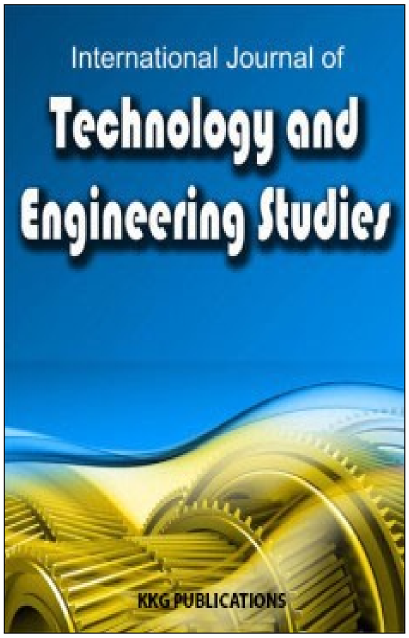

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AIR TRAFFIC FORECASTING USING OPTIMIZATION FOR ECONOMETRIC MODELS

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Abstract. This paper proposes a new way of forecasting air traffic by combining the optimization model with the econometric model. In other words, this paper proposes the way how to combine optimization and modeling together to forecast future air traffic. Forecasting has always been playing an important role for any company or organization. Air traffic forecasting is no exception. General formulas for the calculation of the aircraft volume and passenger volume in airports have been proposed. Using these formulas, an econometric model for passenger volume in Changi airport has been obtained. Furthermore, by using this model, Singapore air traffic passenger numbers have been predicted for 2016-2021. Accurate air traffic forecasting will help plan future projects, management decisions, such as how much investment is needed, which projects to develop, which projects to postpone, etc.

INTRODUCTION

Reliable air traffic forecasting plays an important role in planning for future projects and makes countries ready for coming difficulties or challenges.

There has been three fundamental ways of forecasting: quantitative, qualitative, and decision analysis, which is a mix of the first two methods [1]. Quantitative methods can be divided into time series analysis and causal methods, and econometric analysis is part of causal methods. Recently, some researchers started using optimization software to increase efficiency of the airspace [2].

However, as far as we know, optimization model has not been used for air traffic forecasting. This paper's objective is to find better solution as compared to existing methods to accurately forecast the air traffic. This paper proposes the new model for forecasting of the air traffic which uses optimization for econometric models. Also, case study has been done for Changi airport and traffic forecasting has been done for 2016-2021.

LITERATURE REVIEW

There have been many ways of introducing models for airline industry. [3] proposes a Resource - Based View (RBV) model to investigate competitiveness of airlines. An empirical study was conducted on 114 major airlines and 6 LCCs for the period between 1987 and 2010. Some interesting managerial insights on the effects of internal resources via their endowment, resource efficiency, and resource effectiveness on airline performances are obtained. [4] investigated the operational efficiency of 21 major airports in the Asia-Pacific region. The traffic in the Asia-Pacific region was increasing from 2002 to 2011 and several major airports in Asia-Pacific region had been world top 30 busiest airports. This was done theoretically by using Data Environment Analysis (DEA) because it has become a recognized method for efficiency evaluation due to easiness in identifying efficient or inefficient airports [5].

Another paper [6] describes an effort to define a future Personal Air Transport System (PATS) and studies of different aspects with the aim to help with the introduction of PATS. The paper provides details on the Functional Hazard Assessment (FHA) done for the Personal Plane (PPlane) System and summarizes the recommendations for future PATS.

PPlane vehicles are operated from small airports close to the urban areas. The users/passengers on the board aircraft are only able to perform high-level tasks such as the decision to change destination. The operations of PPlane vehicles are supported by a ground infrastructure (ground segment) that includes Remote Pilot Stations (RPS), Air Trac Control (ATC), and a PPlane System Operation Management Centre (PSOMC). In the case of an emergency situation (failure, health problems on the board, etc.), a pilot at a ground pilot station takes over the control and brings the PPlane vehicle to the nearest airport.

The ground pilot can also be contacted by the users/pas-

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sengers on the board. In normal situations, the ground pilot supervises multiple aircraft, and he takes over in emergency situations only. Even in an emergency situation, the ground pilot can only change the aircraft trajectory and has general control over aircraft systems: direct handling and control of the aircraft are not foreseen.

There is another paper i.e., [7], which introduces one of the ways how to calculate efficiency of the airspace using new term utilization rate. Utilization rate in this paper is a ratio of the airspace that has been used for flights to the airspace which is possible to be used for flights. The formula for utilization rate is
$U = \sum_{i=1}^{m} P_i U_i = \sum_{i=1}^{m} P_i \frac{(\sum_{k=1}^{n_t} t_i k)}{(C_i C_{0i} T_i)} * 100\%.$

As different aircraft have different separation times, it should be considered by calculating P_i, which is the probability of each aircraft type flying throughout the region. U_i is the utilization rate of an i^{th} flight level.

$\sum_{k=1}^{n_t} t_i k$ is the actual airspace load, where t_{ik} is a flying time of kth aircraft on $i^t h$ flight level. $C_i C_{0i} T_i$ is an airspace load.

Similarly, [8] shows a significant negative effect of an airport belonging to an airport group and provides some reasons like no flexibility in minimizing cost due to cross-subsidies. In addition, the motivation to establish additional revenues at group level seems to be low in comparison with individual airports [9].

There is an efficiency comparison done by Ulku on Spanish and Turkish airports [10], [11]. In Spain, there are 46 airports and 2 heliports under Aeropuertos Espanoles Navegacion Aerea (AENA). In Turkey, there are 52 airports under DHMI. That is why it was said that airport density in terms of per square meter and in terms of per capita is higher in Spain than in Turkey because Spain has a population of 47 million and an area of 500 thousand square meters while Turkey has a population of 76 million and an area of 780 thousand square meters.

In the forecasting area, many different models have been proposed. Some researchers used neural network approach as in [12], and some researchers used support vector machines [13], [14] to determine air traffic.

[15] proposes a model which forecasts air traffic movements taking into account airport capacity. The model consists of 5 steps. However, it has a lot of assumptions in each step.

[16] uses time series to forecast safety performance of the air traffic. It is done by estimating the number of occurrences of each event. However, it is very difficult to have accurate database for it.

In the past, many researchers and organizations proved that there is a correlation between GDP and air traffic like in [17], [18]. In addition, ICAO has been using worldwide GDP to estimate world traffic in [1] on page I-31 as well. They have been using model $Y = aX_1^b X_2^c$ where Y is world air traffic, X_1 is world GDP, and X_2 is the yield.

However, this model would not be able to represent some specific airspace or country air traffic accurately. That is why this paper proposes an econometric model combined with optimization problem to find air traffic forecasting. As we can see, forecasting area is very big. That is why this paper focuses on econometric models using GDP values.

METHOD AND MATERIALS

In order to find congestion level of an airport, we need to find numbers of aircraft flying to or from the airport. Mathematical model was developed in order to find it. General formulas which this paper proposes are:

$$\text{Number of aircraft flying to or from country } j = \sum_{k \epsilon \text{Countries}} \text{Number of aircraft flying between } j \text{ and } k + \text{domestic flights} \quad (1)$$

$$\text{Number of aircraft flying between } j \text{ and } k = \frac{\text{Number of passengers flying between } j \text{ and } k}{\text{Average number of occupied seats + cargo flights between } j \text{ and } k} + \text{Cargo flights between } j \text{ and } k \quad (2)$$

$$\text{Number of passengers flying between } j \text{ and } k = A * GDP_j^x * GDP_k^y + m \quad (3)$$

$$\text{Number of aircraft domestic flights in country } j = \frac{\text{Number of passengers flying in domestic flight}}{\text{average number of occupied seats}} + \text{cargo flights in } j \quad (4)$$

$$\text{Number of passengers flying in domestic flights} = A * GDP_j^x * GDP_k^y + m = A * GDP_j^x + m \tag{5}$$

$$\text{Cargo flights between } j \text{ and } k = B * \text{export of country} j^{z_1} * \text{export of country}(k^{z_2}) + r \tag{6}$$

$$\text{Cargo flights in j = B*export of country} j^z + r \tag{7}$$

$$\text{Overflights} = C^{*}\text{year} + D \tag{8}$$

A, B, C, D, and *r*, *m* are constants to be found by optimization program. From Formula (1), it can be seen that the number of aircraft flying in airspace *j* is equal to the number of passengers flying between *j* and *k* (other countries) plus internal flights. From Formula (2), it can be found that the number of aircraft flying between j and k is equal to the number of passengers flying between *j* and *k* over average number of occupied seats plus cargo flights between *j* and *k*. Formulas (3) and (5) show how numbers of passengers flying between 2 countries or domestic flights are calculated. Formula (4), similar to formula (2), shows that the numbers of domestic flights in *j* are equal to the number of passengers in internal flights over average number of occupied seats plus cargo flights in country *j*.
Cargo flights between *j* and *k* can be found by Formula (6), internal cargo flights can be found by Formula (7), and overflights can be found by Formula (8). These general formulas can be applied to any country.

Let us suppose airport *j* has w number of airways from 1 to w, the number of aircraft flying to or from airport *j* to be T_j, the number of aircraft flying to or from airport *j* using airway a to be T_{aj}.

Then $\sum_{a=1}^{w} T_{aj} = T_j$. If we assume that the ratio between T_{aj} and T_j is constant or linear:

$T_j / T_{aj} = p_1 + p_2 * t$,

where p_1 and p_1 are constants, then the number of flights in airway a of airport *j* can be found by formula:

$T_{aj} = \dfrac{T_j}{p_1 + p_2 * t}$

where T_j can be found by Formula (1) and p_1 and p_1 can be found from historical data. Due to the limitation of data, we simplified formulas for our simulation:

$$\text{Number of passengers arriving at airport } j = GDP_j^x * (\textstyle\sum_{i \epsilon \text{Countries}} B_i * GDP_i) + l * \text{year} + m \tag{9}$$

In order to apply this model to Singapore, we restricted the number of countries for GDP which was used for the model to be 4. They are Singapore, China, Thailand, and India. Singapore does not have internal flights, which is why internal flights have not been considered. Formula 10 shows how the number of passengers flying to or from Singapore airport can be calculated.

$$\begin{aligned} \text{Number of passengers arriving at Changi airport} &= GDP_{singapore}^x * (B_{china} * GDP_{china}^y + \\ B_{Thailand} * GDP_{Thailand}^y &+ B_{India} * GDP_{India}^y) + l * (year - 1997) + m \end{aligned} \tag{10}$$

Here *x*, *y*, *B*, *l*, and *m* are variables which will be found through optimization program. Optimization program used for this calculation is *CPLEX*. By giving data of GDP and number of passengers flying in Singapore airspace from 1998-2009, we can find values of *x*, *y*, and *B* where sum of square of errors will be minimal. Then we did testing on 2010-2014 data. After that, we did forecasting of the Singapore air traffic from 2016-2025. First of all, in order to find constants of the model, we used historical GDP data collected from [18], shown in Table 1.

In addition, data on aircraft movements, airfreight movements, and aircraft movements in Singapore are given in Table 2.

TABLE 1
GDP OF COUNTRIES FROM 1998-2014
IN BILLIONS OF US$ [19]

Year	Singapore	China	Thailand	India
1998	85.71	1025.28	113.675	428.7
1999	86.29	1089.45	126.668	464.3
2000	95.84	1205.26	126.39	474.7
2001	89.29	1332.24	120.3	492.4
2002	91.94	1461.91	134.3	522.8
2003	97	1649.92	152.28	617.6
2004	114.19	1941.75	172.9	721.6
2005	127.42	2268.59	189.312	834.2
2006	147.79	2729.78	221.76	949.1
2007	179.98	3523.09	262.94	1238.7
2008	192.24	4558.43	291.38	1224.1
2009	192.41	5059.42	281.58	1365.4
2010	236.42	6039.66	340.92	1708.5
2011	275.37	7492.43	370.61	1835.81
2012	289.94	8461.62	397.29	1831.78
2013	302.25	9490.6	419.89	1861.8
2014	306.34	10351.11	404.32	2048.52
2015	292.74	10866.44	395.28	2073.54

TABLE 2
OPERATIONAL STATISTICS [20]

Year	Passenger Movements (Millions)	Airfreight Movements (Millions of tonnes)	Aircraft Movements
1998	23.80	1.28	165242
1999	26.06	1.50	165961
2000	28.62	1.68	173947
2001	28.09	1.51	179359
2002	28.98	1.64	174820
2003	24.66	1.61	154346
2004	30.35	1.78	184932
2005	32.43	1.83	204138
2006	35.03	1.93	214000
2007	36.70	1.92	221000
2008	37.69	1.88	232000
2009	37.20	1.63	240360
2010	42.04	1.81	263593
2011	46.50	1.87	301700
2012	51.18	1.81	324722
2013	53.73	1.85	343800
2014	54.09	1.84	341386
2015	55.45	1.85	346334

RESEARCH RESULTS AND DISCUSSION

First of all, in order to prove soundness of the model, we collected data from 1998 to 2009 and used optimization software to find values for the constants of the model and then predicted passenger numbers for 2010-2015. Average error, maximum error, and Root Mean Square (RMS) error are 2.84%, 7.82%, and 3.79% respectively, which is acceptable error for forecasting. That is why it is decided that this model can be applied for the prediction of passenger volume. After that, optimization model has been used for 5 models to find the coefficients of the model, which gives least possible errors. Table 3 shows average, maximum and RMS errors for 5 models, where numbers of variables have been decreasing by 1. It was done by eliminating the least important variables.

After coefficients have been found, real values and values from models have been compared. Table 3 shows average, maximum, and RMS value of the errors for different models. From Table 3, we can see that from model 1 to model 3, errors do not increase much, but the number of variables decreased significantly, and average error is still less than 3.5 % but maximum error can reach up to 10%. The paper proposes that model 1 to model 3 can be used to forecast because average and RMS errors for these models are less than 3% and maximum error is less than 10%.

TABLE 3
AVERAGE, MAXIMUM, AND RMS ERRORS FOR DIFFERENT MODELS

Sr	Model Name	Average Error	Maximum Error	RMS Error
1	Model with China GDP Thailand GDP India GDP, Singapore GDP combined with linear model	2.41	10.47	3.62
2	Model with China GDP, India GDP, Singapore GDP combined with linear model	2.64	9.16	3.79
3	Model with India GDP, Singapore GDP combined with linear model	3.09	9.12	4.09
4	Model with Singapore GDP combined with linear model	3.36	18.42	5.21
5	Linear model	7.54	24.13	9.37

However, for prediction purposes and high accuracy, GDP data from 1998 to 2015 should be used. From Table 3, we can see error percentage for model 1, where all data have been used from 1998 to 2015, including 4 countries' GDP. Maximum error for this model is 10.47%. In order to simplify the model, we used model 2 which did not consider Thailand's GDP. Similarly, numbers of variables have been decreased 1 by 1, up to the point where the model becomes linear. Table 4 shows us GDP prediction of the World Bank from 2016 to 2021 for Singapore, China, Thailand, and India.

TABLE 4
GDP FORECASTING FROM THE WORLD BANK [21]

Country	Unit	2016	2017	2018	2019	2020	2021
China	Billions of USD	11383.03	12263.43	13338.23	14605.29	16144.04	17762.01
India	Billions of USD	2288.42	2487.94	2724.76	3006.95	3315.36	3660.21
Singapore	Billions of USD	294.56	304.10	313.44	324.66	336.69	347.32
Thailand	Billions of USD	409.72	428.77	442.82	462.75	484.61	509.61

Table 5 shows forecasting of the passengers from 2016 to 2021 for all 5 models. Passenger forecasting for Singapore from 2016 to 2021 using these models has been shown in Figure 1.

TABLE 5
PASSENGER FORECASTING FOR THE 5 MODELS IN MILLIONS OF PEOPLE

sr	Model Name	2016	2017	2018	2019	2020	2021
1	Model with China GDP, Thailand GDP, India GDP, Singapore GDP combined with linear model	54.80	56.18	57.37	58.42	59.45	60.25
2	Model with China GDP, India GDP, Singapore GDP combined with linear model	54.47	55.90	56.93	57.89	58.85	59.67
3	Model with India GDP, Singapore GDP combined with linear model	52.34	52.85	53.09	53.30	53.61	53.73
4	Model with Singapore GDP combined with linear model	54.84	57.10	59.40	62.09	65.05	67.87
5	Linear model	55.70	57.63	59.56	61.49	63.42	65.35

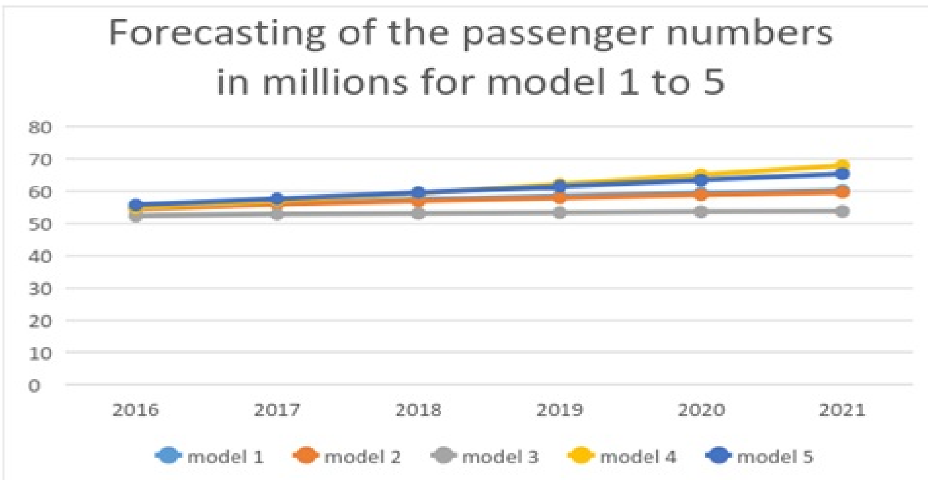

Fig. 1 Passenger number forecasting

CONCLUSION AND RECOMMENDATIONS

This paper proposes the way how to combine optimization and modelling together to forecast future air traffic. The paper shows that optimization can be used to find constants which give the least error. For different models, different constants were found. As results show, accuracy of the forecasting improves with the increase of the number of neighbour countries involved. The paper proposes that passenger forecasting of any country has dependence not only on that country, but on the neighbouring countries as well. Forecasting for 2010 to 2015 has been done using model 1, and maximum error has been 10.47%. It was due to SARS virus outbreak in Singapore and other parts of Asia in 2003. Similarly, any issues might happen in the future. We expect the forecasting to have up to 8% of error. In addition to causal issues, model accuracy depends on accuracy of the forecasted GDP values. The paper shows that the number of passengers will rise from 56.3 million to 64.9 million in 5 years, from 2016 to 2021.

Declaration of Conflicting Interests

This work has no conflicts of interest with or among any stakeholder/s.

REFERENCES

[1] International Civil Aviation Organization. (2006). *Manual on Air traffic Forecasting* [Online]. Available: https://goo.gl/b2VkVN

[2] T. Sailauov and Z. W. Zhong, "Effects of internal resources on airline competitiveness", *International Journal of Modeling and Optimization,* vol. 6, no. 2, pp. 86-90,2016.

[3] J. M. W. Low and B. K. Lee, "Effects of internal resources on airline competitiveness," *Journal of Air Transport Management,* vol. 36, pp. 23-32, 2014.

[4] W. H. K. Tsui, H. O. Balli, A. Gilbey and H. Gow, "Operational efficiency of Asia-Pacific airports" *Journal of Air Transport Management,* vol. 40, no. 5, pp.16-24, 2014.

[5] D. Gillen and A. Lall, "Developing measures of airport productivity and performance: an application of data envelopment analysis," *Transportation Research Part E: Logistics and Transportation Review*, vol. 33, no. 4, pp. 261-273, 1997.

[6] J. Hlinka and H. Trefilova, "Identification of major safety issues for a futuristic personal plane concept," *Journal of Aviation,* vol. 18, no. 3, pp. 120-128, 2014.

[7] Z. Zhang and P. Wang, "Computing model of airspace utilization rate based on airspace load", *Journal of Networks,* vol. 9, no. 1, pp. 71-77, 2014.

[8] N. Adler, T. Ulku and E. Yazhemsky, "Small regional airport sustainability: Lessons from benchmarking," *Journal of Air Transport and Management*, vol. 33, pp. 22-31, 2013.

[9] N. Halpern and R. Pagliari, "Governance structures and the market orientation of airports in Europe's peripheral areas," *Journal of Air Transport and Management,* no. 13, vol. 6, pp. 376-382, 2007.

[10] M. S. Nugroho and M. Suryanegara, "Analysis of interference of Unmanned Aircraft System (UAS) and fixed service at frequency band 12.5-12.75 GHz by considering the factor of rain attenuation," *Journal of Advances in Technology and Engineering Studies,* vol. 2, no. 5, pp. 164-169, 2016.

[11] T. Ulku, "A comparative efficiency analysis of Spanish and Turkish airports," *Journal of Air Transport Management,* vol. 46, pp. 56-68, 2015.

[12] B. Vujic, S. Vukmirovic, G. Vujic, N. Jovicic, G. Jovicic and M. Babic, "Experimental and artificial neural network approach for forecasting of traffic air pollution in urban areas: The case of Subotica," *Journal of Thermal Science,* vol. 14, pp. 79-87, 2010.

[13] R. Guo and Z. W. Zhong, "Forecasting the air passenger volume in singapore: An evaluation of time-series models," *International Journal of Technology and Engineering Studies,* vol. 3, no. 3, pp. 117-123, 2017.

[14] Y. Bao, T. Xiong and Z. Hu, "Forecasting air passenger traffic by support vector machines with ensemble empirical mode decomposition and slope-based method," *Discrete Dynamics in Nature and Society,* pp. 1-12, 2012.

[15] S. Wenzel, K. Kolker, P. Bieblich and K. Lutjens, "Approach to forecast air-traffic movements at capacity-constrained airports," in *14th AIAA Aviation Technology, Integration, and Operations Conference, AIAA Aviation Forum,* Atlanta, GA, 2014.

[16] S. M. Phyoe, Y. X. Lee and Z. W. Zhong "Determining the future demand: Studies for air traffic forecasting," *International Journal of Technology and Engineering Studies,* vol. 2, no. 3, pp. 83-86, 2016.

[17] G. Di, Gravio, M. Mancini and R. Patriarca, F. Costantino, "Overall safety performance of air traffic management system: Forecasting and monitoring," *Safety Science,* vol. 72, pp. 351-362, 2015.

[18] V. A. Profillidis, "Econometric and fuzzy models for the forecast of demand in the airport of Rhodes," *Journal of Air Transport Management,* vol. 6, no. 2, pp. 95-100, 2000.

[19] Trading Economics Data. (2014). *GDP of countries from 1998-2014* [Online]. Available: https://goo.gl/iiECke

[20] Singapore Changi Airport. (2016). *Traffic statistics* [Online]. Available: https://goo.gl/efPNAr

[21] International Monetary Fund. (2016). *GDP forecasting* [Online]. Available: https://goo.gl/EeXtQd

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