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An alternative methodology for planning baggage carousel capacity expansion: A case study of Incheon International Airport

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ABSTRACT

Intensifying competition for air transportation passengers has led airports to research optimal designs and determine the infrastructure expansion capacities of their terminals. As a result, many researchers have studied this subject from a variety of perspectives. In this study, we propose an alternative methodology of determining the expansion of baggage carousel capacity over a series of steps that includes both a simulation and a cost-benefit analysis. The methodology consists of three stages. In the first stage, we forecast the volume of arriving passengers (excluding transfer passengers) and aircraft traffic with an autoregressive integrated moving average (ARIMA) model. Next, we conduct an elaborate analysis to estimate passenger delay using a discrete event simulation model in which we consider the conveyor load and the baggage carousel allocation to aircraft rates. Finally, we determine a plan to expand baggage carousel capacity that accounts for expansion costs and passenger benefits. Construction and conveyor costs were applied to expansion costs, and capacity expansion leads to passenger benefits due to reduced waiting time. Using a real case with 23 candidate baggage carousels at Incheon International Airport during 2013–2015, our experiments demonstrate the strength of the proposed methodology in planning appropriate capacity expansion that reflect the operational flow of passengers within the airport based on the future trend of passenger demand. In particular, our results show that carousel no. 18 should be expanded during the first quarter of 2013, carousels no. 17 and no. 19 should be expanded in 2014, and carousel no. 5 should be expanded in 2015 to obtain optimal benefit-cost ratios of 1.65, 1.79, and 1.76 for each year, respectively.

1. Introduction

Since opening in 2001, Incheon International Airport has developed into a genuine world-class airport, ranking 2nd in international cargo traffic and 9th in international passenger traffic. Beginning in 2005, Incheon Airport has also been ranked 1st for nine straight years in the Airport Service Quality survey conducted by Airports Council International. The number of passengers at Incheon Airport has increased at a rate of approximately 7% from 2001 to 2013, on average (Fig. 1). In response to this growing demand, Incheon Airport is attempting to expand various types of infrastructure, including the expansion of the airport terminal, to maintain its current level of service.

Developing an analytical model of passenger flow in an airport terminal to determine the optimal infrastructure capacity in expansion planning is difficult due to the complexities of the terminal structure and demand uncertainty (Solak et al., 2009). Cause of this difficulty, several studies in this field has not considered passengers' practical flow in the airport terminal. Nevertheless, it is important to determine whether the entire utilizable area is considered when planning for terminal capacity expansion. Solak et al. (2009) developed a maximum delay function in passageways and processing stations for calculating the maximum walking times by accounting for density, free-flow walking speeds (264 ft/min), and the length and width of passageways based on truncated Taylor series expansions (Rice, 1995); these authors suggested three approximations (triangular, parabolic and half-elliptical) to represent the shape of the peak for the processing stations. Suryani et al. (2010) calculated congestion with the M/G/1 queuing model that considers an arrival pattern of flights, service capacity, and runway capacity. Ronzani Borille and Correia (2013) incorporated arrival

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Fig. 1. The pattern of annually increasing passenger demand at Incheon International Airport.

components into their simulation model and analyzed 720 scenarios that accounted for aircraft size, aircraft load factor, intervals between flights, passenger profiles, conveyor length, and differences in the arrival times of passengers and baggage at the conveyor belt.

However, the foregoing studies have certain limitations with respect to including various airport events in their calculations. For example, passenger waiting time at baggage claim is affected by equipment specifications and operation, such as conveyor loading and baggage carousel allocation to aircraft. Fig. 2 demonstrates that new luggage will not be loaded onto the conveyor when the total weight of the luggage on the conveyor is heavier than its maximum load capacity. After passengers remove luggage from the conveyor, luggage will begin to be loaded again. Such loading stoppages are components that increase passenger waiting time.

The basic premise of planning for the expansion of airport infrastructure capacity is to invest in improving the quality of service offered to passengers. The studies discussed above addressed passenger congestion and delay time to evaluate service levels after infrastructure capacity was expanded. However, according to Jorge and de Rusb (2004), it is necessary to evaluate the economic rationale of public investment decisions by applying analytical tools such as cost-benefit analyses.

The purpose of this paper is to determine the optimal expansion of baggage claim capacity at Incheon International Airport, considering future passenger arrival patterns and the operational aspects of baggage claim. For this determination, we propose a combination model that employs an autoregressive integrated moving average (ARIMA) model to forecast passenger demand, a simulation technique for estimating passenger waiting time and a cost-benefit analysis that uses expansion cost and passenger benefit. The proposed model is tested for facilitating its application to the real case of capacity expansion at Incheon International Airport.

This paper is organized as follows. Section 2 performs a literature review in terms of forecasting model, simulation model, and airport capacity expansion of airport. Section 3 presents the detailed procedures of our study. Section 4 describes the experimental results using real case of Incheon International Airport. Finally, in Section 5, the conclusion is presented.

2. Literature review

An accurate airport passenger demand forecast can help reduce airport risk regarding both short- and long-term planning for airport facility expansion and other decisions. Several approaches have been used in the literature to forecast air passenger volume. In its Airport Development Reference Manual (ADRM), the International Air Transport Association (IATA) (2004) defined airport capacity and described the relation between the capacity of passenger terminal facilities and an airport's level of service. Scarpel (2013) applied an integrated mixture of local experts model (IMLEM) to forecast air passenger volume at São Paulo International Airport. The model was employed to address rapidly changing situations, i.e., when the time series presents turning points or any type of structural changes in the short term. Due to regional differences in input spaces, gross domestic product (GDP) growth was used as a leading indicator to forecast domestic passenger volume in the IMLEM. Mean absolute percentage error

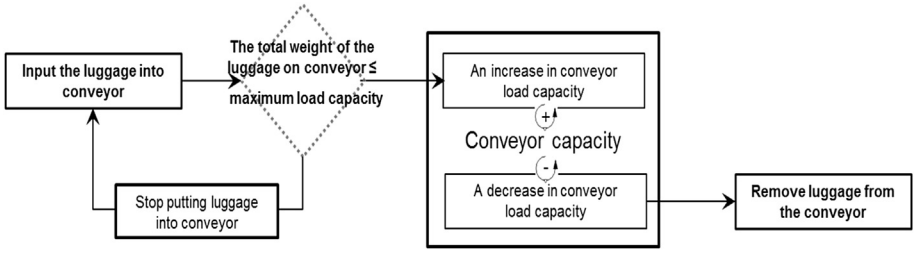

Fig. 2. The relevance of conveyor load capacity and baggage allocation to conveyor.