

Phyoe et al., 2016

Volume 2 Issue 3, pp. 55-69

Date of Publication: 15th November, 2016

DOI- <https://dx.doi.org/10.20319/Mijst.2016.23.5569>

This paper can be cited as: Phyoe, S. M., Guo, R., & Zhong, Z. W. (2016). An Air Traffic Forecasting Study and Simulation. Matter: International Journal of Science and Technology, 2(3), 55-69.

This work is licensed under the Creative Commons Attribution-Non Commercial 4.0 International License. To view a copy of this license, visit <http://creativecommons.org/licenses/by-nc/4.0/> or send a letter to Creative Commons, PO Box 1866, Mountain View, CA 94042, USA.

AN AIR TRAFFIC FORECASTING STUDY AND SIMULATION

S.M. Phyoe

School of Mechanical and Aerospace Engineering, Nanyang Technological University, 50 Nanyang Ave 639798, Singapore
SMPhyoe@ntu.edu.sg

R. Guo

School of Mechanical and Aerospace Engineering, Nanyang Technological University, 50 Nanyang Ave 639798, Singapore
guorui@ntu.edu.sg

Z.W. Zhong

School of Mechanical and Aerospace Engineering, Nanyang Technological University, 50 Nanyang Ave 639798, Singapore
MZWZhong@ntu.edu.sg

Abstract

This paper analyzes the forecasting performance for air traffic movement by comparing different models. The relationship between economic variables and the air traffic demand is analyzed by tracing the past several years' data. The econometric models are emphasized, and a long term forecast is concentrated in this air traffic forecasting study. The aim is to find the suitable methods and variables to be applicable to the situation similar to Singapore FIR and also to improve the forecasting accuracy. The conflicts and the density of air traffic in Singapore FIR are estimated in this paper by using the results of forecasting.

Keywords

Air Traffic Forecasting, Traffic Growth, Econometric Models, ARIMAX, ARIMA, Exponential Trend Projection

1. Introduction

During the past 55 years, there is rapid growth in air transport industry and an average growth rate of about 10% has been reached (Manual on air traffic forecasting, 3rd Edition, 1985). This rate is only more than three times average growth of the real gross domestic product (GDP), the largest available figure of world economic activity (Manual on air traffic forecasting, 3rd Edition, 1985). Market research, trend projections and econometric relationships: three traditional methods of forecasting civil air traffic are mainly used (Ashford, Mumayiz, & Wright, 2011) (Profillidis, 1996). In our previous paper (Phyoe, Lee, & Zhong, 2016), trend projection methods were used and only historical traffic data was taken into account. The study obtained two equations by using 18 years of air traffic data and two trend projection methods (linear and parabolic trend methods).

In view of the linear trend model, the air traffic growth rate was predicted to be 3% and the amount of traffic was estimated to be 920,878 in 2030 (Phyoe, Lee, & Zhong, 2016). The growth rate was predicted to be 6% and the amount of traffic was estimated to be 1,589,076 in 2030 from the parabolic trend model (Phyoe, Lee, & Zhong, 2016). However, the models in the previous study were relatively general and only year was used as the independent variable. Thus, for the purpose of enhancing forecasting reliability, there is necessity to further explore the variables and methodologies for air traffic forecasting.

In this paper, the analysis will be done from different perspectives. This study analyzes the relation of economic variables and the air traffic demand by using historical air traffic data and GDP. The hardest part of econometric forecasting is a specified type of functional relationship between the dependent and the independent variables to be considered in the forecasting (Profillidis, 2000). The prediction of the future development of the independent variable is important (Profillidis, 1994).

The paper aims at comparing and finding the suitable variables and methods for the econometric model to adapt to the situation similar to Singapore FIR.

2. The Data

This study uses the number of flights in Singapore from 1998 to 2015 and 2015 June flight plan data for simulation and modeling. GDP data from 1998 to 2015 was collected from World Bank. GDP data from 2016 to 2030 used in our model is forecasted by using annual growth rate of 3% ("World Economic Outlook Database April 2016", 2016) for 2016 to 2020 and 5% ("Slower, but quality economic growth over next 20 years", 2013) for 2021 to 2030. The number of flights was validated by referring to Wikipedia (Singapore Changi Airport) ("Singapore Changi Airport", 2016).

3. The Effect of Gross Domestic Product to Air Traffic Movements

In general, it is acknowledged that the air transport demand is closely related to GDP (Profillidis, 2000). Figure 1 shows the positive correlation between GDP and air travel for each country. It is noteworthy that Singapore has a high volume of air traffic under the condition of high GDP per capita because Singapore is a mature market in global trade business and tourism. On the other hand, it is surrounded by emerging economic countries (e.g. Thailand and Malaysia). These countries make a great contribution to the increasing Singapore air traffic volume. IATA suggests that "growth has been concentrated in the emerging economies, where economic activity generates proportionately more air passengers than the mature developed markets" ("IATA raises profit forecasts - the world's airlines can now upgrade from an espresso to a sandwich | CAPA - Centre for Aviation", 2016). As Singapore is an economic center of the ASEAN region, the traffic growth is significantly affected.

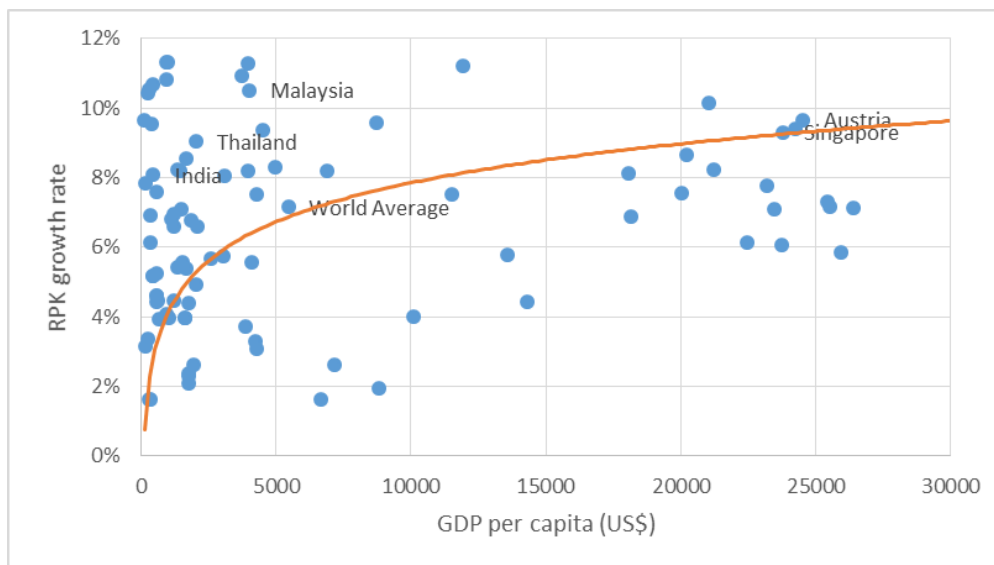


Figure 1: Relationship between GDP and air travel ("Air transport, passengers carried / Data", 2016)

Figure 2 shows that the world GDP growth rate has a positive effect on the world RPK (Revenue passenger kilometers) growth rate. Figure 2 shows that the world RPK growth rate decreases due to world GDP reduction. Likewise, Singapore reveals the same behavior. As shown in Figure 3, Singapore air traffic growth follows the trend of GDP based on the analysis of historical data.

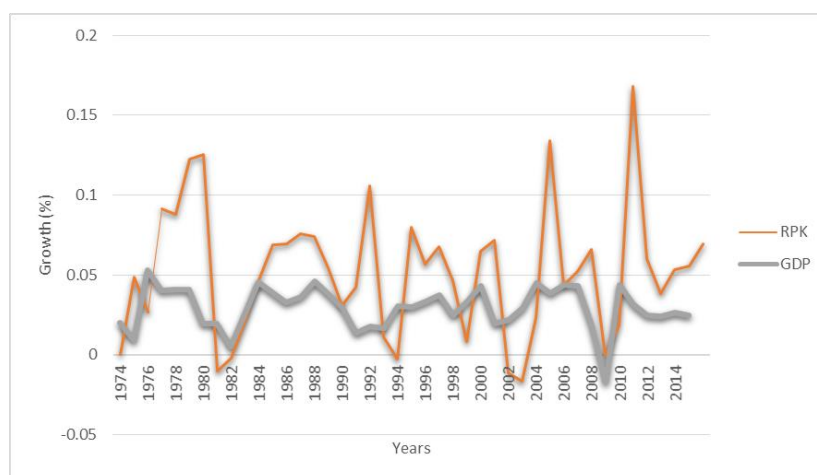


Figure 2: World GDP growth and world economic growth: 1974 to 2014 ("Air transport, passengers carried / Data", 2016)

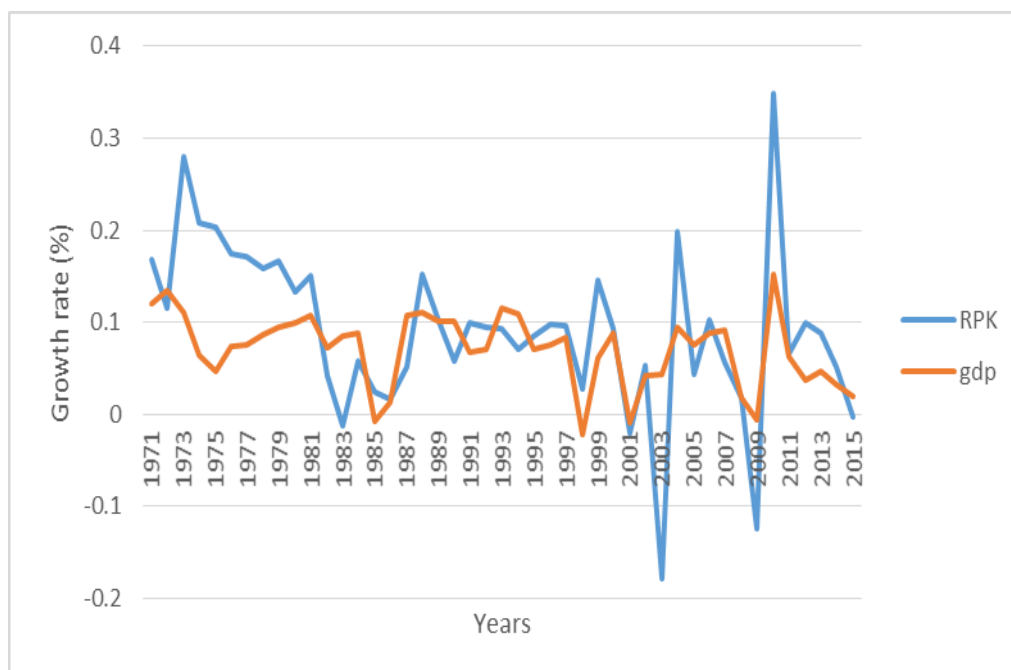


Figure 3: The relationship between Singapore GDP and Singapore air traffic growth ("Air transport, passengers carried | Data", 2016)

This is the evidence that GDP has a great influence on air traffic changes. Therefore GDP can be one of the convincing explainable variables for forecasting of future air traffic volumes. In addition, the economic dimension has influence on allocating and distributing resources, goods and services, and also impacts on the behavior of the companies (Taghizadeh & Shokri, 2015). Hence, with economic change (GDP changes), the behavior of airline companies also changes, which affects air traffic movements.

4. Exponential Trend Projection

Exponential trend projection is used as the forecasting benchmark for air traffic in this study. The exponential trend method is useful for fitting non-linear data patterns with arc shape. The exponential trend is used when the data increased at an increasing rate over past time unit (Hyndman & Athanasopoulos, n.d.). The general equation is shown as Equation (1) (Hyndman & Athanasopoulos, n.d.):

$$Y = ae^{bt} \quad (1)$$

where a, b are coefficients, and t is time (Hyndman & Athanasopoulos, n.d.).

5. Arima Model

ARIMA is a widely used model that is fitted to time series data. ARIMA combines three types of processes: auto regression (AR), differencing to strip off the integration (I) of the series, and moving averages (MA) (Cho, 2001). This method attempts to establish the most appropriate difference filter and at the same time is designed to accommodate any increasing seasonal or non-seasonal variation (Coshall, 2005). A non-seasonal ARIMA model is classified as an "ARIMA ()" model [8] (Chatfield, 2001), where p is the order of autoregressive part, d represents the degree of first differencing involved and q represents the order of the moving average part. The general equation is shown as Equation (2) [8] (Chatfield, 2001):

$$\phi(B)(1 - B)^d Y_t = \theta(B)Z_t \quad (2)$$

where

$\phi(B)$: Coefficient of non-seasonal AR with order p

$\theta(B)$: Coefficient of non-seasonal MA with order q

$(1 - B)^d$: Operator for differencing of order d

Z_t : the difference of Y_t and Y_{t-1}

6. Arimax Model

ARIMAX (p, d, q) model is an extension of the ARIMA model with an explanatory variable X. The general equation is shown as Equation (3) (Greene, 1990).

$$y_t = \mu + p_1 y_{t-1} + p_2 y_{t-2} + \dots + p_p y_{t-p} + \beta_0 x_t + \beta_1 x_{t-1} + \dots + \beta_k x_{t-k} + \varepsilon_t \quad (3)$$

$$- q_1 \varepsilon_{t-1} - \dots - q_q \varepsilon_{t-q}$$

where μ is the constant, β parameters are the regressors of delayed distributed x explanatory parameters, p variables are the autoregressive parameters of delayed distributed y exogenous dependent parameters, q variables are the moving average variables of delayed distributed ε random parameters, and d is the difference degree (Greene, 1990).

7. Results Analysis and Discussion

The equation of the exponential trend model was calculated to be:

$$\hat{Y}_t = 3.336 \times 10^{-30} e^{0.0403t} \quad (4)$$

R^2 of Equation (4) is calculated to be 0.9121. Figure 4 shows that the predicted value highly fits the actual traffic value.

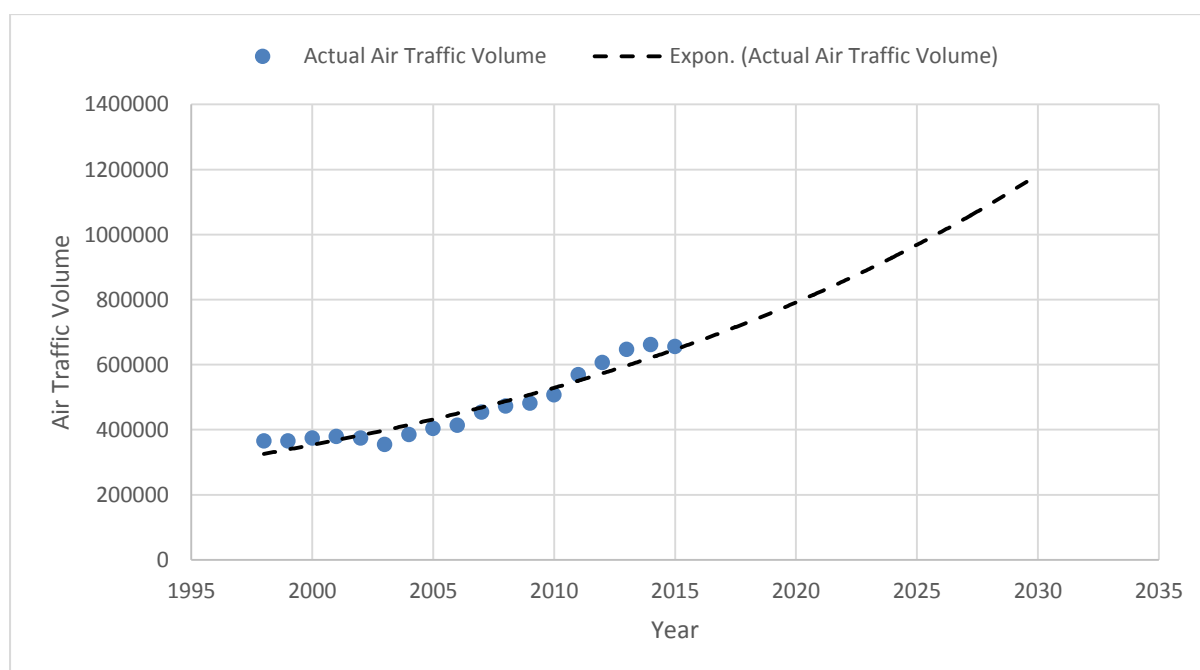


Figure 4: Singapore Air Traffic Forecasting for next 15 years by using Exponential Trend

The ARIMA (2, 2, 1) model was simulated and the equation was calculated to be Equation (5):

$$\hat{Y}_t = 2Y_{t-1} - Y_{t-2} + 0.273 \times (Y_{t-1} - 2Y_{t-2} + Y_{t-3}) - 0.139 \times (Y_{t-2} - 2Y_{t-3} + Y_{t-4}) - 0.732(Y_{t-1} - \hat{Y}_{t-1}) \quad (5)$$

where \hat{Y}_t is the forecasting traffic volume for year t, Y_{t-1} is the actual traffic volume for year t-1. R^2 is calculated to be 0.9697. Figure 5 shows the prediction using this model. It can be observed that the predicted value follows the actual trend but with a delay. Moreover, the forecasted volume shows a stable growth of the traffic. However, due to the effect of the period from 2013 to 2015 of the obtained traffic, which presents decreasing growth situation, the forecasted traffic provides a lower growth rate of following period.

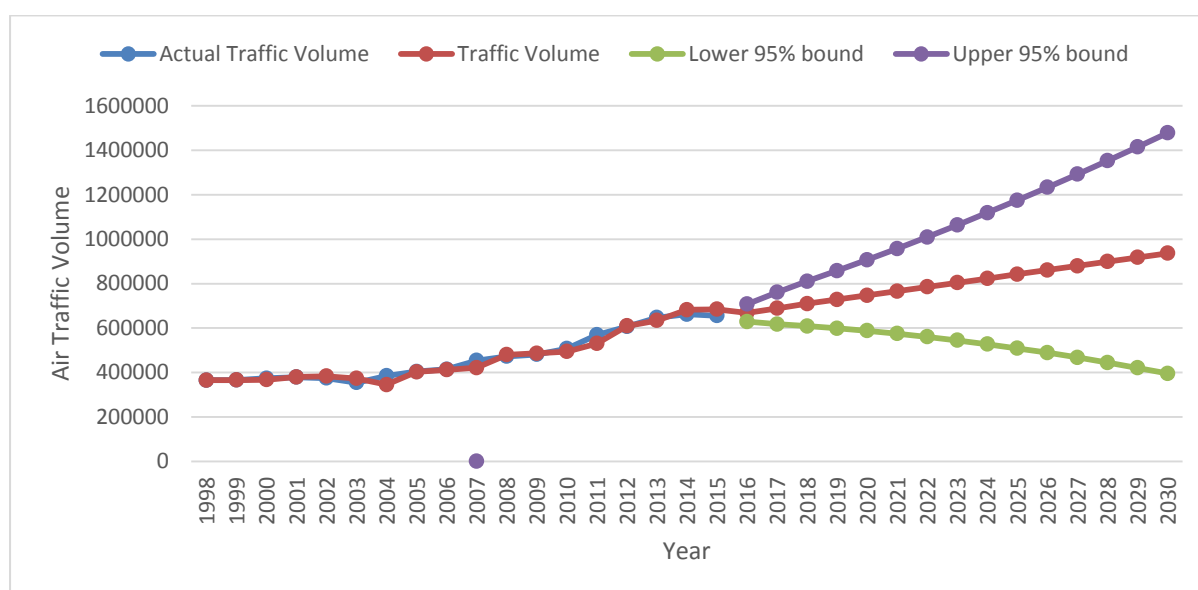


Figure 5: Singapore Air Traffic Forecasting for next 15 years by using ARIMA (2, 2, 1)

The equation of the ARIMAX (1, 1, 0) model was obtained as Equation (6):

$$(1 - 0.046L)(1 - L)\hat{Y}_t = 168412.985 + 1.18 \times X_t \quad (6)$$

where L is the lag operator, and X_t is Singapore GDP for year t.

R^2 is calculated to be 0.978. Figure 6 illustrates the trend of the forecasts. It can be observed that the gradient of the forecast value is increasing. In other words, the traffic growth rate for the next 15 years shows an increasing tendency.

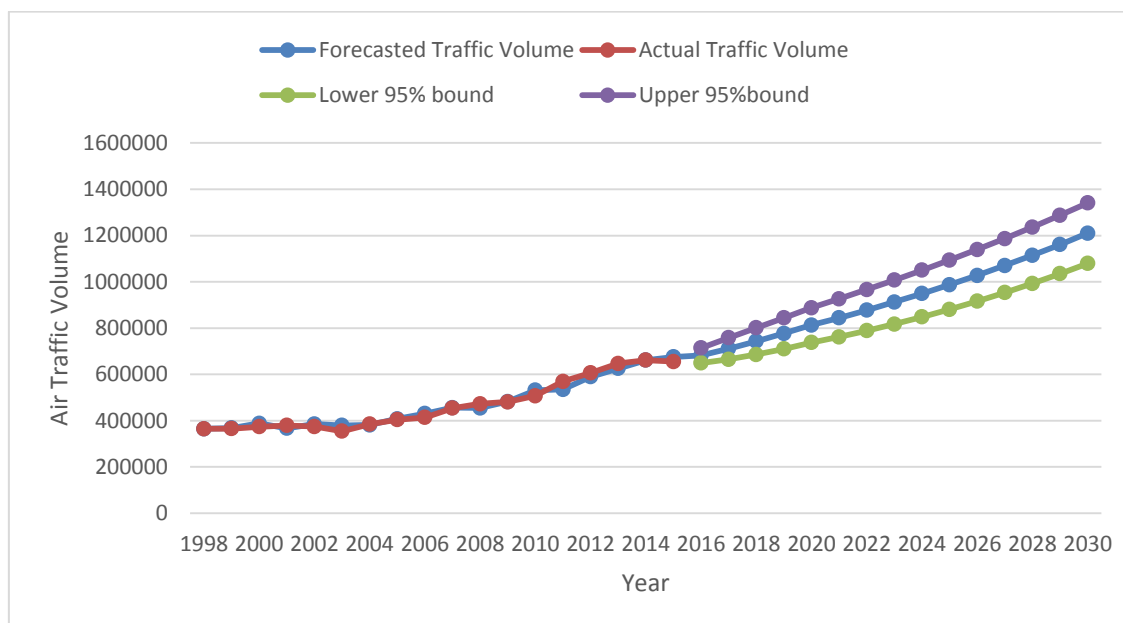


Figure 6: Singapore Air Traffic Forecasting for the next 15 years by using ARIMAX (1, 1, 0)

Figure 5 and Figure 6 show that the ARIMAX model outperforms the ARIMA model. By calculating the average growth rate from 2016 to 2030, the value for lower and upper bound of the ARIMA model was 3.2% and 5.4%, respectively. As for the ARIMAX model, the values were 4% and 5.4%, respectively. Hence, the 95% confidence interval is found narrower in the ARIMAX model. Furthermore, even under the worst condition when using the ARIMAX model, the average growth rate can reach 4%. In view of the ARIMA model, however, the average growth rate may drop to 3.2%, which may happen with a small possibility.

Table 1 shows the predicted average growth rate that is extracted from these three models. The forecasted value from ARIMA (2, 2, 1) was observed to be smaller than the actual value 3.6% due to trend delay. Both the exponential trend model and ARIMAX (1, 1, 0) show an increasing growth rate. Due to the GDP rapid growth, the ARIMAX model predicts a higher growth rate, implying that Singapore air traffic will grow rapidly in the next 15 years and may double the current air traffic volume.

According to Table 2, RMSE (root mean square error) (Lewis, 1982) (Ruzni Nik Idris & Afiah Misran, 2015), MAPE (mean absolute percentage error) (Fildes, Wei, & Ismail, 2011) and R^2 are measured to compare the reliability and accuracy of the three models.

According to Lewis (1982), when the MAPE value is less than 10%, the forecasting model is considered acceptable (Lewis, 1982). Thus, all the three forecasting models are considered as applicable to Singapore situation. Table 2 illustrates that ARIMAX (1, 1, 0) is the best performed model among these three with smallest RMSE and MAPE. R^2 of ARIMAX is the highest, which indicates a good match. However, the exponential trend model had the largest RMSE and MAPE lowest in this study. On the basis of ARIMAX (1, 1, 0) forecasts, it can be inferred that the bad performance may be because the predicted growth rate is lower than the expected growth rate in reality. The comparison of the ARIMA and ARIMAX models demonstrates that Singapore GDP has a great influence on the air traffic growth, since the international trade business is a major contribution to Singapore GDP.

Table 1: Comparison of average Traffic Growth Rate from 2016 to 2030

Model	Exponential Trend Projection	ARIMA(2,2,1)	ARIMAX(1,1,0)
Average Traffic Growth Rate from 2016 to 2030	4.1%	2.4%	4.7%

Table 2: Comparison of error measurements of different models

Model	Exponential Trend Projection	ARIMA(2,2,1)	ARIMAX(1,1,0)
RMSE	38280	18779	16000
MAPE	6.28%	2.77%	2.66%
	0.9121	0.9697	0.978

8. Simulation And Modeling

As mentioned above, ARIMAX (1, 1, 0) was found to be the best forecasting model in this study. Hence SAAM (The System for traffic Assignment and Analysis at a Macroscopic level) simulation was conducted to investigate whether there is a potential traffic conflict in Singapore. Figure 7 shows the simulated status of Singapore air traffic in 2030.

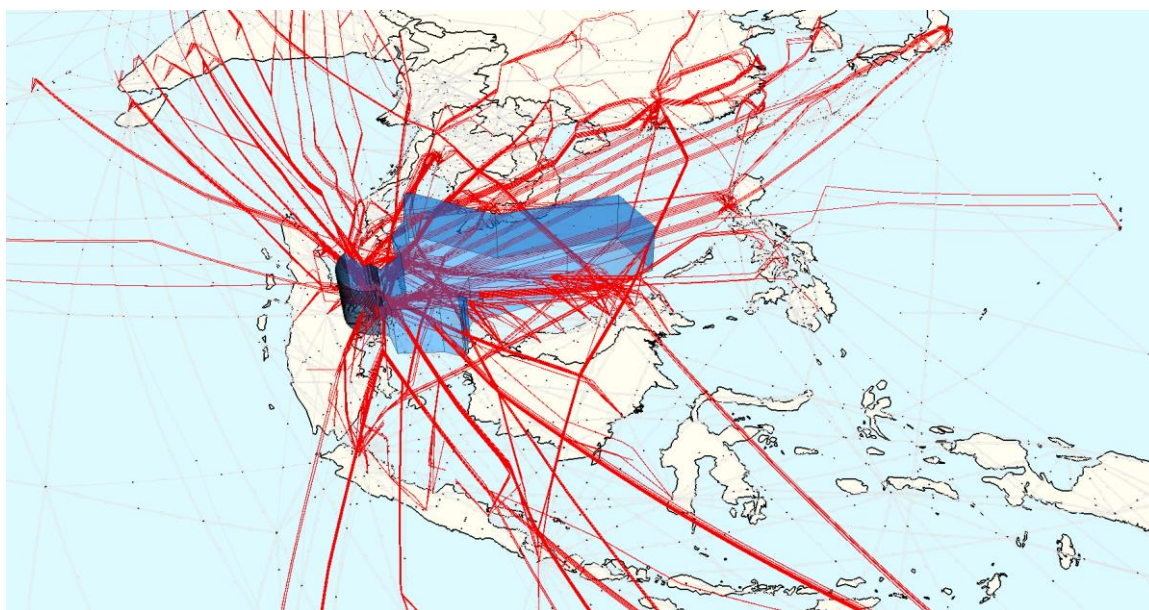


Figure 7: SAAM Simulation of Singapore Air Traffic in 2030

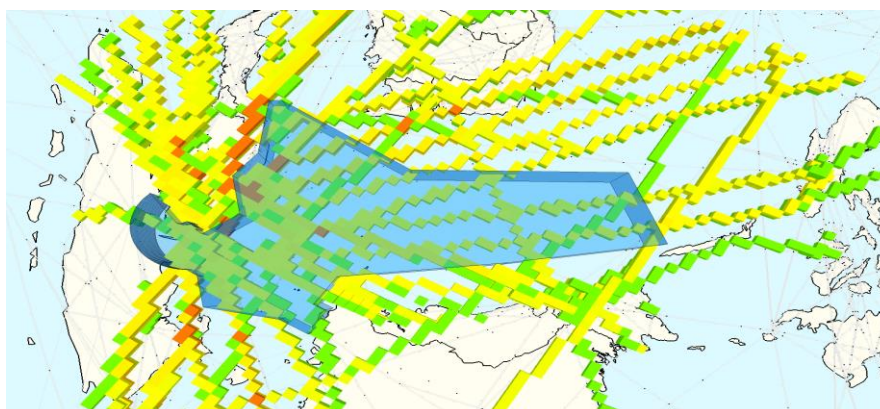


Figure 8: 3D Density of Singapore FIR in 2015

The traffic density of Singapore FIR in 2015 is shown in Figure 8, which is still acceptable. Color tone from green to red represents density from low to high. The light green represents 5 or fewer flights, green yellow for 6-10 flights, yellow for 11-20 flights, orange yellow for 21-50 flights, blaze orange for 51-100 flights and red for 101-200 flights per day for that airway area. Figure 8 shows most airways had 11 to 20 flights per day but some junction parts of airways are crowded and had 51-100 flights per day. Conflicts of 507 times per day are obtained under the condition of two runways by using SAAM.

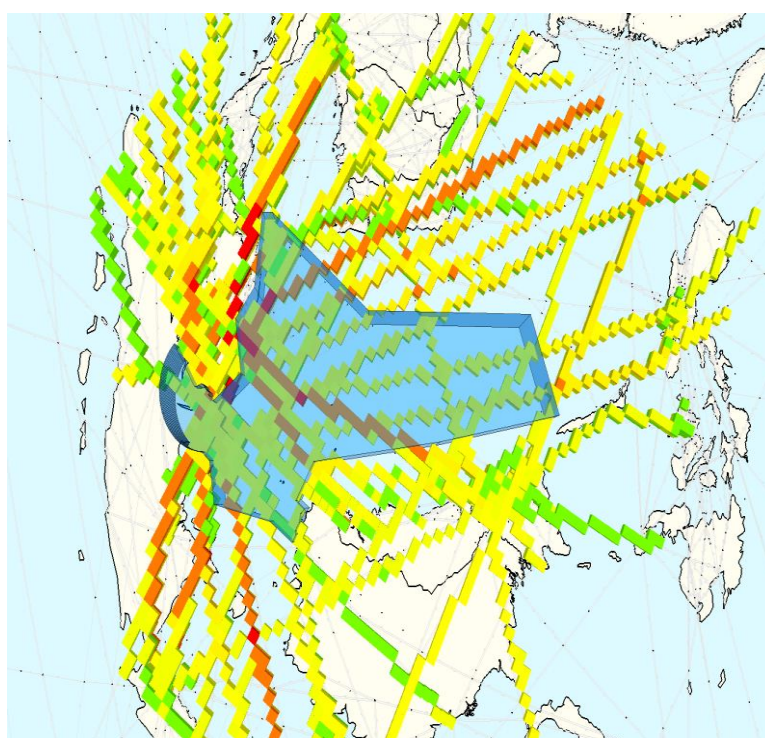


Figure 9: *Estimated 3D Density of Singapore FIR in 2030*

Figure 9 shows the estimated 3D density of Singapore FIR in 2030. It shows significant increment of density in some major airways. Most of the airways will maintain 11 to 20 flights per day; however, some junction parts of airways may have 101- 200 flights movements per day. Conflicts of 1762 times are obtained under the condition of three runways by using SAAM for this situation, which is three times the current number. In view of this, more efficient capacity planning may be needed in advance.

9. Conclusion and Future Works

In conclusion, this study found that GDP has a much influence on the air traffic. This study used three forecasting models: exponential trend, ARIMA and ARIMAX. RMSE and MAPE are used as the gauge of model performance. The ARIMAX model is found to be the best approach for this study. Simulation using SAAM for Singapore future air traffic is a part of this study. The conflicts and the density of the air traffic volume within Singapore FIR are estimated in this paper. By using the results of forecasting, the sector capacity and air traffic controller workload can be calculated as future work. That work may be helpful for future airspace capacity and infrastructure planning. In addition, more explanatory variables can be discussed. For instance, low cost carrier market share may also affect the growth of the air traffic volume.

10. Acknowledgement

This research was sponsored by the ATMRI of NTU and CAAS via ATMRI Project No. 2014-D2-ZHONG for Regional Airspace Capacity Enhancement – ASEAN Pilot.

References

- Air transport, passengers carried | Data. (2016). Data.worldbank.org. Retrieved 10 October 2016, from <http://data.worldbank.org/indicator/IS.AIR.PSGR>
- Ashford, N., Mumayiz, S., & Wright, P. (2011). Airport engineering. Hoboken, N.J.: Wiley.
- Chatfield, C. (2001). Time-series forecasting. New York: Chapman and Hall.
- Cho, V. (2001). Tourism Forecasting and its Relationship with Leading Economic Indicators. *Journal Of Hospitality & Tourism Research*, 25(4), 399-420.
<http://dx.doi.org/10.1177/109634800102500404>
- Coshall, J. (2005). A selection strategy for modelling UK tourism flows by air to European destinations. *Tourism Economics*, 11(2), 141-158.
<http://dx.doi.org/10.5367/0000000054183487>

- Fildes, R., Wei, Y., & Ismail, S. (2011). Evaluating the forecasting performance of econometric models of air passenger traffic flows using multiple error measures. *International Journal Of Forecasting*, 27(3), 902-922.
<http://dx.doi.org/10.1016/j.ijforecast.2009.06.002>
- Greene, W. (1990). *Econometric analysis*. New York: Macmillan Publishing Company.
- Hyndman, R. & Athanasopoulos, G. *Forecasting: principles and practice*.
- IATA raises profit forecasts - the world's airlines can now upgrade from an espresso to a sandwich | CAPA - Centre for Aviation. (2016). *Centreforaviation.com*. Retrieved 10 October 2016, from <http://centreforaviation.com/analysis/iata-raises-profit-forecasts--the-worlds-airlines-can-now-upgrade-from-an-espresso-to-a-sandwich-113244>
- Lewis, C. (1982). *International and Business Forecasting Methods*. Butterworths, London.
- Manual on air traffic forecasting, 3rd Edition. (1985). Montreal.
- Phyoe, S., Lee, Y., & Zhong, Z. (2016). Determining future demand: studies for air traffic forecasting. In 11th International Conference on Engineering & Technology, Computer, Basic & Applied Sciences (ECBA-2016). Singapore. Retrieved from <http://kkgpublishings.com/ijtes-volume2-issue3-article1-4/>
- Profillidis, V. (1994). Modernization of railway and airway transport the impact of liberalization. *International Conference*, Democritus University of Thrace.
- Profillidis, V. (1996). *Transport Economics and Policy*. Athens, Greece.
- Profillidis, V. (2000). Econometric and fuzzy models for the forecast of demand in the airport of Rhodes. *Journal Of Air Transport Management*, 6(2), 95-100.
[http://dx.doi.org/10.1016/s0969-6997\(99\)00026-5](http://dx.doi.org/10.1016/s0969-6997(99)00026-5)
- Ruzni Nik Idris, N. & Afiqah Misran, N. (2015). Combining aggregate data and individual patient data in meta-analysis: an alternative method. *MATTER: International Journal Of Science And Technology*, 1(1), 144-158.
- Singapore Changi Airport. (2016). *Wikipedia*. Retrieved 10 October 2016, from https://en.wikipedia.org/wiki/Singapore_Changi_Airport
- Slower, but quality economic growth over next 20 years. (2013). *The Straits Times*. Retrieved 10 October 2016, from <http://www.straitstimes.com/singapore/slower-but-quality-economic-growth-over-next-20-years-0>
- Taghizadeh, H. & Shokri, A. (2015). A comparative study of airline companies from the social responsibility perspective case study. *PEOPLE: International Journal Of Social Sciences*, 1(1), 270-281.

World Economic Outlook Database April 2016. (2016). Imf.org. Retrieved 10 October 2016,
from <http://www.imf.org/external/pubs/ft/weo/2016/01/weodata/index.aspx>