Dynamic simulation model of air cargo demand forecast and terminal capacity planning

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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 2018 based on the optimistic projection; meanwhile, based on pessimistic projection, the capacity can meet demand in 2030, which means no need to increase the capacity.

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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 [5]. 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. Growth in the use of just-in-time (JIT), where particular parts must arrive for assembly at specific times resulting manufacturers depend on air freight services for efficient just-in-time inventory management and to ensure their availability for final assembly. Air freighters enable the most economical sourcing of components and assemblies. 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 [28]. Air cargo, trade, and GDP have a direct relationship and interdependent [26]. Gross domestic product (GDP) is the total market value of all final goods and services produced in a country in a given year, equal to total consumer, investment and government spending, plus the value of export, minus the value of imports. The demand of air cargo will increase as the trade volume and economic activity increase. The development of e-commerce will affect the growth in online retail sales that is also one of the key drivers that stimulate the air cargo growth. Air freight is required to deliver high value density goods such as microchips to other country to make sure that it would be competitive and viable for international business. Porter [22] has documented the correlation between air cargo and GDP growth. According to Porter and international business academicians, outward foreign direct

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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.

Taiwan is the world's largest producer of computer components and now producing the telecommunications equipment [9]. Taiwan maintains partnerships with the US and Japan to integrate its domestic and international production to support its international manufacturing network. Air cargo is required for quick time delivery of high-technology components and goods that have high value and fragile.

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 a very powerful method if we compare to other conventional forecasting methods that present some problems, such as follows:

- It does not account for discontinuities in the external environment.
- Cause effect relationships between different parameters are not always correctly account, and might generate spurious correlations between variables, leading to inaccurate forecasts if one of the variables changes.

Conventional forecasting methods that rely on historical data might not predict the impact of major changes in strategy accurately. According to Senge [25], conventional forecasting methods are not suited for dealing with dynamic complexity with deep uncertainty: prediction of dynamic behaviors, model validity, and optimality may not be obtained. It might be harmful if there is a little time to solve or uncertainties cannot be reduced, and time-consuming [23].

System dynamics is more suitable in the context of the forecasting problem that has complexity with deep uncertainty, by modeling and simulating complex issues and analyzing the non-linear behaviors over time in order to develop and test the system behavior. System dynamics is an effective way to forecast the demand for air travel because of some advantages [16,24] such as:

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. With the detailed and calibrated models, we will be able to accurately predict the demand volume based on demand scenario analysis. As a result, firms can avoid unnecessary capacity expansion because from the model output, it gives clear information on when the firm should expand the existing capacity to meet the future demand.
3. System dynamics models can provide more reliable forecasts than statistical models, allow user to determine key sensitivities, and therefore more robust sensitivities and scenarios.

This paper is organized as follows. Section 2 provides the previous related work. Section 3 describes the system dynamics modeling and validation. Section 4 demonstrates scenario planning for the next 20 years. Finally in Section 5, 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% in 2005, and achieved 4.0% 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]. Today, Taiwan becomes a leading producer of high-technology products such as computers and mobile phones. 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 [14].

Some researchers consider FDI and export have a relationship, which means that FDI can stimulate export [33]. There is an endogenous relationship between foreign direct investment and economic growth [32]. Love and Chandra [15] 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).