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A Study on forecasting container volume of port using SD and ARIMA

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Abstract : *The forecasting of container volume which is the basis of port logistics facilities expansion has a great influence on development of an port. Based on this importance, various previous studies have presented methodology on container volume forecasting. The results of many previous studies pointed out the limitations of future forecasting based on past container volume and emphasized that more various factors should be considered to compensate this. Taking notice of this point, this study forecasted future container volume by using ARIMA model, time series analysis and System Dynamics (SD) method, a dynamic analysis technique and performed the comparative review with the forecast of the Ministry of Land, Transport and Maritime affairs. Recently with rapid changes in economic and social environment, the non-linear change tendency for forecasting container traffic is presented as a new alternative to the country.*

Key words : *Container volume forecast, System dynamics, ARIMA analysis, Bass model , Vensim*

1. Introduction

Modern port facilities not only perform traditional trade functions but respond to various social and economic changes and due to larger vessels, clustering, rapid transition to container cargo etc. the life cycle of facilities is getting shortened (Son, 2009).

Accordingly, ongoing redevelopment of worn out ports is required and in planning new facilities, container volume forecasting almost in real time considering a variety of variables became eagerly needed.

However, examining the previous studies, they just predict the future container volume by simply using times series that the existing ports have. But modern ports confront the limitations forecasting the future container volume only with the simple past data and it is because port container volume is affected very flexibly by exogenous variables occurring from around the world (exchange rate, economic growth rate, relationship between nations etc.). This study is different from normal existed forecasting methods, such as ARIMA, regression method used by the Ministry of Land, Transport and Maritime affairs, using SD method which reflects the change of environment to forecasting the container volume in the future, the purpose of this study is to diversify the method and find more flexible and exact method to forecasting the container volume.

By performing the comparative review on the analysis result with the forecast of the Ministry of Land, Transport and Maritime affairs which is used officially in the country, we verify the usefulness and limitations of ARIMA model. This study forecasts future container volume by securing the monthly handling performance for 20 years of nationwide container handling volume and using time series analysis ARIMA model frequently used in the previous studies. Also, by introducing SD(System Dynamics) method which is capable of dynamic simulation and can be an alternative of time series analysis, we forecast container volume. The model performs the simulation by comprehensively considering trend in container volume, GDP change, change rate of international trade using bass model, and tests the model's validity with actual measurement value and the real data we used. And comparing the derived results with existed forecasting methods.

This paper is organized as follows. chapter 2 provides the literature review about variety methods forecasting the container volume and chapter 3 presents the ARIMA and SD method to forecast the container volume in Korea, and with the result after simulation to tests the validity of the SD model, finally in chapter 4 compares the forecasting result among difference methods and shows the limit of this study.

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2. Literature Review

Since facilities expansion of port logistics Industry is carried out based on container volume forecasting, container volume forecasting has a significant meaning greatly affecting port development.

However, forecasting should be carried out by considering various domestic and international environment and uncertainty that can result in different results according to a forecasting model still remains.

Looking at the existing research that forecasted container volume, in order to analyze the relationship between port size and growth,

Forecasting import and export container volume of major ports in Korea, Jang et al (2005) said that as GDP increases by 1%, import and export container volume on ton increases by about 0.8～1.1% and container import and export volume increases by 1.0～1.2%.

However, they analyzed that in a situation where competition for container volume procurement of Northeast Asia is becoming vehemently due to variables such as North China port development etc. the ports of Korea should exert every effort in securing its own container volume along with facilities expansion.

Analyzing the correlation between import container volume of the Gwangyang port and economic variables, Mo (2009) analyzed that recession and currency turmoil around the world will continue and in case of exchange rate, as it increases by 40 won, Korea port container volume will decrease by about 809 thousand TEU in a year. Also, he presented that if economic indices fall by 5 points, 475 thousand TEU will decrease.

Jeon et al (2004) insisted that since a lot of time and capital are required in building infrastructure such as ports, airports, terminals etc. it is important to forecast future container volume from the stage of planning facilities. In addition, they insisted that it is improper to simply use past time series data for container volume prediction. Choi (2007) studied the correlation between container volume and exchange rate fluctuation and found out exchange rate fluctuation had a negative effect on container volume of Korea.

Also, he judged that as competition between Northeast port facilities is deepened, securing container volume would be tough and sudden exchange rate fluctuation would affect greatly in securing container volume.

Jeon et al (2006) asserted that container volume forecasting of future 10 years ～ 20 years should be done in the stage of planning ports.

But they suggested that it is hard to forecast exact container volume by simple time series analysis in the rapidly changing shipping market conditions and the analytical methods which can thoroughly respond to change factors should be used. To estimate the demand and container volume, many studies identified the characteristics of past container volume data, trends, seasonality etc. and predicted future container volume.

The method used most frequently in the previous studies was ARIMA analysis method using the past time series data.

Examining the previous studies, Kim (2008) asserted that the most important factor to establish the national port basic plan is to forecast future port container volume. To predict future container volume (container, all kinds of oil, other cargo) of North Port in Busan, the ARIMA model and the exponential smoothing model were used. To predict marine container volume, Kim (2007) used the multiplicative seasonal ARIMA model which considers the seasonal characteristics of container volume and can solve them.

The result of forecasting container volume for 2007～12 year by introducing the $\text{ARIMA}(1,1,1)(1,0,1)_s$ model showed that it increased from 696,310,000 to 832,120,000 ton.

Kim (2008) also divided the container volume of Korea into import and export, coast, transshipment by using ARIMA and predicted future container volume.

The result of calculating the total annual container volume based on the final model, $\text{ARIMA}(0,1,0)(1,1,0)_{12}$ model without constant showed that container volume in 2011 appeared 21,170,000 TEU and 29,790,000 TEU in 2020. However, Kim analyzed that this increase will be somewhat lower figure when considering exchange rate, international oil price and the economic downturn around the world. Despite the results of previous studies, the logistics industry including the port logistics industry is greatly affected by surrounding exogenous variables (exchange rate, GDP etc.), there are limits to perform accurate prediction by ARIMA analysis method based on the past container volume trend.

Jung(2008) forecasted future demand and supply, price of nickel using system dynamics. With mean absolute percentage error to compare the forecasting result between regression analysis and SD, it shows that the mean absolute percentage error of regression analysis bigger than SD. Nickel price trend showed non-linear pattern system dynamic method is better than the regression analysis. The model has been calibrated for the past 6 year quarterly data (2002-2007) and tested for next 5 year quarterly data(2008-2012). The results were acceptable and showed higher accuracy than the results obtained from the regression analysis. And the simulations for scenarios made by possible future changes in demand or supply related variables. This simulations implied some meaningful price change patterns. And the study through comparing the real data and the result from simulation to test the validity of the model.

The container volume forecasting method using by the ministry of land, transport and maritime affairs is regression model, through analysis trend of traffic volume for each commodity and the trend commodity effected to each industry, forecasting each commodity of the container volume.

The forecasting of the Ministry of Land, Transport and Maritime affairs according to the characteristic of each commodity using regression model with main factors such as GDP, exchange rate, dummy variable, because of applying unit of won to get the forecasting value so the forecasting error is increased. And the unidirectional causality fails to reflect the change of various socio-economic systems from delivered results.

But the forecasting method SD used in this study is identifying the feedback loops dominate the dynamics behavior of the system. This feedback describes the causality direction that implies how a change in any variables within the feedback loop. So with dynamics thinking, SD is different from existed forecasting method used in Korea container volume.

3. Study Application

3.1 Application of ARIMA model

To identify the limits of ARIMA analysis method pointed out in the previous studies, Korea's entire container handling volume was analyzed by using monthly figures of 1990-2010. Generally, the methods forecasting container volume are divided into a qualitative method and quantitative method and the qualitative method refers to a method relying on the decision of experts and practitioners and the quantitative method is a method to predict the future by using the past time series data and time series analysis is usually used.

There are moving average using time series data, exponential smoothing, autoregression, ARIMA model of Box-Jenkins etc. and regression analysis predicting causal relationship, structural econometric models etc. in the quantitative method.

This study forecasts the future container volume by using ARIMA model, which is the time series analysis, based on monthly container handling of Korea's ports for 21 years, 1990-2010. ARIMA model is the method invented by Box and Jenkin in England in 1970 and is carried out over 5 steps.

To forecast national container volume, monthly container handling data of Korea for 252 months of 21 years, last 1990-2010 years was used. Looking at time series raw

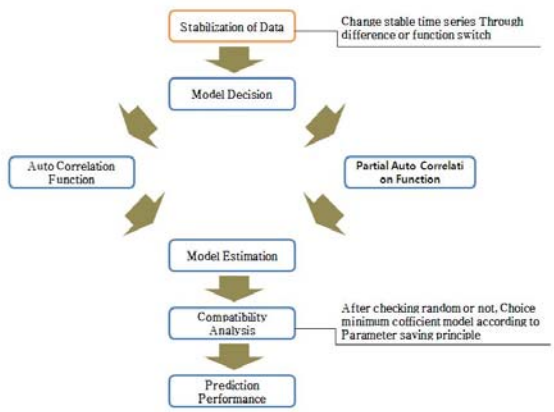

Fig. 1 Structuring of effects affecting the economic size

data, container volume handling keeps increasing and this shows that 1st handling process is needed in applying the methodology.

Also, looking at the estimated ACF and PACF indicators, since they show the form that strong spikes appear in 12 month cycle and decrease gradually, it can be judged that seasonal difference is needed.

For estimation of ACF and PACF, 63 maximum degrees of autocorrelation and Bartlett's approximation as the standard deviation method were used.

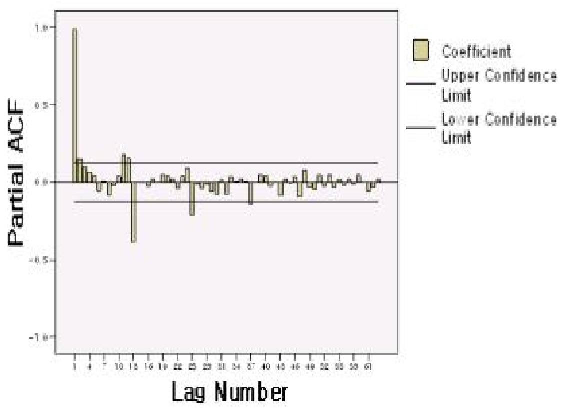

Fig. 2 Structuring of effects affecting the economic size

By combining these circumstances, the national container volume forecasting models can be tentatively identified by the models such as ARIMA(0,1,0)(0,1,0)$_{12}$, ARIMA(0,1,1)(0,1,0)$_{12}$, ARIMA(1,1,0) (0,1,0)$_{12}$ etc.

In addition, to reflect seasonality, ARIMA(0,1,1)(0,1,1)$_{12}$ model was added in the analysis by considering the spike identified in residual ACF and PACF and ARIMA(0,1,9)(0,1,1)$_{12}$ presented in Expert Modeller of SPSS is also added to the analysis.

The models and goodness of fit index considered in this study are as follows.

Table 1 Estimation of ARIMA

	ARIMA (0,1,0) (0,1,0)	ARIMA (0,1,1) (0,1,0)	ARIMA (1,1,0) (0,1,0)	ARIMA (0,1,1) (0,1,1)	ARIMA (0,1,9) (0,1,1)
R-squared	0.988	0.988	0.988	0.992	0.992
RMSE	50378	50408	50378	41425	42347
Normalized BIC	21.7	21.7	21.7	21.3	21.3
Ljung-Box Q sig.	0.000	0.000	0.000	0.005	0.000

Looking at the descriptive power of the tentatively identified models, all models were found to be significant because the values of Ljung-Box Q sig. appeared lower than 0.05. In particular, R-squared value representing the descriptive power appeared higher in ARIMA(0,1,1)(0,1,1) and ARIMA(0,1,9)(0,1,1) models.

However, in case of the values of root mean square error (RMSE), since the lowest value was shown in ARIMA (0,1,1)(0,1,1), it was selected as the optimal model.

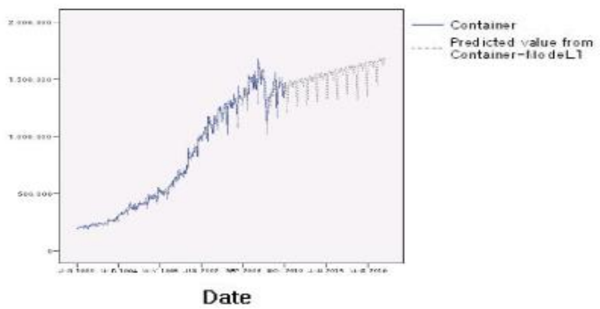

Fig. 3 Structuring of effects affecting the economic size

From the result it can be found that the forecast of univariate ARIMA analysis based on the past container volume trend shows a significant difference with that of the Ministry of Land, Transport and Maritime affairs.

To overcome the above limitations, this study considers additional exogenous variables and introduces System Dynamics that can track the dynamic relationships between variables.

Table 2 Comparison of ARIMA model and the forecast of the Ministry of Land, Transport and Maritime affairs

(unit: TEU)

Year	ARIMA	Ministry of Land, Transport and Maritime affairs
2011	17,250,805	19,936,000
2012	17,520,682	21,360,000
2013	17,788,794	22,76,1000
2014	18,055,140	24,134,000
2015	18,319,722	25,525,000
2016	18,582,539	26,902,000
2017	18,843,590	28,338,000
2018	19,102,877	29,779,000
2019	19,360,398	31,24,7000
2020	19,616,155	32,731,000

Source: Ministry of Land, Transport and Maritime affairs(2009), Forecasting report on port container volume by item / Calculating loading and unloading capacity of TOC ports by the type of a ship, pp.231

3.2 Application of System Dynamics

System Dynamics is the technique that defines the system composed of the variables directly or indirectly related to them about given problems or expected a set of problems and does modeling by studying the relationship between variables quantitatively and then helps solve the problem by finding out dynamic characteristics of a system through a series of simulations (Gwak, 2005)

This study forecasts future Korea container volume by using the vensim program, a software for SD.

Because forecasting the demand of the container volume is difficult, it is important to utilize system dynamics for several reasons(Lyneis, 2000). First, SD model can provide more reliable forecasts of short-to mid-term trends than statistical methods and therefore lead to better decisions, Second, forecasts using calibration can minimize the error between real data and forecasting data ,SD model are likely to be better and more informative than those from other approaches. Third, SD model provide a means of determining key sensitivities and therefore of developing more robust sensitivities and scenarios.

The analysis is based on the container volume data from 1970s and is progressed in the order of finding the factoring affecting container volume and identifying feedback structure between factors and building an overall model by using them.

The part considered in the 1st step to forecast national container volume in this study is the effect by changes in international trade. This element can be expressed as the change of Korea container volume according to the changes in international trade.

Fig. 4 shows the influence on container volume that international trade has.

This model was built based on Bass diffusion model.

Bass(1979) showed the diffusion process as the sum of market external factors (technology development etc.) and internal factors (the imitation factor by word of mouth effect etc.)

This is obtained from Logistics model ($y_t = bY_t[L - Y(t)]$), the basis of the early research on technology diffusion and uses net increase represented as y_t.

This can be represented as the following formula.

$$y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-1}^2 + \epsilon_t \qquad \text{(Equation 1)}$$

Bass model consists of the cumulative demand function form of the former period. Also, it has the advantage that can estimate the diffusion model without information on the maximum limitation of potential demand.

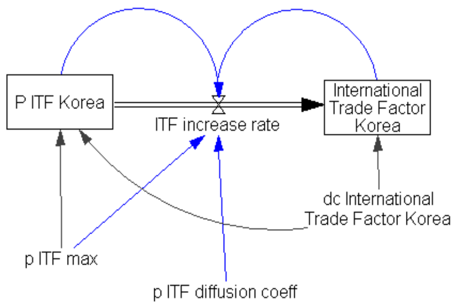

Fig. 4 Effect on container volume by changes in international trade

Examining the model, 'International Trade Factor Korea' representing 'changes in international trade' increases and decreases depending on the rate of international trade and the representative variable affecting the rate of increase and decrease is composed of Diffusion coefficient. International trade diffusion coefficient can be usually understood as exchange rate, policy variation in other countries etc.

In the 2nd step, Korea's economic size variation according to GDP change was considered.

The economic size variation is the value that divides the current economic size by the economic size of the initial analysis. The economic size can be represented as GDP growth rate and this study analyzed it by using actual Korea GDP growth rate from 1970 to 2010.

The 3rd step consideration is the actual container volume data from 1970 until now.

This study forecasted container volume of Korea ports until 2020 based on year container volume from 1970s to 2010. The following figure is the container volume forecasting model built by integrating the processes of 1st step ~ 3rd step.

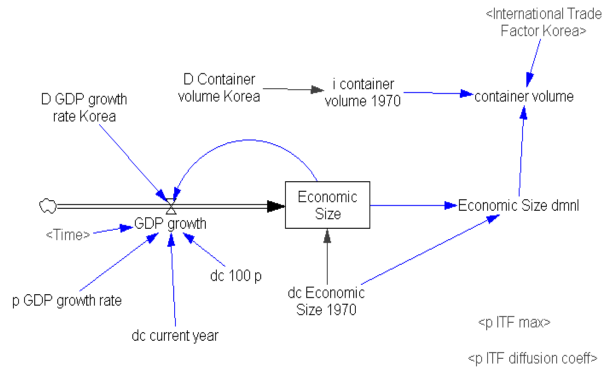

Fig. 5 Container volume forecasting model

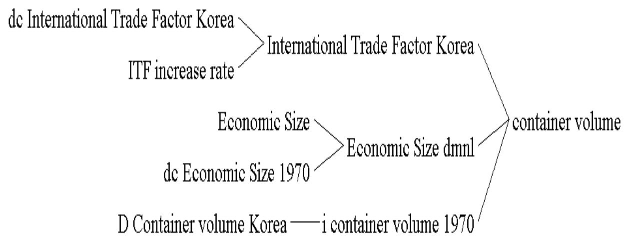

Fig. 6 Structuring of elements

The defining values used in the model are as follows.

(1) container volume= container volume 1970 *Economic Size dmnl * International Trade Factor Korea

(2) Economic Size dmnl=Economic Size / dc Economic Size 1970

(3) GDP growth rate=0.05

(4) dc 100 p=100(Expressing growth rate as percentage)

(5) GDP growth= Economic Size* IF THEN ELSE (Time<dc current year, D GDP growth rate Korea/dc 100 p, p GDP growth rate)

(6) i container volume 19700= INITIAL(D Container volume Korea)

(7) International Trade Factor Korea= INTEG (ITF increase rate, dc International Trade Factor Korea)

(8) p ITF max=173.386(The maximum value of

international trade factors
-the determined value calculated by the model)
(9) p ITF diffusion coeff=0.0008685 (diffusion coefficient)
(10) dc International Trade Factor Korea=1 (valued as 1)
(11) P ITF Korea= p ITF max – dc International Trade Factor Korea
(12) ITF increase rate=P ITF Korea * International Trade Factor Korea * p ITF diffusion coeff / p ITF max

As a result of applying System Dynamics by considering the variables such as changes in international trade, GDP growth rate, actual yearly container handling etc. national container volume in 2020 was forecasted as 32,796,000 TEU. This is the close result with 32,731,000 TEU, the forecast of the Ministry of Land, Transport and Maritime affairs.

Table 3 Comparison of SD model and the forecasting result of the Ministry of Land, Transport and Maritime affairs

(unit: TEU)

Year	SD	Ministry of Land, Transport and Maritime affairs	ARIMA model
2011	19,584,000	19,936,000	17,250,805
2012	20,877,000	21,360,000	17,520,682
2013	22,205,000	22,76,1000	17,788,794
2014	23,571,000	24,134,000	18,055,140
2015	24,979,000	25,525,000	18,319,722
2016	26,432,000	26,902,000	18,582,539
2017	27,936,000	28,338,000	18,843,590
2018	29,495,000	29,779,000	19,102,877
2019	31,113,000	31,24,7000	19,360,398
2020	32,796,000	32,731,000	19,616,155

Source: Ministry of Land, Transport and Maritime affairs (2009), Forecasting report on port container volume by item

(unit: TEU)

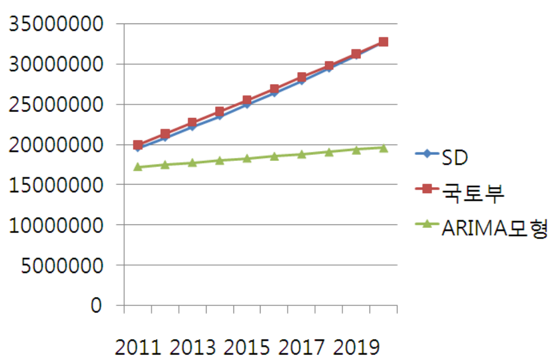

Fig. 7 Result comparison

3.3 Testing of System Dynamics

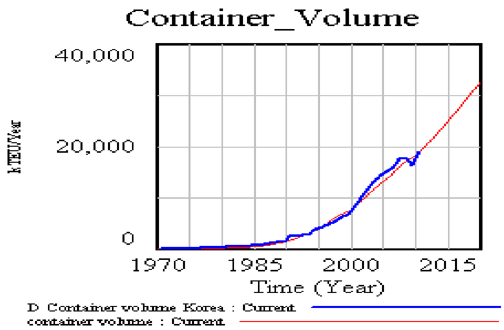

Fig. 8 Compare between real data and forecasting

The purpose of the test is comparing the simulated behavior of the model to the actual behavior of the system through the calibration in vensim. Using the RSQ function which calculate the square of the pearson product-moment correlation coefficient for two supplied sets of values. The value of correlation coefficient more closer to 1, the two sets are more similar. The two sets are real data of container volume from 1970 to 2010 and the data from simulation of SD. The correlation coefficient is calculated as 0.991504, that means through calibration the simulation is similar to the real data of container volume.

4. Experimental Results

Container volume forecasting which is the criteria on port logistics facility expansion has a great influence on the development of a port. Based on this importance, a variety of previous studies presented methodologies on container volume forecasting. The results of many previous studies pointed out the limitations of future forecasting based on the past container volume and emphasized considering more various factors to supplement this.

Based on this point, this study secured monthly handling performance for 20 years of national container handling volume and forecasted future container volume by using time series analysis ARIMA model frequently used in the previous studies. As a result of performing the comparative review with the forecast of the Ministry of Land, Transport and Maritime affairs used officially in the country, it was confirmed that ARIMA model was significantly different from the forecast of it.

To overcome the limitation of this forecasting capability, the simulation was performed by introducing SD model which can comprehensively reflect the change rate of international trade using Bass model, GDP change, trend in container volume and as a result, compared the result with forecasting methods.

This study is mainly compared the forecasting between linear and non-linear method to forecasting the container volume in Korea. Recently with rapid changes in economic and social environment, the non-linear change tendency for forecasting container traffic is presented as a new alternative. Although there isn't an universal method for forecasting, the SD method used in this study shows more better forecasting capability than other forecasting methods. But to improve the SD model, it is necessary to verify whether existed factors such as GDP, exchange rate and so on is flexible used and to reflect the change, some new factors should be developed. And in order to know each factors in the model have how much effect to the container volume and with the factors how will container volume change, scenario should be used in the model for future study.

References

[1] Choi, B.H.(2007), "A Study on the Relation Exchange Rate Volatility to Trading Volume of Container in Korea", Journal of Korea Port Economic Association, Vol. 23(1), pp.1-18

[2] Gwak, S.M.(2005), Chapter 3 Study on military application of system dynamics theory, Korea Research Institute for Strategy Army warfighting experiment in 2005 pp. 141-209

[3] Jung, J.H(2008), "Resource Demand/Supply and Price Forecasting-A Case of Nickel", Korean system dynamics society, Vol. 9 (1), pp.125-141

[4] Jang, B.G. · Yang, H.J.(2005), "Estimation of Port Traffic in Korea", Journal of Korea Port Economic Association, Vol. 21(4), pp.255-274

[5] Jeon, C.Y., Song, J.M.(2006), "Analysis of Port Cargo through Use of Data Mining Techniques", Korea Maritime Institute, pp.1-129

[6] Jeon, I.S., Kim, H.J., Kim, J.W.(2004). "Estimatith rt Using Stated Preference Methodology",ng Container Traffic of New Incheon Outer-Sou Journal of Korea Port Economic Association, Vol. 20(2), pp.151-167

[7] Kim, C.B.(2007), "Forecasting the Trading Volumes of Marine Transport and Ports Logistics Policy-Using Multiplicative Seasonal ARIMA Model-", Journal of Korea Port Economic Association, Vol. 23(1), pp.149-162

[8] Kim, J.H.(2008), "The Forecast of the Cargo Transportation for the North Port in Busan, using Time Series Models", Joutnal of Korea Port Economic Association, Vol. 24(2), pp.1-17

[9] Kim, J.H.(2008), "The forecasting of port-container volume in Korea", The Journal of Shipping and Logistics Vol. 59, pp.175-194

[10] Lyneis, J. (2000). System dynamics for market forecasting and structural analysis. System Dynamics Review, 16, 3 - .25.

[11] Ministry of Land, Transport and Maritime affairs(2009), Forecasting report on port container traffic by item / Calculating loading and unloading capacity of TOC ports by the type of a ship, pp.231

[12] Mo, S.W.(2009), "The Effects of the Changes of Economic Variables on the Import Container Volume of Gwangyang Port", Journal of Korea Port Economic Association, Vol. 25(3), pp.269-282

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