THE COMPARISON OF PORT DEMAND FORECAST METHODOLOGY

A CASE STUDY ON PORT DEMAND FORECAST FOR CONTAINER TRANSPORTATION

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abstract :The transportation demand forecast is a part of the process of an overall port planning. In the past, the establishment of the supposed condition, item and the error estimate forecast in many documents and reports is difficult to compare, because the purpose of planning is different. However, in the study, it is thought that the variation trend and the characteristics of the port transportation demand in Taiwan is the important point of the forecast model. Therefore, the study is based on the Linear Regression (LR) , which is the forecast methodology usually used for forecasting the container transportation demand of the ports in Taiwan, also the Fuzzy Linear Regression (FLR) and the Time Series Hierarchy Regression (TSHR) to compare the variation trend and the characteristics of the port demand in Taiwan.

1.INTRODUCTION

Before the port planning, it is necessary to understand the resource of cargo and proceed the forecast of the transportation volume, so that the demand of constructing port and the investment of port facilities could be observed, and the port facilities such as appropriate berths, handling machinery and warehousing system could be schemed. Therefore, the forecast work is the first step of planning. In the past documents, it is mostly to forecast the port demand in Taiwan with the regression methodology, which is analyzed as Table 1.

Table 1 Reviewing the Documents Amount for the Forecast Method of the Port Demand in Taiwan

Method	Regression	Growing Rate	Time Series	Others
70's	3	1	0	1
80's	13	3	0	3
90's	4	0	1	0

Since the study purpose, supposed condition, forecast items and cargo classification of each document is different, it is difficult to judge the result which is better by different methodologies. The study takes the forecast of container transportation demand in Taiwan for example, forecasting the difference of the three forecast methodologies. First of all it is forecast by the traditional regression analysis. In the traditional regression analysis, the primary cause of the errors between the practical value and the forecast value are the choice of the independent variables , the conclusion of the forecasted model, the surplus errors , the scale of the sample, and the information which are appropriately or not. In order to improve the errors by the traditional forecasted methodology, the study is going to process the transportation forecast with the Fuzzy Linear Regression and the Time Series Hierarchy Regression. Finally, comparing the said three forecast models, we could provide a more appropriate forecast methodology for the short and middle phase port transportation volume.

2.THE VARIATION TREND OF THE CONTAINER TRANSPORTATION DEMAND AND ITS CHARACTERISTIC ANALYSIS

The variation trend forecast by the regression is the trend that the dependent variables simulated by the independent variables. Therefore, as to the characteristic of the forecast of the container transportation demand, it is discussed according to the following three points:

2.1 Choosing the Independent Variable

By Huang & Liu research in 1992, the choosing of the independent variable has the time coordination, and the chosen independent variables should not be influenced by the difference of short-term and middle-term forecast model. Showing on Table 2, taking GDP (the gross domestic product) and AAI(average annual incoming per person) for example, while shifting the different models, forecasting the export container demands of 1987-1991 from the information of 1971-1986, it is shown that it is better to take GDP to be the independent variable, and the forecast is more correct.

Table 2 Different Formula Comparison

export model		statistic value				1987~1991 error		much better
independent variable	formula	t_1	F t	R^2	D_{urbin}-W_{atson}	A.A.P.E.	R.M.S.P.E.	
GDP	$Y = c_0 + c_1 X$	43.84	1921	.99	2.35	6.96	3.7	√
AAI	$Y = c_0 + c_1 X$	30.96	958	.99	1.27	9.27	4.83	
GDP	$Y = c_0 + c_1 X + c_2 \frac{1}{X}$	13.04	907	.99	2.43	6.90	3.63	√
AAI	$Y = c_0 + c_1 X + c_2 \frac{1}{X}$	15.21	459	.99	1.28	31.8	15.9	

P.S.: A.A.P.E.(Absolute Average Percentage Error)%
R.M.S.P.E.(Root Mean Square Percentage Error)%

2.2 The Conception of S-Curve

After choosing the independent variable, since the information modified by time, the types are also different in different growing stage. S-Curve is shown as Fig. 1; A-B is the initial stage, B-C is the growing stage, C-D is the strengthening stage, D-E is the mature stage, E-F is the senile stage.

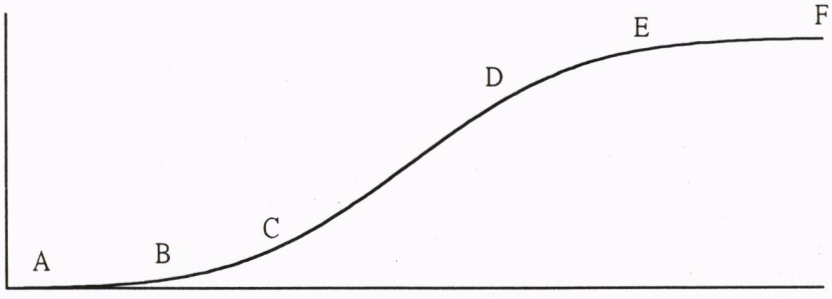

Fig 1 Port Transportation Demand by S-curve Concept

We should decide the model type according to the location during the period of surveying information, which is shown on Table 3. The surveying period in the study is only from 1981-1991. According to the conception of curve S, linearity is the appropriate forecast type, and the acceptable objective year is the future 5-10 years.

Table 3 Determine Forecast Model Depend On Curve Position

possible model	curve position
linear	A-B,B-C,C-D,C-E,D-E,E-F,B-D
non-linear	A-C,A-D,A-E,A-F,B-E,B-F,C-F

2.3 The Reasonable Forecast Confidence Interval

The port demand forecast is the initial process in the planning. As to the object, the confidence interval of the traditional regression forecast is 95%, which seems not to content the requirement of port planning. The port planning requires the forecast error of berth number should be ±1. By Huang & Liu research in 1992, the forecast confidence interval is required to be above 80% to content the requirement of the plan, and the error of berth could stay in the level of ±1.

3.THE ANALYSIS OF PORT DEMAND FORECAST IN TAIWAN

3.1 Linear Regression (LR):

The Linear Regression (LR) is delineating and analyzing the independent variable X_i and dependent variable Y_i with the view point of the minimum square difference. The value of the dependent variable Y_i is modified with the independent variable X_i (which is the explanation variable: GDP, AAI, the product index of year, population and industry). According to the concept of port transportation demand forecast in Huang & Liu research in 1992, in order to reduce the forecast mistakes , it is forecasted that the model established by the short-term and middle-term container volume in Taiwan shall be in accordance with the following four principles:

(1) The optimum independent variable is chose by the model is as follows:
The forecasted model of import volume : The Index of Industry Produce (IIP)
The forecasted model of export volume : Gross Domestic Product (GDP)

(2) The independent variable should be converted into the currency value or index in the same basic year. The Gross Domestic Product (GDP) in the study is based on

the currency value of the year 1986. The index of the industry product in the year 1986 is 100%.

(3) The regression model is base on 1981~1992 data , only by 11 years data point ,so the forecasting future goal year below 5~10 year could be better .

(4) The regression confidence interval is 95%,it maybe not fit the port planning requirement. Port planning require the forecast errors of berth number should be 1. So, in this paper I allow the forecast berth number error is one ,(each berth have 1.5~2.0 machine) the confidence interval is 80%.

(5) When we determine the forecast model is linear or nonlinear , it needs to observe the future curve position. Owing short time observation at this paper, so we use linear model to analysis it .

The forecast model parameters and estimators by port container transportation demand of Taiwan Area show in Table 4. The import & export model of Durbin-Watson values are high than the Durbin-Watson upper boundary values , therefore, the model residual is random distribution . All statistic estimator is good such as like determine coefficient R^2 ,t-test ,F-test , so we can accept those model to forecast future year .

Table 4 The Model Parameter and Estimator by Port Container Transportation Demand of Taiwan Area

	C_0	C_1	X_1	R^2	F	$C.V.$	S_e	*Durbin-Watson*
Import	-8243636 (-10.182)	175674 (21.697)	I I P	.981	470.7	6.1	550871	2.2
Export	-2955419 (-3.583)	3.69814 (13.635)	GDP	.954	185.9	8.4	666166	1.6

After the parameter and estimator , the future predict value $\tilde{Y}_t$ under 80% confidence interval is ($\tilde{Y}_t - t_{\frac{\alpha}{2}(n-p-1)} S_f$, $\tilde{Y}_t + t_{\frac{\alpha}{2}(n-p-1)} S_f$). And future year standard deviation S_{f_t} is calculate by:

$S_{f_t}^2 = S_e^2 \ (1 + \tilde{X}_t' (XX')^{-1} \tilde{X}_t)$

$\tilde{X}_t' = (1 , X_{t1} , X_{t2} , \ldots . X_{tp})$ is the future year independent variable matrix

X is data year independent variable matrix , $\tilde{X}_t'$ is $\tilde{X}_t$ transpose matrix

3.2 Fuzzy Linear Regression (FLR)

This paper applies Fuzzy Set theory in regression analysis method , we call it "Fuzzy Linear Regression", it's used to compare with the port throughput Forecast Concept, This method is according Tanaka research, the error is depend on the fuzzy of system structure parameter , it means that the error is reflected under Fuzzy linear function. The fuzzy Linear regression is by H. Tanaka, S. Uejnna & Asai it had applied in trips, rends computer future market.

The model formula is $y = \alpha^t x$, estimated value is define $y_i = \alpha^t x_i$,then, α^t is the vector $\alpha = (\alpha_1, \alpha_2, \ldots, \alpha_n)$ transpose , x_i is the i-th samples of all independent variable vector, the observation value Y_i between estimate $\hat{Y}$ error is $\varepsilon_i = y_i - \hat{y}_i$ (i=1...N, N is the

sample number).

If the historical data comply with fuzzy set, we use the wide H to describe The FLR Method can both use in Fuzzy data and non-fuzzy data. The FLR Model is $\hat{Y}_i = \hat{A}_1 x_1 + ... + \hat{A}_n x_n$, the relationship function is

$$\mu_{\hat{Y}_i}(y_i) = 1 - \frac{|y_i - x_i^t \alpha|}{c^t |x_t|}$$

It is the evaluation fitness of the model $\hat{Y}_i = \hat{A}_1 x_1 + ... + \hat{A}_n x_n$, The decision Maker choose H to confidence level, then $\hat{Y}_i H(y) = \{y | \mu_{Y_i}(y) \geq H\}$

In addition , $\hat{y}_i^h \supset y_i^h$ when the data print relationship $\geq$H , we can say the model is a good forecast.

We define the FLR's as J, It's all fuzzy parameter wide, the value should be small as possible. Solve the FLR problem is under $h \geq H, \forall i$, get the fuzzy parameter $\hat{A}_i$, and to get the minimize J . Then FLR is transferred to Linear Program, the object function is

$$\text{Min} \quad J = c_1 + c_2 + ... + c_n$$

the constraint is

$$\alpha^t X_i + (1-H)\sum_j C_j |x_{ij}| \geq y_i + (1-H)e_i$$

$$-\alpha^t X_i + (1-H)\sum_j C_j |x_{ij}| \geq -y_i + (1-H)e_i$$

$$c_i \geq 0, i = 1,...,N$$

N is the sample number , H is the fit degree of decision maker choose

We try to explain the FLR model and by using regression analysis statistic estimator , showed in Table 5.

Table 5 Comparison between FLR and Regression

	Fuzzy Linear Regression	Regression
Method	Min $J = \sum C_i$	Least Squares
The Determination Coefficient	ε /Total error	R^2=SSE/SST
Confidence interval	H	α

Table 6 is the parameter and statistic estimate value of one independent simple FLR Model , it shows that the import model's fuzzy wide is 20.17, determination coefficient is 0.47, Export model's fuzzy wide 30.54, determination coefficient is 0.74, above of is not good.

Table 7 is two-independent variable of multiple Fuzzy linear regression model, it's compared with Table 6. This would not change the forecast value, but the statistic estimated value is better than simple Model.

Table 6 One Independent Variable FLR Model Parameter and Estimator

Model Code	FR1IM (Import)	FR1EX (Export)
Independent Variable X_i	I I P	G D P
Parameter of C_1	56.91	2.69
Wide of e	20.17	0.54
ε /Total error	0.4739	0.7386
Fitness of H	0	0
Data year	1981 - 1991	1981 - 1991
Future target year	1996,2001	1996,2001

Table 7 Two Independent Variables FLR Model Parameter and Estimator

Model Code	FR2IM (Import)	FR2EX (Export)
Independent Variable X_i	Year & Population	Year & GDP
Parameter of C_1	847454.9 145.51	435500.5 1.78
Wide of e	0 58.08	0 0.5
ε /Total error	0.9443	0.9821
Fitness of H	0	0
Data year	70 - 80	70 - 80
Future target year	85,90	85 , 90

3.3 Time Series Hierarchy Regression (TSHR)

In this paper, the port transportation demands model separated with month is defined with the time series in broad definition. Therefore, the key point of this section is to modify the port transportation demand with the time interval of "month" instead of "year", and investigate the optimal forecast standard of the port transportation demand from February to May in every year. The following is the intention:

(1) The traditional forecast of the port transportation demanded is less analyzed with time series, and the general regression analysis is expected separate with "year".

(2) The time series is to arrange the number sequence in order with time. The regression analysis in the article adopts "month" to be the time interval.

(3) If adopting " year" to be the time interval, which means to take the average of month (1/12 = 8.33%) to be the forecast volume, then the port facilities would be more crowded during half a year.

(4) If the effect caused by crowded port facilities and unused port facilities is the same, then it is better to adopt to "year" to be the time interval. However, actually the gross cost loosed by the crowded port facilities is much higher than the unused port facilities, which means that the ratio of crowded port facilities in a whole year should be reduced while scheming. Therefore, the future forecast of the port transportation demands shall be schemed with a forecast value that higher than the average value, which might promote the optimal using of the port facilities every year.

(5) To review the other transportation scheme such as highway transportation or air transportation, the smaller time unit such as "hour" or "day" is used to be the time interval as the standard of the schemed facility capacity. Aiming to the theory, since the navigation of the marine ship is not as acute as the vehicle or air transportation, it is suggested to adopt to the month variable to be the forecast interval in the

forecast of the port transportation demand.

(6) While proceeding the forecast of the port transportation demand, according to the general evaluate index such as A.A.P.E. or R.M.S.P.E., the forecast error is +5% and -5%, which is similar to each other. However, to reduce the ratio of port facilities congestion, it is better to adopt to +5% than -5%, which means that over evaluate the demand is better than less evaluate to reduce the loosed benefit from the crowded port facilities.

(7) As to the highway capacity analysis adopted by the scheming of highway engineering, it is regulated in the AASHO to adopt to the 30th high-hour volume (30HV) to be the designed volume in one year.

(8) The airport facility capacity demand is schemed as following,
The runway:
The aircraft in rush hour on the runway is according to the take-off and landing aircraft during the peak two hours in the 37th peak day in one year.
The passenger capacity of the airport:
- annual capacity × 10.7% = the passenger volume in the Peak Month
- the passenger volume in the Peak Month × 4.4%
  = the passenger volume in the Peak Day
- the passenger volume in the Peak Month × 20%
  = the passenger volume in the Peak Hour

The ratio of the evaluation report of the Chiang Kai-Shek International Airport by the American airport expert Leigh Fisher is as following,
the month coefficient: 11.0% the day coefficient: 4.5%
the hour coefficient: 10.0%

Therefore, to replace the "year" interval with the "month" interval and forecast the monthly information of each year, it is expected to obtain the suitable forecast model to be the basis of the port facility scheming. The related contents as following:

3.3.1 Traditional Time Series Analysis

The traditional time series analysis divides the time series into several aspects, which is listed as following formula:

$Y = T \times S \times C \times I$

in this formula,

Y: Time Series (the forecast dependent variable, here is the port container transportation demand)

T: Secular Trend, which means a phenomena is effected by some basic reasons in a long time, and it modifies in a trend. The basic reasons could be economical, social, cultural, scientific or other aspects; which are also called the Secular Force. The trend will be effected by the basic reasons and continually modifies regularly

S: Seasonal Movement, which is a kind of cyclical fluctuation , the period is one year . it is effected by geography climate or society custom .

C: Cyclical Fluctuation, which is regular by a period , but the cycle does not fixed , usually about 3 year or 5 year .

I: Irregular Movement , the fluctuation is random of time , the period is irregular . included special fluctuation .

3.3.2 Box & Jenkins Method

George E.P.Box & Gwilym M.Jenkins , both of them develop an analysis method of

time series in 1970, it is need computer calculate to forecast . This Time Series analysis method process have 4 steps, Identification ,Estimate ,Diagnostic Checking and Forecast.

The model identification is to set and judge model of time series is stationary or non-stationary , the stationary is observed series Y_t , it around the mean value fluctuation . In general case, the series only need diagnostic checking for week stationary condition , we say it is stationary series . In most conditions , economic and commercial data series is not stationary , those problem we can use Regular Difference method or Seasonal Difference method to transfer a new stationary series . Table 8 is model stationary determine case .

Table 8 Box & Jenkins Model stationary

	Model
stationary	AR(p),MA(q),ARMA(p,q)
non-stationary	ARIMA(p,d,q)

AR : Autoregression Model
MA : Moving Average Model
p : degree of Autoregression Model
d : Difference of model
q : degree of Moving Average Model
ARMA : Autoregression & Moving Average Mix Model
ARIMA : Autoregression & Moving Average Difference Model

If it have a few models to be identified in the same time, we use Akaike Information Criterion (AIC) to choose , the minimize AIC is the best model .

$$AIC(p, q) = N \ln(S_{error}) + 2(p + q)$$

there N : sample number

S_{error} : standard deviation of error

This study had collected container transportation of port throughput in Taiwan from 1981~1991 each mouth data , also is separated with import and export . this series is a long trend . Diagnostic Checking by above process , this time series is not stationary , we disposal ARMA(p,q) model . We use hierarchy method to stationary it , sorting every year of month throughput ,from highest to lowest . it is a cyclical stationary by time lag = 12 ,then we pick up the second high month throughput each year ,also the third high month throughput, until 5th high throughput ,(we called it 2HM ,3HM ,4HM, 5HM), and we use regression method to analysis it . We hope to modify the passed report forecasted value is low . This study time series model TSHR is

$$Y = C_0 + C_1 X_i$$

Y : container transportation of port throughput by the n high month of each year
X_i : Time lag (1981 = 1)

3.3.3 Modified data

The THSR model needs base data under nature stationary , in fact , real work days differ on each month , we need real work day to be same with each month . So , this modified process as follows :

1. Consider the typhoon rest and holiday , we need to adjust the real work day of each month. Modify Reason is shown in Table 9.
2. Modify the container counter unit.(Weight , F.T. , TEU , No.)
3. Resort by high throughput data .

The modified model statistic estimated value and parameters are shown in Table 10 & 11.

Table 9 Modify Reason of Each Year

Year	2.29	China New Year Holiday	Typhoon Number Pass
1981		Feb. 4 , 5 , 6	1
1982		Jan. 24 , 25 , 26	3
1983		Feb. 12 , 13 , 14	4
1984	Yes	Feb. 1 , 2 , 3	3
1985		Jan. 19 , 20 , 21	3
1986		Feb. 8 , 9 , 10	3
1987		Jan. 28 , 29 , 30	4
1988	Yes	Feb. 17 , 18 , 19	4
1989		Feb. 6 , 7 , 8	1
1990		Jan. 26 , 27 , 28	2
1991		Feb. 14 , 15 , 16	4

Table 10 Statistic Estimator of TSHR Model by Modify data

	Model	t_0	t_1	R^2	F	D_{urbin}-W_{atson}	c.v.	S
Import	TSIM2	-8.7	17.6	.972	310.8	1.45	7.9	2162.1
	TSIM3	-9.0	18.5	.974	342.1	1.44	7.5	1997.3
	TSIM4	-8.6	17.3	.971	300.8	1.49	8.1	2111.3
	TSIM5	-7.4	14.8	.961	218.9	1.62	9.6	2425.2
Export	TSEX2	-2.0	9.3	.907	87.4	1.94	11.4	2805.8
	TSEX3	-3.1	12.2	.943	149.4	2.01	9.2	2186.3
	TSEX4	-4.0	14.2	.958	202.8	2.03	8.3	1871.6
	TSEX5	-3.3	12.1	.942	147.2	1.86	9.5	2113.9

I I P is independent variable of Import Model ;
GDP is independent variable of Export Model

Table11 The Parameter of TSHR Model by modified data

Import	x_0	x_1	Export	x_0	x_1
TSIM2	-27499	560.24	TSEX2	-7004	.010680
TSIM3	-26491	543.02	TSEX3	-8439	.010881
TSIM4	-26662	538.20	TSEX4	-9358	.010853
TSIM5	-26363	527.41	TSEX5	-8662	.010442

I I P is the independent variable of Import Model
GDP is the independent variable of Export Model

4.THE COMPARISON OF FORECAST FUTURE TARGET BY DIFFERENCE METHODOLOGY

This section will make a comparison with Regression , Fuzzy Linear Regression ,Time Series Hierarchy Regression , and difference methodology forecast values of future

target year . The study is under the follow principle :

1. Forecast purpose is port facilities optimize planning.
2. Container counter unit is weight tonnage.
3. Future target year is 5~10 year of now. That is use 1981~ 1991 port throughput data , to forecasting 1996 & 2001 transportation demand .
4. Confidence interval is 80% .

The forecast value compared by each method , as Table 12 , Fig 2 , Fig 3 ,

1. Future year part , fuzzy linear regression is a conservative forecast method.
2. The two model of fuzzy linear regression ,the determine coefficient of two independent variable forecast model is better than single variable , also the forecast value of future year is much close the regression method forecast value .
3. Totally , the export model forecast value is better than import .

it needs to be noted that fuzzy regression theory is completely developed, but the application and limit condition still needs widely discussing and studying.

Table 12 Compare with Forecast Value of Three Method Unit:10^4 Ton.

Method		Regression			FLR		TSHR			
	Year	Upper	forecast	Lower	2 variable	Single	2HM	3HM	4HM	5HM
Import	1996	2339.6	2223.4,	2107.2	2081.2	1441.5	2509.1	2437.8	2401.5	2344.9
	2001	3383.7	3215.8	3047.9	2657.1	1910.9	3648.4	3542.1	3496.0	3417.5
Export	1996	2005.1	1860.4	1715.7	1734.5	1568.2	1989.2	1979.8	1940.8	1879.7
	2001	2840.1	2630.5	2421.0	2322.9	2128.4	2789.9	2795.6	2754.5	2662.5

The analysis of three methods compared result as follow :

1. Traditional method is regression analysis , so our case study is base on the regression method forecast demand value in future year, to compare with others method forecast demand value .
2. By trend analysis , FLR is smooth than other methods.
3. FLR is more conserved , it's forecast value is low than the regression lower boundary of 80% confidence forecast value ,whether it is import or export.
4. TSHR compare with regression method :
   - Import value : 2HM~4HM all is high than regression upper boundary of 80% confidence forecast value.
   - Export value : 2HM~5HM forecast value , is between mean value and upper boundary of 80% confidence forecast value.
   - Total summary : 4HM of Time Series is mostly close regression upper boundary of 80% confidence forecast value.

   By this , the 3HM or 4HM is feasible to replace of yearly throughput historical data. But it need to deep and more analysis or research ,when it apply to planning of optimum berth number .
5. Paring with these results, improvement of traditional regression forecast value is too low, we suggestion the monthly throughput of Time Series Hierarchy Regression method. it is feasible to forecast the port transportation demand, all have to do is to discuss which one is high month,is the optimum planning under cargo and berth kind.

5. COCLUSION AND SUGGESTION

5.1 Conclusion

1. The port transportation demand forecast should be focused on short and middle

target with 5 ~ 10 years . And LR FLR TSHR method does not fit for long trend accuracy forecasting .

2. The port transportation demand forecast model , it is possibly non-linear of more than ten year .
3. The port transportation demand forecast model of fuzzy linear regression , future 5 ~ 10 year forecast value is estimated too low , it seems not to be applied on port transportation demand forecast .(special in planning of facilities)
4. Input the historical data in monthly throughput of TSHR method is suitable for port demand forecast and port planning of port system character . Therefore , by using 3HM～4HM data to forecast is very feasible

5.2 Suggestion

1. If the target year is more than ten year of the port transportation demand forecast, we suggest using Industrial Connection Matrix Model addition to LR FLR TSHR method .
2. It is necessary to investigate the optimum high mouth of planning facilities , when we use TSHR method by monthly data .
3. Because of port condition difference (like climate ,cargo kind ,berth , shipping), it is important to investigate port system character at first , when we use TSHR method forecast port transportation demand .

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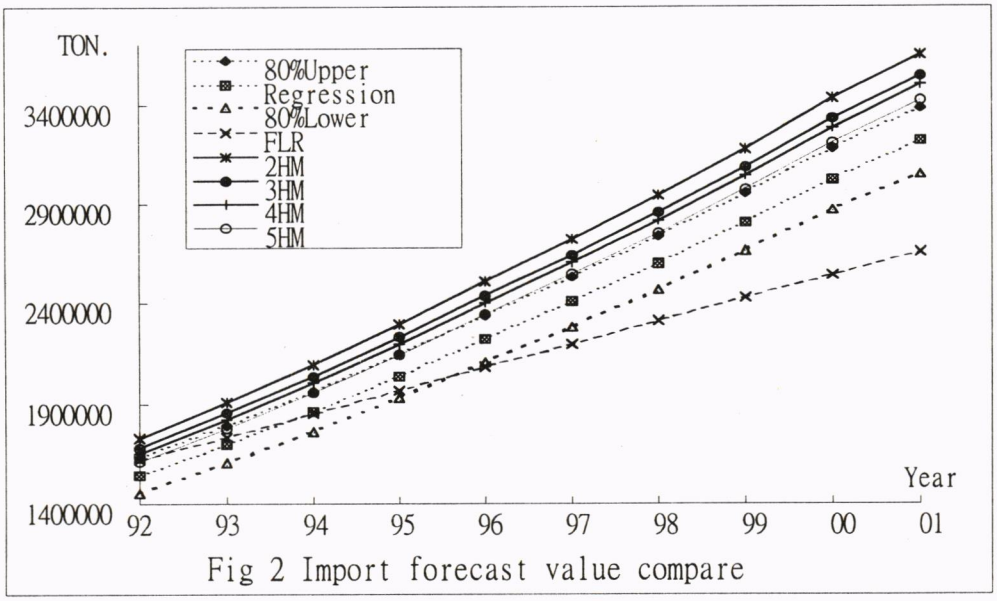

Fig 2 Import forecast value compare

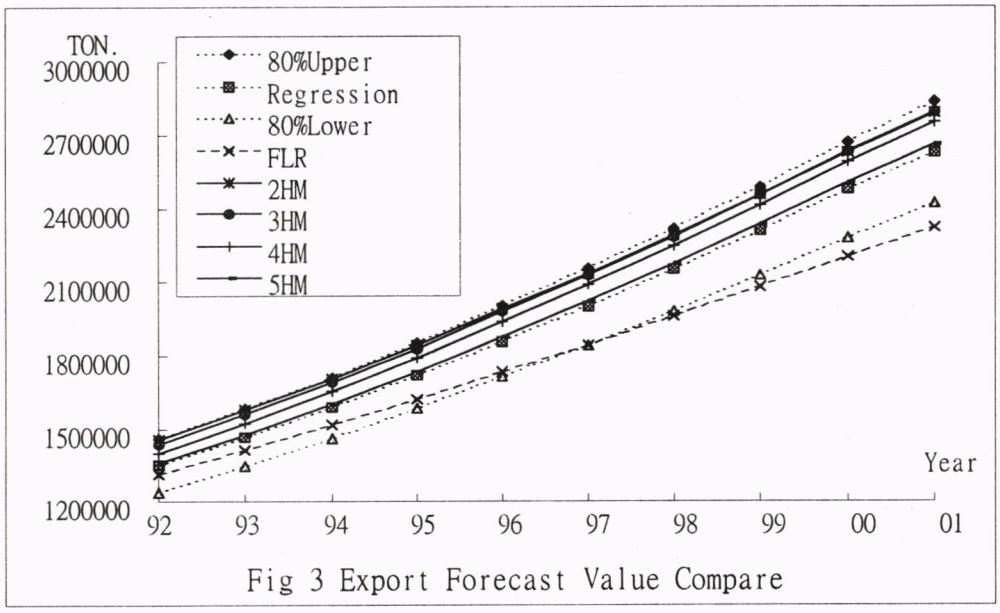

Fig 3 Export Forecast Value Compare