DYNAMIC SIMULATION OF AIR CARGO DEMAND FORECAST

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ABSTRACT

This paper establishes an approach to forecast air cargo demand related to terminal capacity expansion. To balance capacity and demand, it is required to forecast the future demand based on optimistic and pessimistic projections to decide when and how much, the airport should expand the capacity. System dynamics simulation model can provide reliable forecast and generate scenarios to test alternative assumptions and decisions. It was found that GDP and FDI play an important role in fostering the demand. Terminal expansion would be required in 2014 and 2021 at the optimistic projection; meanwhile, based on pessimistic projection, capacity should be expanded in 2025.

Keywords: Air cargo, Demand forecast, Terminal capacity expansion, System dynamics, Scenario analysis

1 INTRODUCTION

In line with world trade liberalization and global logistics operation, air cargo industry has been booming for the past decade. Transport by air cargo has become increasingly important, in consequence of the development of a leading global manufacturer. Manufacturing, especially in the high technology industries has a major contribution to air cargo volume. By value, 40% of global trade transactions are delivered by using aircraft [4]. Air freight is required for time-sensitive (high-value) commodities such as computers and cell phones which have a short marketing life and perishable products (fresh flowers, fruit, and live animals) because it offers speed, security and reliability. Products that have high inventory carrying costs such as medical devices and jet engines are delivered via air freight to avoid critical time in transit [15]. Air cargo, trade, and GDP have a direct relationship and interdependent [14]. The demand of air cargo will increase as the trade volume and economic activity increase. Porter [12] has documented the correlation between air cargo and GDP growth. According to Porter and international business academicians, outward foreign direct investment (FDI) can generate a competitive strength to the nation’s industry. Foreign direct investment (FDI) is investment of foreign assets directly into a domestic company's structures, equipment, and organizations.

In this paper, we developed model to forecast air cargo demand in the future to determine terminal capacity required to support long-term growth. For this study, we analyzed air cargo demand in Taiwan Taoyuan International Airport (TTIA) by utilizing system dynamics model. Although such analysis may differ from one airport to another, we keep the proposed model as generic as possible to facilitate its implementation in a wide spectrum of real-world cases. System dynamics framework is a method that can be used to analyze and to develop a model to forecast the air cargo demand and to evaluate some scenarios based on optimistic and pessimistic projections related to air cargo terminal capacity expansion. System dynamics is an effective way to forecast the demand for air travel because of some advantages [11, 13] as follows:

1. System dynamics models offer the ability to incorporate expert knowledge in the model and the ability to model highly non-linear behavior.

2. System dynamics models are calibrated to historical data, and used to produce a forecast of the future demand. It will enable us to accurately predict the demand volume based on demand scenario analysis.
3. System dynamics models can provide more reliable forecasts than statistical models, allow user to determine key sensitivities, and therefore more robust sensitivities and scenario

This paper is organized as follows. Section 2 provides the previous related work. Model development and model validation are described in Section 3 and Section 4 respectively. Section 5 demonstrates scenario planning for the next 20 years. Finally in Section 6, conclusion and further research required are presented.

2 PREVIOUS RELATED WORK

The demand for air cargo transportation had shown enormous for the last several years, due to strength of economic growth, improvement of political stability and gradual free market environment through the open-skies policies. Globalization, digitization, aviation and time-based competition make the worlds of commerce and supply chain management rapidly changing. High technology products that typically small, light, compact, components and assembled products are increasingly shipped internationally by air in a fast and flexible manner. Air rights liberalization, improvement in customs quality, and reduction in corruption are three critical policy levers that affect the air cargo growth.

Gross domestic product (GDP) which represents the economic activity is the main driver of air cargo growth. World GDP growth rate was 3.5 percent in 2005, and achieved 4.0 percent in 2004 [2]. Global air cargo market will continue to grow based on a number of factors, such as economic growth in diverse areas of the world [3]. The increasing importance of high-tech products in Taiwan's export and the growth of science-based industrial parks such as the one located in Hsinchu county is one of the key drivers of the economic development. Taiwan's principal export destinations are China, Hong Kong, USA. Trade between Taiwan and China grew in double digits annually in the 1990s [9].

Some researchers consider FDI and exports have a relationship, which means that FDI can stimulate exports [19]. There is an endogenous relationship between foreign direct investment and economic growth [18]. Love and Chandra [10] have analyzed that GDP, export, and the terms of trade are having relationship and co-integration. Other variable that has impact to export volume is foreign direct investment (FDI). Foreign direct investment (FDI) is a good variable to be utilized in analyzing the emerging markets for the air freight traffic growth [7]. Frank and Chu [5] have developed an economic model to analyze the relations among foreign direct investment (FDI), exports, and gross domestic product (GDP) as a proxy for economic growth. They found the causality relations among FDI, exports, and GDP. GDP causes exports and inward FDI also causes exports. The air cargo volume throughput of the world has strongly linked to trade growth and has grown at between 1.5 and 2 times the rate of worldwide GDP growth [20]. There is an established relationship between air cargo growth and two key economic development factors such as GDP and inward foreign direct investment [8].

Lyneis [11] has developed system dynamics model to forecast demand of commercial jet aircraft industry. Galvin [6] have utilized system dynamics to determine the future behavior of the principle components of the air traffic control (ATC) system over time. With high demand uncertainties, acquiring the right amount of air cargo terminal space has often been a major challenge for the airport authority. By forecasting the future demand of air cargo volume, a finite-horizon planning model is used to support the long-term capacity management. In this research, we utilize system dynamics to forecast and to develop several scenarios based on optimistic and pessimistic projection.

3 MODEL DEVELOPMENT

To develop the system dynamics model, first, we have to define the purpose of the model, which means that we should focus on a problem and narrow down the model. In this case, our aim is to develop a model to forecast air cargo demand in the future related with terminal capacity expansion to support long term growth. Air freight volumes are rising in response to gently accelerating economic growth as the impact of globalization and trade liberalization. Fig. 1 shows the flow diagram of air cargo demand based on existing condition. As we can see from Fig. 1, *Air Cargo Demand* is determined by *Air Cargo Export*, *Air Cargo Import*, and *Air Cargo Transit*. There are four air cargo terminals in Taiwan, those are EGAC, EVERTER, TACT and FTZ. The utilization of the air cargo terminal is the proportion of air cargo demand (capacity at the terminal is being used) and the terminals capacity. Excess of capacity will happen as long as the amount of capacity is greater than the demand.

In this research, we set the simulation timing for 12 years starting from 1996 to 2007 based on consideration of learning the system behavior of air cargo demand before and after the terrorist attack on September 11, 2001 and the availability of the data. The simulation time step is one year. Fig. 2 shows the *Air Cargo Demand* during 1996 to 2007. As we can see from Fig. 2, the average growth of air cargo demand was around 6.9% as the impact of air cargo export, import, and transit. With increasing globalization, in period 2001 to 2004, the demand grew between 8% and 15%, as the transport of air cargo has become increasingly important. The demand growth started to decline during the period of 2005 to 2007 in line with the worst economic crisis in decades.

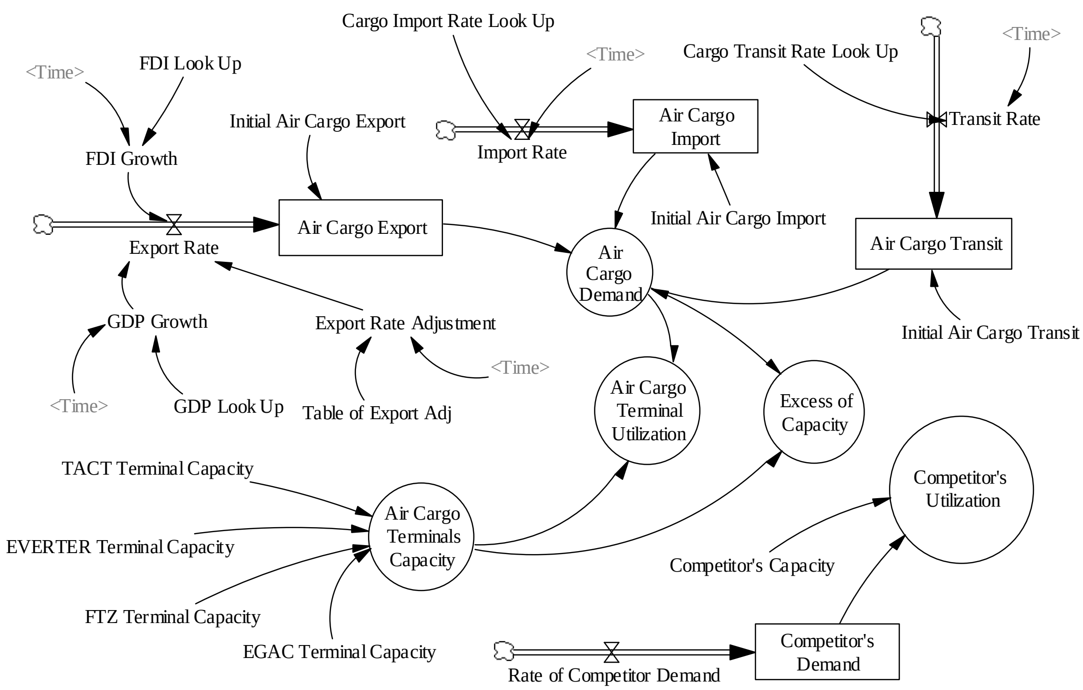

Fig. 1. Flow diagram of air cargo demand based on existing condition

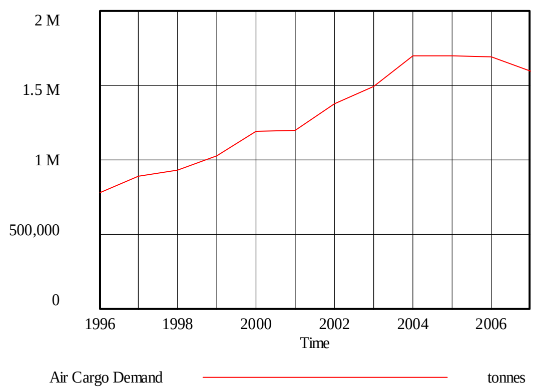

Fig. 2. Air cargo demand

4 MODEL VALIDATION

Validation is a process of evaluating model simulation to determine whether it is an acceptable representation of the real system. Historical data during the time horizon of simulation of the base model (1996 – 2007) is required. A model will be valid if the error rate is smaller than 5 % [1]. From the simulation result (Fig. 2), we can obtain the average value of simulation $(\bar{S})$ of *Air Cargo Demand* = 1,296,099.92 tonnes. As we can see from Eqs. ((1)-(3)), in this validation process, we also need historical data of air cargo demand. From the historical data during 1996-2007, we obtained the average value of historical data $(\bar{A})$ of *Air Cargo Demand* = 1,306,776.06 such as depicted in Table 1.

$$ErrorRate = \frac{\left|\bar{S} - \bar{A}\right|}{\bar{A}} \qquad (1)$$

where:

$$\bar{S} = \frac{1}{N}\sum_{i=1}^{N} S_i \qquad (2)$$

$$\bar{A} = \frac{1}{N}\sum_{i=1}^{N} A_i \qquad (3)$$

Based on these results, we can calculate the error rate as follows:

$$Error\ rate\ of\ demand = \frac{|1,296,099.92 - 1,306,776.06|}{1,306,776.06}$$

$$= 0.008$$

Table 1: The average value of simulation result $(\bar{S})$and data $(\bar{A})$

Variable	Average Value of Simulation $(\bar{S})$	Average Value of Data $(\bar{A})$
Air Cargo Demand	1,296,099.92 (tonnes)	1,306,776.06 (tonnes)

According to the above result, the error rate is smaller than 5%, which means that our model is valid.

5 SCENARIO PLANNING

Scenario is an approach to develop a set of stories that might happen in the future. Several alternative scenarios can be obtained from a valid model by adding some feedback loops, adding new parameters, and changing the structure of the feedback loops (structure scenario) or by changing the value of the parameter to see the impact to other variables (parameter scenario). We combined between structure scenarios and parameter scenarios to generate more robust sensitivity analysis. The scenario block diagram is given in Fig. 3. We set the time horizon of the scenario model for 20 years based on consideration of the learning behavior of the system. This time span will provide a better understanding of the system behavior of air cargo demand which will have an impact on the outputs and the policy alternatives to be developed.

5.1 Parameter scenario

In this scenario, we modify the value of the parameter based on optimistic and pessimistic projection related to terminal capacity expansion.

5.1.1 Optimistic parameter scenario

This scenario is made to check the air cargo terminal capacity to meet the future demand if *GDP* is predicted to grow with average growth rate 6% annually. This assumption is made by considering Taiwan government prediction. Based on this prediction, the average economic growth will achieve 6 % annually [16]. FDI is expected to grow with average growth rate 28.57 % based on the average growth of Taiwan FDI during 1996-2007. Air cargo import is projected to grow with average 12.9 % based on Hong Kong outward to Taiwan in 2001 and 2004. Freight transit is expected to grow with annual average growth rate 14% based on the transshipment data of Hong Kong transshipment outward during 2002 to 2004 .

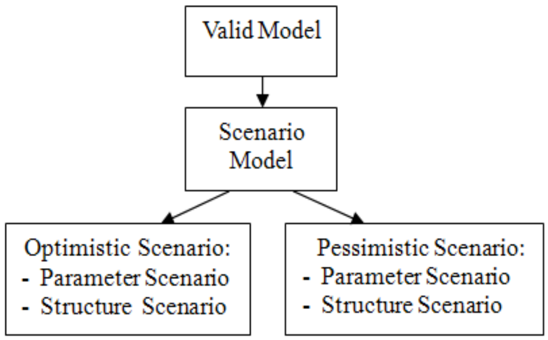

Fig. 3. Scenario block diagram

5.1.2 Pessimistic parameter scenario

This scenario is made to check the existing air cargo terminal capacity whether it can meet the future demand if *GDP* is predicted to grow with average growth rate 2.8 % annually. This assumption is made by considering that *global GDP* growth rate would be only 1% and for *developing countries* would be around 4.5% [21]. We set the average GDP growth rate at around 2.8% by considering the global GDP growth rate and the developing countries growth rate. FDI is expected to grow with average growth rate 18% based on the estimation of the UN Conference in Trade and Development [17]. Air cargo import and air cargo transit are expected to grow with average 4.5 % based on UNCTAD forecast. Import growth and transit growth are projected to grow with average 4.5% by considering UNCTAD forecast.

5.2 Structure scenario

In this scenario, we add a new structure to the base model to check the air cargo terminal utilization and excess capacity related to the demand forecast based on optimistic and pessimistic projection.

5.2.1 Optimistic structure scenario

Air Cargo Terminal Utilization Scn depends on *Air Cargo Demand Scn* and *Air Cargo Terminals Capacity*. *Excess of Capacity Scn* is the difference between *Air Cargo Terminals Capacity* and *Air Cargo Demand Scn*. Additional capacity would be required if excess capacity is less than zero. We divide the capacity expansion into two parts to avoid low capacity utilization. The first expansion is required to cover demand starting from 2014 to 2020. Based on the optimistic projection, the demand of air cargo in 2020 is projected to be around 9.13 million tonnes, therefore backlog would be around 5.63 million tones. The second expansion would be required starting from 2021, to cover demand until 2028. Based on the optimistic projection, the demand of air cargo in 2028 is projected to be around 27.23 million tonnes, and the backlog would be around 23.73 million tones.

5.2.2 Pessimistic structure scenario

Air Cargo Terminal Utilization Pessimistic Scn depends on *Air Cargo Demand Pessimistic Scn* and *Air Cargo Terminals Capacity*. *Excess of Capacity Pessimistic Scn* is the difference between *Air Cargo Terminals Capacity* and *Air Cargo Demand Pessimistic Scn.* Fig. 4 represents the air cargo demand in Taiwan during 1996 to 2028 based on optimistic and pessimistic projections. Based on the optimistic projection, demand is projected to grow with average growth rate 15% and would reach 27.23 million tonnes in 2028. Export would contribute 50%, import 23%, and transit 27% to the demand volume in optimistic projection. Meanwhile, according to the pessimistic projection, demand is projected to grow with average growth rate 4.7% and would only reach 4.1 million tonnes in 2028. Based upon this pessimistic projection, export, import, and transit would contribute 38.2%, 31.8%, and 30% respectively to the demand volume.

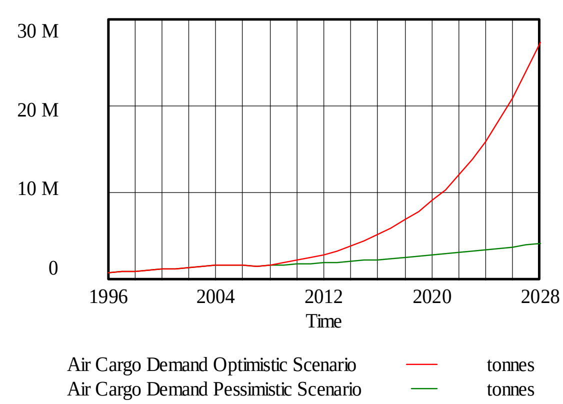

Fig. 4. Air cargo demand optimistic and pessimistic scenario

Based on the optimistic projection, there would be shortage capacity around 0.36 million tonnes starting from 2014, would reach 5.632 million tonnes in 2020, and 23.73 million tonnes in 2028. Meanwhile, under pessimistic projection, the existing capacity will meet the future demand until 2024. According to this pessimistic condition, shortage capacity around 0.12 million tonnes would happen starting from 2025.

Fig. 5 shows the excess of capacity during the period of 1996 to 2028 based on optimistic and pessimistic projections. Based on the optimistic projection, there would be shortage capacity around 0.36 million tonnes starting from 2014, would reach 5.632 million tonnes in 2020, and 23.73 million tonnes in 2028. Meanwhile, under pessimistic projection, the existing capacity will meet the future demand until 2024. According to this pessimistic condition, shortage capacity around 0.12 million tonnes would happen starting from 2025.

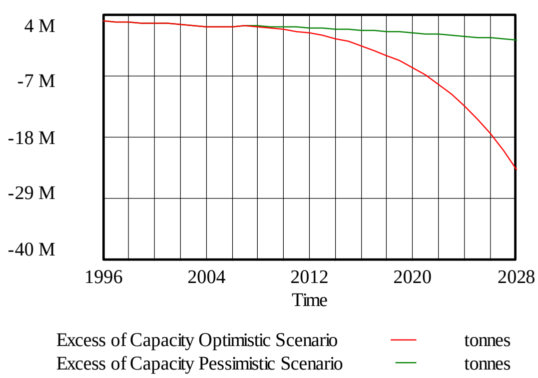

Fig. 5. Excess of capacity optimistic and pessimistic scenario

6 CONCLUSION AND FURTHER RESEARCH

This paper has established a method for developing model to foreceast air cargo demand and scenarios related to planned capacity expansion to meet the future demand based on optimistic and pessimistic economic projections. From the results, we can conclude that GDP Growth has a very strong effect to air cargo demand compared to other factors such as FDI growth, import growth, and transit growth.

According to the optimistic projection, demand would exceed the existing capacity starting from 2014, therefore capacity expansion would be required. To avoid low capacity utilization, capacity expansion could be done gradually based on the demand projection. The first expansion is designed to cover demand during 2014 to 2020, meanwhile the second expansion is required to cover demand during 2021 to 2028. Additional capacity required for the first expansion would be around 5.62 million tonnes and 18.1 million tonnes for the second expansion.

Based on the pessimistic projection, shortage capacity of around 0.12 million tonnes would happen in 2025 and would reached 0.6 million tonnes in 2028. Capacity expansion might be done at once starting from 2025. These models provide a powerful basis for learning and understanding the system behavior and alternative futures which would accommodate new developments through scenarios planning development (please see Sec. 5).

Further research is required to analyze air cargo revenue and performance management due to specific characteristics of cargo inventory, cargo business, and cargo booking behavior.

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