3-16)}$$

Giving:

$$TV_k = y_{12}\, \theta e^{u} \cdot e^{y} \quad \text{(3-17)}$$

Where

$$u = -\beta y_1^{[(\alpha_1 d) + (1 - \beta_1 l)]} + y_2 e^{-(\alpha_2 d + \beta_2 sv)} + y_3 e^{-(\alpha_3 d + \beta_3 f_{ki})}$$

$$v = y_4 e^{-(\alpha_4 nb + \beta_4 nc + \gamma_4 hv + \delta_4 wr)}$$

θ: unknown parameter can be determined by regression analysis

3.4 Results of Analysis

Using the derived equations and data availability using MRSC model concept, the results obtained are as follows.

1) Transportation Fare and Traffic Volume

The results for the relationship between transportation fare and total traffic volume using equation(3-7) and between transportation fare factor, frequency at a calling port, and traffic volume using equation (3-8) are given by Table 3.3 and Table 3.4 respectively.

Table 3.3 Regression results for transportation fare and traffic volume

	Partial Regr. Coefficient	Std. Partial Regr. Coefficient	t-value
TF	-0.00127	-0.923	4.16
Constant	13.00181	*	12.11
Coeff. of determination: 0.852 ; Data numbers=5			

Note: TF means sum up sea transportation fare of 4 routes(from Hong Kong, Singapore, Kaoshiung, Kobe, Pusan to Europe route-Rotterdam, N. America route-Los Angeles, SE Asia route-Singapore, Feeder route in the NE Asia-Shanghai respectively), it is a calculated data(except Pusan, Kobe).

From the above table, it is shown that there is a high correlation between transportation fare and traffic volume and thus further analysis were carried out involving the main factor in transportation fare (frequency) and traffic volume as shown by the table below. As expected, the correlation between them are high.

Table 3.4 Regression results for transportation fare (frequency) and traffic volume

	Partial Regr. Coefficient	Std. Partial Regr. Coefficient	t-value
Fq	0.0000463	0.977	16.68
Constant	7.739	*	155.79
Coefficient of determination: 0.955 ; Data numbers=15			

Note; Fq means frequency at a calling port per year, ship's class of full and semi-container vessel, it is a calculated data(except Korea, Hong Kong) also. The assumption is as follows; Singapore as the same HK(T/S 60%), Kaoshiung 35%, Kobe 20%, and Korea 10%.

2) Port Service Charge and Traffic volume

The relationship between port service charge and traffic volume using equation (3-9) and between port service charge factors (number of crane and number of berth) and traffic volume using equation (3-10) were analyzed and the results as shown by Table 3.5 and 3.6 respectively.

Table 3.5 Regression results for port service charge and traffic volume

	Partial Regr. Coefficient	Std. Partial Regr. Coefficient.	t-value
PC	-0.00495	-0.847	5.74
Constant	9.475	*	47.46
Coefficient of determination: 0.717 ; Data numbers = 15			

Table 3.6 Regression results for port service charge factors and traffic volume

	Partial Regr. Coefficient	Std. Partial Regr. Coefficient.	t-value
nb	-0.0588	-0.139	8.49
nc	0.0468	1.334	10.43
Constant	7.583	*	56.66
Coefficient of determination: 0.903 ; Data numbers = 15			

The above table shows a significant correlation between the two variables and thus proceeded to the analysis of the port service charge factors (nc and nb) with traffic volume as in the table below. A high correlation was observed.

3) Transportation Fare and Port Service Charge

The analysis between the relationship between transportation fare and port service charge using equation (3-11) and between transportation fare factors (frequency, number of berth, number of crane) and port service charge using equation (3-12) are the essence of the MRCS model. The results are as in Tables 3.7 and 3.8 respectively. For both cases, exponential value are used in the calculation since they are related with exponential relationship towards total traffic volume (equation 3-3).

Table 3.7 Regression results for transportation fare and port service charge

	Partial Regr. Coefficient	Std. Partial Regr. Coefficient.	t-value
	1.438	0.979	8.39
Constant	14.807	*	3.38
Coefficient of determination: 0.959 ; Data numbers = 5			

The above table shows a significant correlation between port service charge and traffic volume and thus justified in performing further analysis but this time taking account the port service charge factors (number of berths and crane). The results (table below) show that a high correlation exists between them.

Table 3.8 Regression results for transport- ation fare(frequency) and port service charge using factors

	Partial Regr. Coefficient	Std. Partial Regr. Coefficient.	t-value
nb	-0.0835	-1.049	10.63
nc	0.0708	1.374	13.92
Constant	7.583		52.51
Coefficient of determination: 0.942 ; Data numbers = 15			

4) Traffic Volume, Transportation Fare and Port Service Charge

The integration of three variables (TV, TF, PC) completes the MRCS model. Using equation (3-13) the results of the variables relationship are given in Table 3.9.

Table 3.9 Regression results for traffic volume, transportation fare, and port service charge

	Partial Regr. Coefficient	Std. Partial Regr. Coefficient.	t-value
PC	-0.00633	-0.799	3.04
TF	-0.00023	-0.202	0.77
Constant	10.76442	*	20.12
Coefficient of determination: 0.993 ; Data numbers = 5			

From the above table, the correlation between all the port variables were correlated but the value of TF was not correlated as given in the t - value.

3.5 Comparison of the Results

Table 3.10 shows the comparisons between computed results using MRCS to the actual figures for the hub-ports in the E/SE Asia.

Table 3.10 Comparison of actual data and computed figures.

Port	Computed(a)	Actual(b)	Ratio(a/b)
Pusan	4,543	4,500	1.00956
Kobe	1,315	1350	0.974
Hong Kong	13,170	12600	1.045
Kaoshiung	5,667	5,232	1.0832
Singapore	10,516	11,850	0.8874

Table 3.11 shows the comparisons done between computed results using MRCS to forecast figures as obtained from the existing Korean ports development plan.

Table 3.11 Comparison of existing plan and new MRCS value

Target Year		1995	1997	2001	2011
Existing	Berth	7	7	15	21
	Crane	20	20	38	46
Planned	Berth	*	8	6	36
	Crane		18	8	72*
Total	Berth	7	15	21	57
	Crane	20	38	46	118
Korean Forecast Vol.(a)		4,500***	6,560**	9,850	19,000
MRCS Forecast Vol.(b)		4,543	7,289	6,630	14,885
Ratio(b/a)		1.0096	1.1111	0.6731	0.7834

Note:* Crane numbers are calculated by 2crane per berth, ** The value was interpolated by the value of during the 1995-2001. ***Actual figures. Vol. unit:1,000TEU

3.6 Summary and Discussion

Comparing the MRCS results and the simple regression analysis based on the GNP growth, MRCS proves to be more reliable and because of its comprehensives with an average error ratio of 5.5% when compared to the actual data.

The real focus in this chapter is the introduction of a simple Multiple Regression Curved Surface (MRCS) model which only requires the use of simple data consisting of transportation fare and port service charge. MRCS proves to be effective in analyzing transportation policy, such as handling cost, establishment of new route (for frequency, ship size), construction of new port (for berth), and rearrangement of port equipment (for cranes). However, as with other methods proposed by previous studies, reliability is still yet to be perfected since the definition of reliability is complex because of its dependence on the behavior of shippers and carriers, transportation fare changes and improvement of service facilities within a given range.

There are certain limitations in adopting this MRCS model as mentioned above, but these are only minor problems which do not discredit the model as a whole. MRCS integrate the main port variables represented by 3D figure and thus more comprehensive and closer to the real world situation. This is truly so when compared to previous studies whereby only individual port variables are considered. Its simplicity by using non complex data is also an advantage.

4. Conclusion

According to MRCS analysis, berth development leads to port charge increase while adding crane numbers caused decreasing port charge. Thus to set the condition in the port charge aspect, minimum rate for berth per crane is 1.85cranes/berth. If a lower value than minimum rate is selected, it leads to increasing port charge. In the total traffic volume aspect, minimum rate for berth per crane is set at 1.13cranes/berth and for lower value than this minimum rate is selected, it leads to decreasing cargo traffic volume.

Both the above rates need to be considered in the port development plan and by analyzing the Korean ports development plan, the below findings are met:

1) For the year 2001, the number of berth and crane need to review if the forecast volume need to be handled smoothly.
2) For the year 2011, the forecast volume is overestimated as compared to MRCS results. In other words the port facilities is inadequate.

요 약 문

우리나라에서의 해상물동량은 거시적분석법과 미시적분석법을 병행해서 예측하고 있다. 우선 거시적방법으로 국내외경제동향 및 각종 지표분석을 하여 항만물동량을 전망하고, 미시적방법으로는 품목별 생산, 소비, 수출입 수급량예측을 한 다음, 정부 및 관련업계, 기관의 추정치를 참고로하여 최종 예측물동량을 확정하는 것이 일반적이다. 또, 지정항만의 물동량예측에 있어서도 전체물동량 예측값에서 대상항만이 그 나라에서 차지하는 비율 혹은 평균증가율에 따라 그 예측치를 산정 하고 있다. 이러한 방법은 다른 경쟁항만의 개발 및 변화에 따른 영향이 요소로서 전혀 고려되고 있지 않아 국제경쟁력시대에 맞지 않아 예측량이 실제값과 근사한 값으로 접근할 가능성은 작다.

따라서 이러한 문제점들을 최대한으로 수정, 보완해서 항만의 운영효율고취 및 대외경쟁력고취를 위한 종합적인 분석을 통해 항만의 물동량을 예측해야 할 필요가 있다. 본 연구에서는 이러한 종합적인 분석을 위해서 우선 주위 경쟁 중심항만(Hub Ports)간에 나타나고 있는 물동량 유동 형태(Flow Pattern)를 MRCS(다변량곡면)를 통해 파악했다. 그리고 그 유동형태를 구성하는 각 요소간의 관계를 분석했다. 예를들면 선석수와 물동량과의 관계, 크레인수와 물동량과의 관계, 선석수와 크레인 수와의 관계, 선석 및 크레인수와 선박의 기항수와의 관계, 선석 및 크레인수와 항만요금(하역 및 제요금포함)과의 관계, 항만요금과 GNP, 임금수준과의 관계 등의 분석을 통해서 이러한 요소들간의 영향력을 분석했다.

이러한 분석결과, 각 항만 정보요소간의 관계는 표 3.5-표 3.9와 같은 관계를 알 수 있었고, 표 3.11에 나타난 것과같이 평균오차 5.5%란 결과를 도출하였다. 또 동/동남아시아 주요 중심항만(코베, 홍콩, 싱가포르, 카오슝, 부산등)간의 물동량 유동형태를 그대로 유지한다고 가정했을 때, 2011년(총선석 57, 크레인수 118기 기준)의 부산항 예상물동량은 약 1,490만TEU로 계산되었다. 이상의 결과를 미루어 볼 때, 어느 항만의 물동량 예측은 해당항만 자체의 정보뿐만 아니라 경쟁항만의 정보를 종합적으로 분석한 것을 기초로하여 행해져야 할 것으로 사려된다.

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