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Innovative Applications of O.R.

Virtual queuing at airport security lanes

Robert de Lange [a], Ilya Samoilovich [b], Bo van der Rhee [c,*]

[a] *Founder @ CiteFlow, Van Speijkstraat 11B, 2518EV Den Haag, The Netherlands*
[b] *Business Analyst at Capgemini, Eiland van Maui 34, 1705SG Heerhugowaard, The Netherlands*
[c] *Nyenrode Business University, Breukelen, The Netherlands*

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ABSTRACT

Airports continuously seek opportunities to reduce the security costs without negatively affecting passenger satisfaction. In this paper, we investigate the possibilities of implementing virtual queuing at airport security lanes, by offering some passengers a time window during which they can arrive to enter a priority queue. This process could result in a smoother distribution of arriving passengers, such that the required security personnel (costs) can be decreased. While this concept has received attention in a number of settings, such as theme parks, virtual queuing at airports bears an additional level of complexity related to the flight schedules, i.e., passengers can only be transferred forward in time to a limited extent, which we denote by the transfer time limit. We conducted a major simulation study in collaboration with a large international airport in Western Europe to determine the potential impact of virtual queuing and find that nearly one million Euro can be saved on security personnel cost without negatively impacting the passenger waiting time.

1. Introduction

According to a recent article (Ghosh, 2011), the Air Transport Association (IATA) forecasts "that there will be 3.3 billion air travelers by 2014, up from 2.5 billion in 2009." The growth in passenger traffic volume and other trends such as increased competition and a growing demand for customer experience are leaving airports with many challenges for the future. Airports face escalating costs, revenue growth constraints, and an increasing dissatisfied customer base. In addition, a survey among senior airport executives indicated that the common concerns of airports could be clustered into three broad categories: rising costs, customer satisfaction, and revenue constraints (refer to Fig. 1). The main concern is the increasing security costs, which is directly related to the rapid growth of the passenger traffic volume. The increased threat of terrorism is another reason, as it had resulted in the introduction of more rigorous border controls and safety procedures (Fredickson and LaPorte, 2002).

However, cutting back the security budget, for example by reducing the workforce, is risky as this could result in increased queues at security checkpoints. Queues have a negative impact on customer satisfaction (see e.g., Katz et al., 1991) and if the queues are too long, some passengers could even miss their flight. Airports can therefore not afford to make their customers wait too long, especially when nearby airports offer alternatives departure locations for passengers. Nevertheless, airports have no other option than to accept queues to a certain extent in order to keep the security costs at a reasonable level.

In this paper we investigate a cost reduction opportunity based on the principles of virtual queuing (abbreviated to VQ) at airport security lanes. Even if capacity is able to deal with the average demand, queues usually still occur due to fluctuations in arrivals as well as service times. Fluctuations lead to high queues when demand is at its peak and wasted resources during periods of low demand. A virtual queue can be interpreted as an invisible line of passengers waiting to enter a physical queue. In this scenario, the concept is based on the allocation of time windows (TWs) to passengers that allow them to enter a priority lane during a specific time interval. It is a process that offers the opportunity to redistribute the passenger arrivals by shifting the demand out of peak periods into idle periods.

VQ principles turned out to be very successful for call centers (see e.g., Camulli, 2007) and amusement parks (see e.g., Lutz, 2008), which took advantage of people's flexible schedules. However, the situation at airports is more complex from a queuing perspective due to passenger time constraints related to the flight schedules (Narens, 2004). Still, virtual queues at airports could potentially lead to shorter queues with the same number of security agents, or similar waiting times with fewer security agents. Since airports' largest concern are the increasing security costs,

* Corresponding author. Address: Center for Marketing & Supply Chain Management, Nyenrode Business University, Straatweg 25, P.O. Box 130, 3620 AC, Breukelen. Tel.: +31 346291745; fax: +31 346291250.

E-mail addresses: Robert@citeflow.com (R. de Lange), i.samoilovich@capgemini.com (I. Samoilovich), b.vdrhee@nyenrode.nl (B. van der Rhee).

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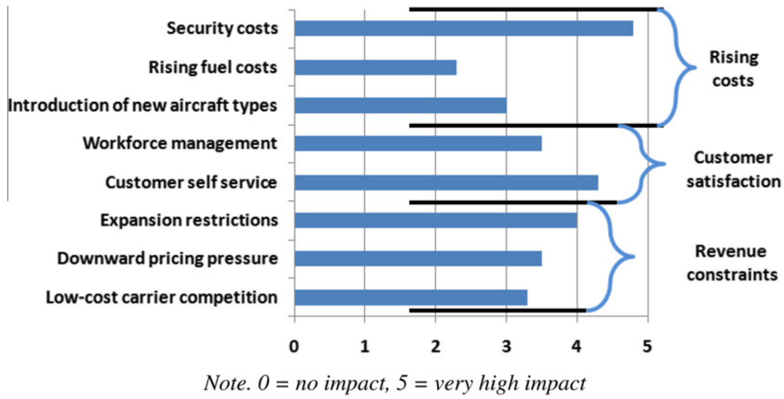

Fig. 1. Key concerns of airports (Vincent et al., 2007).

the main objective of this paper is to identify whether the application of VQ could reduce the number of agents at airport security lanes, while not increasing the average passenger waiting time. Our results can lead to changes in the demand for capacity in terms of staff, resources, and terminal space and could contribute to an increased operational efficiency and reduction of the operating costs at airports worldwide.

The remainder of this paper is structured as follows. In Section 2 we review the relevant literature in the areas of airport security, queuing, and simulation studies in general. Section 3 provides an overview of the simulation study at a large, international airport in Western Europe (abbreviated to WE), including some results and analysis. We end our paper in Section 4 with conclusions and recommendations.

2. Literature review

In this section, we first discuss queuing theory in general, followed by recent work on VQ in call centers and amusement parks. We then briefly discuss the antecedents and implications of VQ to the passengers as well as the chosen research methodology of simulations.

2.1. Queuing theory in general

Queuing theory and simulation modeling are the two approaches most commonly used to translate customer arrivals during different time intervals into the staffing levels needed to maintain the required service standards (Ernst et al., 2004). A general queuing process depends on three main components: (a) *the input process*, (b) *the service mechanism*, and (c) *the queue discipline* (see e.g., Saaty, 1957). *The input process* describes the arrival behavior of the customers at the service point. The arrival behavior is usually expressed in terms of the time intervals between the successive arrivals of the customers, denoted by interarrival times, which follow a certain distribution, or are based on real arrival data. We elaborate on the input process in subsection 3.3.

The *service mechanism* specifies the number of service points in the system that should be used, the maximum number of possible service points in the system and the service time distribution (i.e., how long it takes a passenger to pass through security), given in terms of the time duration of the services. Usually, the service rates (also known as the 'capacity', i.e. how many passengers can pass through security per certain time interval) are assumed to be independent of the arrival process and each other, and to be identically distributed, without regard for which server provides the service. Based on the data we obtained we used a Normal distribution for the service times, with a minimum of 1 second.

The third component is *the queue discipline*. The queue discipline describes the behavior of the customers who find all service points occupied. In this case a customer can act in three different ways by (1) leaving (referred to as "balking", see e.g., Xu et al., 2007) or (2) entering the queue, but leave after a certain amount of time ("reneging", see e.g., Blackburn, 1972), and (3) waiting in the queue until a service point is free. In our case (passengers trying to get to their departing planes), we assume that (1) and (2) do not occur, and that the general principle of first-in first-out is applied, with the possible exception of the passengers in the virtual queue. This means that we leave any other types of priority queues out of this discussion (e.g., those with iris scans).

A queuing problem arises when people have to wait in a queue, especially when the waiting time is longer than their individual waiting time threshold (Chambers and Kouvelis, 2006). To solve such a problem, changes have to be made in either the behavior of the arriving units, or the service facilities or both (van Voorhis, 1956). To affect these changes it is necessary to manipulate or control the factors that influence this behavior. In general, all the factors that influence the behavior of the arriving customers and the service points can be linked to the three following components (Klassen and Menor, 2007): *utilization of the capacity,* defined as the percentage of the total service time that the security agents are actively providing the service, *variability of the arrival of customers* and *of the service times*, and the *level of inventory*, defined here as the number of people in the queue and the people that get served. The general relationship between these three components can be stated as follows: *Inventory = Capacity utilization* × *Variability*.

2.2. Virtual queuing in call centers and theme parks

From a call center's perspective a long queue (i.e., high inventory) can result in many abandoned calls, repeat attempts and customer dissatisfaction. This can either be seen as a capacity utilization problem (i.e., more staff is needed to deal with the incoming calls) taking the customer arrival pattern (i.e., the variability) as given (see e.g., Green et al., 2007), or as a variability problem. VQ systems attempt to solve the latter problem by allowing customers to receive callbacks instead of waiting in a queue. VQ does not eliminate the waiting time, but it does change its perception, since customers are given the possibility to continue their daily activities. When offered a choice between VQ and waiting on traditional hold, approximately half of the customers choose VQ (Merriman, 2006). In addition, additional staff costs can be avoided and call centers experiencing variable peaks of traffic volume would gain more benefits.

VQ is also a common practice at amusement parks. At Disney World, for example, a limited number of customers can obtain a