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Optimum positions for frictions between service centers to minimize passenger delays

Shamain Saparamadu*, Saman Bandara

Transportation Engineering Division, Department of Civil Engineering, University of Moratuwa, Katubedda, Sri Lanka

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ABSTRACT

Waiting time and walking distances for passengers are major considerations to determine the geometry of an airport terminal configuration. Based on a study of passenger arrival and waiting patterns at terminal service centers in an airport, such as: ticket counters, immigration, baggage claim and security checks, this paper is about the effect of placing other frictions such as shops, washrooms, food cabins and internet accesses between mandatory service centers. Going by the information collected the best positions for frictions between service centers were decided on to minimize passengers' waiting time. With regard to the best positions, the first consideration related to the distributions of arrival and waiting patterns at mandatory terminal services. Then, the effects of the distributions for frictions were incorporated separately to find out the change of distributions with the inter change in frictions. Next, the best suitable positions for frictions and services centers were determined from among all combinations of combining frictions and service centers. The frictions placed between the mandatory services centers depend on the means and variances of the frictions. The percentages of passengers going through the frictions were also considered to find out the optimum positions for frictions between service centers. Analytical solutions for optimum positions for frictions between service centers to minimize passenger delays were realized after analyzing the data for frictions and mandatory service centers. Simulation models were used to verify these analytical solutions.

1. Introduction

Travel by air is considered the best means of transport the modern day, especially with long distance travel (ACI EUROPE, 2010). Travel by air has also made it possible for greater numbers of people with their explorations. Travelers, nowadays, are certainly more travelled than their predecessors. Yet, with all advantages that air travel offers, there are drawbacks as well. Much as travel by air cuts down on travel time, air travelers are often made to spend precious time at airport terminals standing in queues, moving at snail's pace (Atkin et al., 2011). To add to the confusion, the airport terminals, very often, are full of passengers laden with baggage, but who have all arrived to meet given time schedules. Waiting long can easily annoy or frustrate travelers. Therefore, a need arises at airport terminals for optimal positions for optional service centers.

Passenger waiting time and walking distances are major considerations to determine the geometry of an airport terminal configuration (Atkin et al., 2010), vital to optimize passenger movements through an airport terminal. This is one important activity that has to be managed efficiently for the proper functioning of an airport. Minimizing walking distances, waiting times and delays at mandatory service centers such as: ticket counters, immigration, baggage claim and security checks and optimally placing other services such as: shops, washrooms, food cabins and internet accesses could improve passenger throughput so that there will be no significant increase in total time spent. Arrival and waiting patterns of passengers at different service centers could vary depending on the airport location and the operating strategy of the terminal. Further, these patterns could depend on the frictions due to other services such as: shops, washrooms, food cabins and internet accesses that are placed in between mandatory service centers. Therefore, knowledge about arrival and waiting patterns at the mandatory service centers, waiting patterns at other services centers (frictions) and waiting patterns at mandatory service centers after combining with one or more friction upstream will help model passenger flow through a terminal.

This paper presents a study evaluating effects of placing optional services such as shops, washrooms, food cabins and internet accesses considered as frictions, between mandatory service centers and the best combinations of frictions between mandatory service centers that minimize passengers' total waiting time of dwell. For this purpose, the

* Corresponding author.
E-mail address: saparamaduds@yahoo.com (S. Saparamadu).

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waiting and service patterns of passengers at airport terminal mandatory service centers, data of passengers' waiting time and service time at each terminal mandatory service center were collected at the Bandaranaike International Airport, Sri Lanka (BIA) and the distributions of arrival and waiting patterns at mandatory terminal service centers were first considered (Saparamadu and Bandara, 2015). Then the effects of the placing of frictions in between mandatory service centers were incorporated. Analysis was done to find the effect of order of placement of different frictions. Acceptable positions of frictions between mandatory services centers were identified based on total dwell time for frictions and mandatory service centers. An analytical solution for optimum positions for frictions between service centers to minimize passenger delays was determined and this solution was verified using a simulation study.

2. Literature review

Simulation and analytical models have been used to decide on operations to minimize delays regarding waiting time at ticket counters, check-in gates, baggage stations and security checks at the airport and minimizing walking distance through airport terminal service centers (Lesire, 2010; Rappaport et al., 2009; Babu et al., 2006; Candalino et al., 2004; Horonjeff, 1969; Olapiriyakul and Das, 2007; Yfantis, 1997; Lu, 2009). Analytical models are useful to find initial solutions during planning stages within a short period of time (IATA, 1982, 1995; Burgain et al., 2009). They are also capable of handling different alternatives. Simulation models can give more detailed information which may be required at the detail design stages.

Much work in this connection has already been done. There are some simulation models to estimate the behavior of passenger and baggage flows for one airport (Brunetta and Romanin-Jacur, 1999). Models in use have proven to be improved in detail and reliability and are user-friendly as well. Yet, tactical simulations, have, of late, revealed two main defects. Models from Gatersleben and Van DerWej (1999) and Joustra and Van Dijk (2001) are limited to the use of one airport only. They cannot be extended to another section as they are modeled for use in one part of the airport only. There are models like the ones introduced by Brunetta and Romanin-Jacur (1999) to extend to other areas. These models used with limited adjustments help describe different airports in detail. But they are not very user-friendly. Therefore, the non-availability of a worthwhile tactical simulation model for use with landside operations drove designers towards a new flexible simulation model that could help determine the time behavior of passenger and baggage flows, the capacity and the delays in a generic airport terminal (Brunetta and Romanin-Jacur, 1999, 2001; De Neufville et al., 2002; Mumayiz, 1990; Odoni and De Neufville, 1992). The simulation model to find the average wait time of passengers to reach the gate area has been used to investigate system behavior under the effect of different scenarios obtaining varying critical input parameters such as: passengers, baggage and aircrafts flows and flight schedules of departures and arrivals (Schultz and Fricke, 2010; Tosic, 1992; Curcio et al., 2006). These simulation models are used to investigate system performance in different situations governed by different resources allocation and availability. A study was carried out to determine optimal gate assignments under possible delay by Yan et al. in 2002. Some simulation frameworks for ticket counters are available. All these efforts were made to minimize passenger waiting time and travel distance.

There is an analytical model to analyze any given facility by providing and estimating the capacity of that facility. The number of passengers, baggage per hour and the level of service associated with it, compared to internationally accepted standards as those suggested were considered for the above model (IATA, 1982). In addition, it provided formulae to estimate the number of counters and recommended space for passengers in queues at airport terminal mandatory service centers. However, passenger arrival distributions, queue arrangement and counter sizes are also important elements in designing service facilities. Another analytical aggregate model is the Simple Landside Aggregate Model (SLAM) (Brunetta et al., 1999), used to estimate capacity and delays in airport passenger terminals. SLAM answers "what if" questions about alternative configurations of the various processing and holding facilities in a terminal. This contains a network of modules based on simple mathematical formulas. It is used to estimate capacity of each facility as related to number of passengers each hour and the Level of Service (LOS) provided. LOS is quantified regarding both "space available per facility occupant" and waiting time for processing.

3. Methodology

For purposes of this study, the waiting and service patterns of passengers at airport terminal mandatory service centers, data of passengers' waiting time and service time at each terminal mandatory service center were collected at the Bandaranaike International Airport, Sri Lanka (BIA). To get a representative sample or data collection, time slots were divided as rush hours (night shift) and non-rush hours (day shift) on rush days and non-rush days using the aircraft schedule for each month.

Collection of data was gathered as described hereafter. When a passenger reached the service counter, the time was set to start and it stopped after the passenger left that counter. The service time of the passenger in that particular counter was taken in this manner. To measure the service time, 20 passengers were selected at a time. It was assumed that all of them got into the queue at the same time. Then, the service time for individual passengers in the selected group was measured at each counter. By using passengers' service time, passengers' waiting time at each counter was calculated as follows. Table 1 explains the way to calculate waiting time by getting at the cumulative service time. i.e. Both waiting time and service time of passengers' were considered as per the below table. The service time and waiting time of the passenger in mandatory service centers of check-in counters, ticketing counters and immigration counters depend on the number of counters at these service centers. For baggage station this will depend on the size of the belt and total number of passengers in the belt. It is assumed that waiting time of the first passenger in a particular service center is zero.

Data related to service time and waiting time of the selected group at each service center were collected by considering only the queue space of the relevant service center.

Using above data of service time and waiting time, the distributions of waiting times and service times at service centers were found separately for arrival and departure procedures (Saparamadu and Bandara, 2015). To find the distributions of combined service centers, the formula of mean and the variance of combining two independent continuous random variables (Bandara and Wirasinghe, 1989) and three

Table 1
Service time and waiting time at Immigration counter in departure procedure.

Service Time (s)	Waiting Time (s)
S_1	$W_1 = 0$
S_2	$W_2 = S_1$
.	.
S_i	$W_i = S_1 + S_2 + \ldots + S_{i-1}$
.	.
.	.
S_n	$W_n = S_1 + S_2 + S_3 + S_4 + \ldots + S_{n-1}$

S_i = Service time of ith passenger.
W_i = Waiting time of ith passenger.

$$W_n = \sum_{i=2}^{n-1} S_{i-1}$$