PASSENGER SLOT ASSIGNMENT FOR AIRPORT'S SECURITY SCREENING

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ABSTRACT
Passenger security screening checkpoints (SSC) keep the area beyond the checkpoint sterile of prohibited items. Despite recent developments in screening device technology has increased the ability to detect these threats; the average amount of time it takes to screen a passenger still remains a concern. Due to the impact of the security screening process on the quality service to passenger and its impact on the scheduled departure time, airports have been analyzing different alternatives to improve the ability of screening devices to detect threats and to speed up the flow of passenger through the airport security screening checkpoint. This paper describes a work in progress proposal to improve the passenger flow experience through the SSC by minimizing the queuing time and in some cases transforming the queuing time into waiting time, without investments on extra airport SSC facilities or staff.

Keywords: security screening, passenger slot assignment, queuing, capacity demand balance

1. INTRODUCTION

The purpose of screening checkpoints is to keep the area beyond the checkpoint sterile of prohibited items and it therefore marks the division between landside and airside. A secured area should only be accessible to those individuals that are "cleared" by means of screening.

Despite recent developments in screening device technology has increased the ability to detect these threats; the average amount of time it takes to screen a passenger still remains a concern. Practical experience warns that the process is drastically affected by the increment on the amount of passengers, with longer queuing periods, increased screening device operational costs, and a large task force of security personnel. Moreover, these effects are magnified as the number of travelers per year increases, along with their impatience and dissatisfaction with ever-changing airport security procedures.

Criteria, guidelines, and standards are provided in the Security Manual of IATA. International standards related to aviation security and passenger screening are contained in the Annex 17—Security: Safeguarding International Civil Aviation against Acts of Unlawful Interference; to the Convention on International Civil Aviation.

2. PROCESS AND PROBLEM DESCRIPTION

The screening process basically consists of two stages, primary screening and secondary screening. Secondary screening of passenger or baggage item will follow if the passenger cannot be cleared in the first stage, if the passenger is identified by risk assessment for increased measurements, or if the passenger is randomly selected as a requirement.

Screening personnel is required to randomly select passengers for additional screening throughout the day, but those random selections may not be concentrated during off-peak hours.

2.1 Description of the screening stages

Before entering the queue to the security screening checkpoint passengers are checked for a valid document/ticket and in some States photo identification is required.

Next, the passenger enters the queue. Posted instructions tell passengers what to do and explain the screening steps.

At some airports transparent sealable plastic bags are provided to passengers, in which all "loose" items the passenger carries with him/her should be placed.

Bins are provided for placement of carry-on baggage, electronic devices (laptop computers, phones, etc.), as well as for shoes, jackets and hats, and the plastic bag. The presence of tables before the screening area improves passenger flow and allows for an easier and quicker divesting of items. The carry-on allowance is usually restricted to two items, whereof each item is restricted in size and weight. The amount each passenger is allowed to carry is limited to one carry-on bag and one personal bag (e.g., purse or briefcase).

All bins are placed onto the conveyor belt of the x-ray machine. Only after placement the passenger will walk through the Walk Through Metal Detector (WTMD). If the passenger sets off the alarm the searcher will ask the passenger if all items were removed. Provided that the flow will not be interrupted the passenger can proceed through the same WTMD again, or use a WTMD offset from the main path.

Otherwise, a second screening with a Hand Held Metal Detector (HHMD) will be necessary. Passengers that need to undergo a second screening should have their belongings removed from the conveyor belt by checkpoint staff and left behind the conveyor belt.

Following the second screening, the passenger may redeem the belongings. The secondary screening consists of "frisking" by a HHMD. If the metal detector keeps on being triggered, a hand search will be necessary. With consent the passenger is hand searched by security staff of the same gender. Refusing a secondary search automatically means that the passenger will be denied access to the airside. The passenger may request that the search is conducted in private starting 2005. Also the pat-down procedure will be changed, besides patting-down the entire back and front of the torso around the abdomen the pat-down search will include the arms and legs.

Carry-on baggage should be hand searched when the content appears suspicious or cannot be readily identified. The time limit for each bag is 5 s. If the bag cannot be cleared within these 5 s, it will be hand searched. If a bag is identified as a potential threat, the conveyor belt should be stopped. This is done to prevent other bags passing the screening without the full attention of the screener. Consent by the passenger should be granted before a manual search, and can only be performed in presence of the passenger. Hand searches should be complemented with Explosives Trace Detector (ETD) inspection. Likewise, continuous random checks by ETD of cleared bags should be performed at each screening station. If restricted or prohibited items are found they should be identified and confiscated. Once passengers and carry-on baggage are cleared, they may enter the sterile area.

Despite existing several configurations for the distribution of the screening facilities (concourse, holding area, and boarding gate), the most extended layout of the security screening checkpoint (SSC) is a central location within the terminal's perimeter, prior to a concourse, and thereby being able to serve various gates (IATA 2005).

2.2 Problem description

Due to the impact of the security screening process on the quality service to passenger, managing and maintenance costs and the impact on the scheduled departure time, airports have been analyzing different alternatives to improve both:

- The ability of new screening device to detect threats
- The flow of passenger through the airport security screening checkpoint.

This paper describes a proposal to improve the passenger flow experience through the SSC by minimizing the queuing time and in some cases transforming the queuing time into waiting time, without investments on extra airport screening capacity.

3. STATE OF THE ART

There are several papers published in the literature that could be considered with some relationship with the slot screening assignment process, such as papers tackling better queue management in the airport, delay analysis generated in the flow of passengers through the screening processes, virtual queues, capacity/demand algorithms and pricing algorithms among others.

However it has not yet been reported a work with the scope of the present proposal in the slot screening assignment to avoid idleness and capacity deficit of screening resources in the airport side, and a service to change queuing by waiting in the passenger side. Thus, in this section, instead of a deep analysis of scientific publications related to the mentioned area, it will be presented tree prototypes and innovative approaches which somehow have some similarities with the new slot assignment approach proposed.

3.1 SecurXpress at Montreal's Airport

SecurXpress, is the brand new mobile solution for *Aéroports de Montréal*. The mobile solution consists of a text messaging service (SMS) to ensure travelers receive priority treatment at security screening checkpoint "A" at the Montreal airport. Available to passengers departing on domestic and international (except U.S.-bound) flights, SecurXpress sends a text message to their mobile device indicating the specific time they must show up at checkpoint "A." The service, offered in both French and English, is the first of its kind in Canada.

The new service means that passengers can now reserve, free of charge, a priority time for going through security. To confirm the time, passengers reply with a text message. The reservation is valid for a maximum of 5 people. The travelers must then show up at the appointed time at a checkpoint in the SecurXpress line.

To sign up for SecurXpress or SMS alerts, passengers only have to fill out a form on the *Aéroports de Montréal* website, up to 24 hours before their flight.

Time window intervals have been established to ensure that the passenger won't have to wait very long for his flight, but will have plenty of time to get to the boarding gate. The first person to reserve priority passage is assigned the priority-passage slot closest to the flight departure time; the second is assigned a slot 5 minutes earlier, and so on.

The system has been designed to accommodate groups of no more than 5 people. If there are more than 5 people in a group, different passage time reservations (each for maximum 5 people) will have to be made using different mobile phone numbers.

Passengers that arrive earlier to the airport than the slot time assigned are allowed to go through the general screening facilities. On the other way around, in case the passenger miss his slot, and there are not extra slots available, the passenger will have to line up in the non-priority corridors and be subject to the normal wait times.

SecurXpress service is a simple way that tries to avoid lineups at the security screening checkpoints during peak periods. Passage times are spread out for priority users in a dedicated checkpoint corridor, preventing unnecessarily long waiting times. The service sends an SMS with a reminder alert 15 minutes before the scheduled passage time. The access to the SecurXpress checkpoint corridor is managed by the passage-time confirmation message displayed in the mobile phone.

This innovative solution was entirely designed and developed in-house at TC Media. This new mobile solution joins the other services already offered by TC Media to *Aéroports de Montréal*, such as the SMS service for flight status updates which is also hosted and maintained by TC Media. For the past several years, passengers have been able to receive real-time updates and alerts via text message (SMS) on their cell phones for flight schedule changes of over 10 minutes. Thus, when a flight is delayed or cancelled, passengers subscribed to the service receive an alert.

3.2 Virtual queuing at airport security lanes (De Lange 2013)

A virtual queue (VQ) 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 passengers would know exactly how long they have to wait, they could choose to occupy themselves by shopping or dining. The parameters of a security lane operation for a queuing analysis are: the passenger service rate, the number of available security lanes, and the passenger arrival rate. The passenger service rate and the number of available security lanes are straightforward. However, verifying the passenger arrival rate is more difficult.

In order to incorporate the VQ principles it is necessary to acknowledge several additional parameters. In Narens 2004, it is showed that for simulating a virtual queue it is necessary to determine a VQ protocol: it is necessary to define who the eligible passengers are and how and when these passengers can arrive at the security checkpoint without waiting in the general line.

It is worthwhile to note that the VQ process does not require a separate security lane (see Figure 1); instead some barriers and enabler accessing mechanisms could be deployed to allow passengers in the VQ to have a straight access to the screening service.

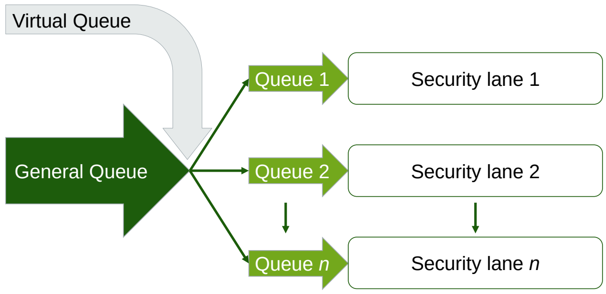

Figure 1. Coexistence of the VQ with the classical security lane queues

In Figure 1 the virtual queue and the general queue are joined together at the point where the passengers are spread across the smaller queues for the security lanes. At this point, passengers in the virtual queue receive priority over passengers in the general queue to proceed to a security lane, similar to how business class travelers receive priority at check-in over the economy passengers.

In this scenario the concept of VQ allocates Time windows (TWs) to passengers. A TW could be interpreted as a time interval during which passengers are allowed to bypass the general queue. The TWs could be provided in a ticket format at the check-in desks. If the passenger decides to come outside the TW, he or she would not be admitted to the priority queue.

Only those passengers who are eligible would receive a TW, which is determined by the passenger arrival time at the checking lanes (Narens 2004), from where it is assumed that they would directly head to the security lanes if no TW is offered. A passenger thus needs to arrive at the check-in lanes just prior to or during a peak interval.

When the number of security lanes is decreased, the average passenger waiting time in general increases. However, by applying the principles of virtual queuing (VQ) this effect could be limited to acceptable levels. In many occasions the average waiting time could even be reduced. The success of VQ depends on the reliability of the forecast model, the passenger arrival pattern, and the number of eligible participating passengers and the length of the time windows (TWs).

3.3 Fast track security lane or express security lane

This service provides passengers with the ability to avoid waiting in the standard queue to the security area that can be developed at peak times. Passengers holding a certain airline ticket type have granted access to this service. Additionally, the Fast Track Lane service can be pre-booked online and inside the airport facilities (i.e. electronic kiosk) several days before the travel date or even 4 hours ahead of departure.

This premium pre-book service provides all departing passengers with swift access to the airport's security area. All passengers departing are subject to the same rigorous security checks regardless of using the Fast Lane or the standard queue lane. The same criteria in relation to prohibited items i.e. limited quantities of liquids and restrictions on sharps still apply.

Having purchased a pre-book ticket for each person travelling, passengers should make their way to the security area. On entry to the security area the passenger will be required to provide the booking reference number or confirmation email and boarding card to the security staff.

If the passenger has made a booking for more than one person then the people on that booking must use the Fast Track lane together. If passengers travelling together want to use Fast Track at different times each one then they need to book the Fast Track on an individual basis. The booking for this service is non-transferable.

The Fast track ticket is valid only on the day of travel between the times specified within the booking. The passengers will not receive a refund if they do not use the Fast Track facility. Passengers must allow sufficient time to arrive at their departure gate at the published boarding time as stated by their airline.

4. SOLUTION APPROACH

The main idea behind the solution approach proposed in this paper is to deal with the queuing time by means of a proper balance between screening airport capacity and passenger demand under a time stamp constraint.

So, instead of acquiring more screening infrastructure, the approach will consist in a better management of the actual screening facilities by lessen the peak demands through a reward mechanism that will allow to avoid idle capacities.

A new paradigm of balancing screening capacity with passenger queuing time will be described for different operational contexts considering:

- A stochastic model for passenger preferences: each type of customer arrives according to a different general distribution
- Scaling the airport capacity considering the demand
- Queue dynamics of the passengers as they proceed through the security checkpoint
- Screening performance: provide a reward mechanism that improves the predictability of the screening service time

As a result it is expected to provide an optimal strategy to smooth the peak congestion of passenger queuing for the screening checkpoint while minimizing also the idle capacity (and in consequence the operational costs).

The key contribution of the screening slot assignment should be the efficient and effective use of available screening resources.

The goal is to revamp the flow of passengers through the screening system paradigm to provide a solution that balances the trade-off between maximizing security and minimizing the expected amount of time it takes to screen passengers and baggage through security checkpoints. In Marin 2007, queue theory is used to address the effect of queue length on service rates, and its consequences on the security screening process.

The allocation of passengers to a queuing system with multiple servers (screening facilities) to minimize the number of passenger in the queue or the amount of time the passenger spends in the queue, has been studied extensively in literature, through either static flow models (Jain 2005, Winston 1977, Filipiak 1984) or dynamic flow models (Kumar 1985, Lin 1984, Kelly 1983, Meyn 2001). However, these models lacks of a trade-off approach to maximize some form of reward.

The problem of assigning passengers to a specific time window (i.e. Slot) is performed under a static passenger assignment policy in which the time window is assigned independent of the queue behavior of prior passenger assignments and requires the proper modeling of the following aspects:

4.1 Passenger arrival Process: Peak smooth policies

The demand for screening capacity fluctuates according to the programmed amount of flights for the immediate future departure flights, the passenger arrival pattern, and its behavior during the screening process.

Assuming the performance of security staff is quite constant (fatigue is not considered), the demand fluctuation can be modeled by a deterministic aspect which corresponds to the programmed flights, and a random behavior which corresponds to the occupancy of the aircraft and the other 2 factors already mentioned (arrival pattern and behavior).

This fluctuating demand leads to idle capacity during the time periods between the peaks and to the generation of queues during the peak periods as sometimes the arrival of passengers exceeds the screening capacity. In Figure 2 it can be seen the idle capacity of screening resources (screening capacity above the demand) and the queue generation when demand is above capacity. In order to balance the capacity with the demand, one solution could be to shift the arriving passengers at the security lanes out of the peak periods to idle capacity between the peak periods.

Figure 2: Unbalanced screening Capacity/Demand

The most obvious solution for this would be to develop a reward mechanism that would compensate the effort of earliness or the risk of tardiness in the preferences of the arrival process of passengers.

The reward mechanism to be designed will be based on a win-to-win approach in which the airport will save money by avoiding idle screening resource periods and the passenger will benefit by avoiding the queuing times.

4.2 Time window range
One of the critical aspects in implementing a slot assignment policy for security screening is the right discretization of continuous time in constant or variable time intervals. Long time interval discretization has the advantage of performing more passenger assignments to the same interval, in such a way that the probability of a non-shown passenger is reduced, however it can generate unbalanced situations inside the time window period.

On the other hand, a time discretization on too short time periods can contribute to a uniform distribution of the arrival process but it can generate also several inefficiencies due to non-shown passengers.

Thus, an algorithm to determine the evaluation of a fixed or a variable time window period should be designed and validated.

4.3 Time window assignment policy
There are several factors that affect passenger pattern behavior regarding the earliness time period to get to the screening security checkpoint before the flight departure.

Among these factors, it should be considered from one side the reliability of the public transport systems that connect the hinterland with the airport, the frequency and diversity of transport means and the facilities for private transport, which somehow could be quantified in a deterministic model.

However there are some other factors which should be described from a stochastic approach due to the inherent uncertainty of the process, such as the user preferences about to be in the safe side by arriving with extra time before the departure to avoid potential queues, or frequent flyer behavior which tends to arrive with very short clearance gap.

When assigning a TW to a passenger it could lead to a situation in which extra earliness time has been assigned to a frequent flyer while a very short clearance gap could be assigned to a passenger with a safe side preference. To avoid this kind of penalties that will affect the reward mechanism, a methodology that could match passenger preferences with available capacity must be in place.

In order to provide a good quality on the TW assignment for those passengers that looks for a short clearance gap, it is important to have a better prediction of the screening process time of precedent passengers.

There is some empirical evidence that frequent fliers with short clearance gaps use to cross the security screening area with minimum time compared to tourists which have a considerable extra time before the departure time.

A mechanism to determine the potential sample of passengers that could use the slot security screening service should be properly designed according to legal regulations. Thus, for example, a potential idea to be explored could rely with an airport and/or airline Data Base in which it keeps record of the alarms fired during the lasts flights by each particular candidate. Thus, every time a passenger fires an alarm in the Rx machine because he forgot to remove liquids or computer elements from the hand baggage or it fires an alarm in the metal arc detector, it will be recorded (using the boarding pass or any other IT identification mechanism) in the airport database and/or in the airline database and it will be excluded from the candidate list for the slot security screening service during a certain amount of consecutive flights without firing any alarm.

The TW assignment model should also consider that by improving the screening process time towards a deterministic and predictable model, passenger behavior will be affected by a better confidence on the performance of the screening security checkpoint which probably will contribute to shorter clearance gaps. Thus, the algorithm should consider the changes of arrival pattern behavior due to a better confidence on the screening processes.

Finally, the slot assignment algorithm should consider some equity and fairness criteria to avoid extra earliness penalization to some passengers which flight departure is concentrated in peak periods.

Thus, the design and implementation of the TW assignment algorithm should consider not only the scheduled flights but also some reward mechanism to preserve equity and fairness criteria.

4.4 Screening dynamic reconfiguration
To avoid the idle capacity or the capacity deficit illustrated in Figure 2 the slot assignment service should consider new efficient mechanisms and layout redesign to allow the use of screening resources by the normal passengers when there are non-shown passengers in the slot assignment services, and also to allow the use of screening resources assigned to the general queue by slot assigned passengers to preserve zero queuing time in the slot service.

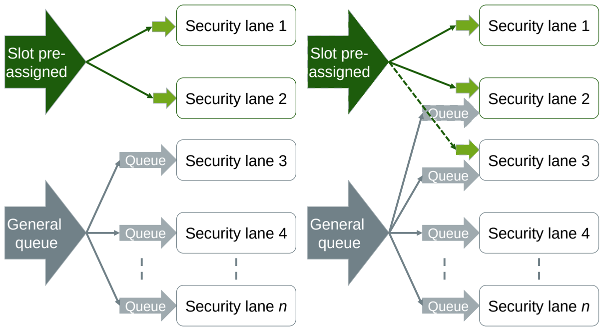

Figure 3: Priority policies for screening checkpoints

Left hand side picture (in figure 3) illustrates a rigid system in which screening facilities are distributed between slot assignment service and general passengers.

This approach is known to generate idle and deficit capacities. At the right hand side it is represented the same architecture but with some policies that allows the dynamic assignment of screening resources according to slot arrival passengers.

It should be said that the implementation of such a dynamic policy would require extra human resources to constantly re-assign resources to slot requirements in order to avoid idleness or deficit capacities.

In Figure 4, it has been represented a different approach based on a layout redesign in which passengers with a slot assigned can access any screening facility. This approach provides a natural capacity/demand mechanism in which the quality of service for slot passengers can be supported.

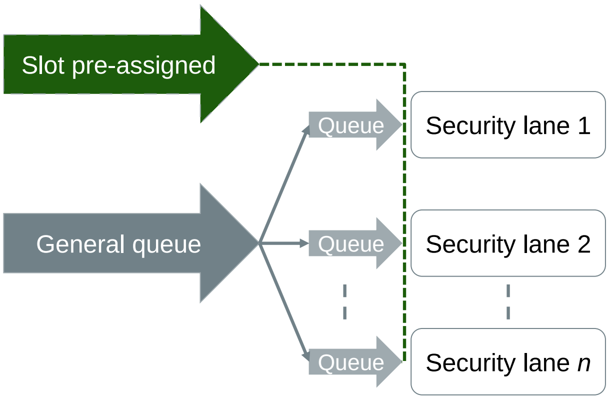

Figure 4: Layout redesign

The implementation of the slot assignment service will require an analysis work to determine both the technologies and the layout re-design that will allow a flexible and efficient assignation of screening resources.

5. DISCUSSION AND FUTHER WORK

This paper describes a work in process concept towards a better balanced demand capacity in security screening process in the context of the European FP7 funded project, INTERACTION.

This solution solves different inefficiencies and points for improvement detected for the Turnaround process. The main ones solved are the need to shorten and better manage the queues at the security control and the inability to locate passengers after their way through check-in counter (if traditional check-in is done).

The solution proposed will help better manage not only the queues at security screening but also the resources being used as one of the aims of the algorithms will be to distribute the demand on the overall capacity (as much as possible).

The assignment of slots to the passengers introduces additional steps to the passenger process, such as the request and reception of the security slot, which makes the passenger process more complex. This negatively impacts the passenger buy-in. But on the other hand, the passenger can have more control over the process as it will be able to better manage its time, which positively impacts the passenger buy-in.

Modeling of demand is critical to the development of this solution. The demand modeling may be done particularly for each airport wanting to implement this solution.

The passenger preferences may depend on different aspects such as cultural characteristics, type of travel, and ground access to the airport, among others. In order to have a realistic prediction of the demand, real data related to each airport and its main users must be carried out. Not only the airport accessibility and its passengers must be studied but the layout and characteristics of the airport itself, which may also influence passenger behavior and preferences.

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