A DEMAND SHIFTING ALGORITHM TO SMOOTH THE PEAKS AT AIRPORT SECURITY SCREENING CHECKPOINT (SSC) FACILITIES

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ABSTRACT
Airports are considered complex systems since they must coordinate the right availability of resources with an unknown demand in a context with poor predictability and fierce competition. This paper illustrates a solution to improve the passenger flow experience through the Security Screening Checkpoint (SSC) by minimizing the queuing time and, in some cases, transforming the queuing time into waiting time, without requiring investments in additional airport screening infrastructure. The main idea is to minimize the passenger queuing time at the SSC by means of a right balance between screening airport capacity and passenger demand under a time stamp constraint, applied in the form of passenger slot assignment. Demand Shifting Algorithms (DSA) is one of the key approaches that could minimize queues in the screening area while also avoiding idleness capacities, thus providing a cost-saving screening service to the airport and a good quality service to passengers.

Keywords: workstation design, work measurement, ergonomics, decision support system

1. INTRODUCTION

Despite recent developments in screening technology and the increased ability to detect threats, the average amount of time required to screen a passenger still remains a concern.

It is well accepted that an increment in the amount of passengers at the SSC entails drastically-longer queuing times, increased screening device operational costs, and a larger task-force of security personnel. Moreover, these effects are magnified as the number of travelers increase each year, along with their impatience and dissatisfaction with the ever-changing airport security procedures.

Due to the impact on the quality service to passengers, the managing and maintenance costs and the impact on the scheduled departure time, airports have analyzed different alternatives to improve:

- The ability of new screening devices to detect threats
- The flow of passengers through the airport security screening checkpoint

The objective of the simulation model implemented is 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 the need for investing in extra airport screening infrastructure.

Several papers have been published which could be considered to be related with the slot-screening assignment process. However, no work has yet been reported with the scope of the present proposal as regards the slot screening assignment, aimed at avoiding idleness and capacity deficit of screening resources on the airport side, and providing a service to change queuing into waiting on the passenger side.

Our previous work (Nosedal 2014) included a description of tree functional prototypes based on innovative approaches in some ways similar to the new slot-assignment approach proposed. These solutions have been implemented in some airports and represent the current state of the art.

Intelligent Transport Systems (ITS) try to avoid extra investments in infrastructures while satisfying extra demands through the enhanced management of the current resources and information technologies (Piera 2014).

The decision-support tool implemented fits ITS philosophy: it reduces passenger 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 of better management of the current screening facilities by smoothing the peak demands through a reward mechanism that allows idle capacities to be avoided.

A new paradigm of balancing screening capacity with passenger queuing time will be described, aimed at a range of different operational contexts, and taking into account:

- A stochastic model for passenger preferences: different arrival probability distributions will be considered according to different passenger profiles

- Scaling the airport capacity taking into account the demand

The intended result is to provide an optimal strategy to smooth the peak congestion of passenger queuing at the screening checkpoint while also minimizing idle capacity (and in consequence, operational costs).

The key contribution of screening slot assignment is the efficient and effective use of available screening resources and a significant time reduction for passengers at the airport.

The proposed new paradigm for the screening slot assignment does not take the following areas into account:

- There is a consensus that using multiple levels of screening can result in a significantly more efficient security system. Thus there are some works on the assignation of passengers to different screening lanes that include a classification of passengers into different security classes. In (McLay 2009, Lee 2009, Nikolaev 2007) different discrete optimization models are described in which passenger classification is performed when perceived risk levels of passengers are known only upon check-in.

- Methods for structuring the optimal use of detection device technologies in security checkpoint screening, given specified cost and capacity constraints. In (Feng 2009, McLay 2007) several methods have been proposed: New Rx or ADM technologies.

2. PROBLEM DESCRIPTION

The demand for screening capacity fluctuates according to the programmed amount of flights departing in the immediate future, the passenger arrival pattern, and behavior during the screening process (Figure 1 and Figure 2).

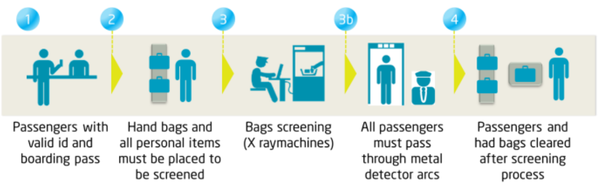

Figure 1. Passenger screening process

As well, after arriving at the airport but before the screening process, passengers experience queuing, particularly during peaks of demand.

During this phase passengers are “trapped” in the system without a chance to employ their time. This situation is concerning and has direct impact on passenger quality perception (Figure 2).

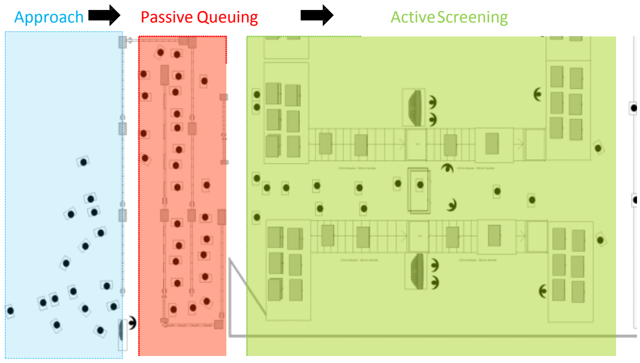

Figure 2: Queuing before security screening

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 stochastic aspect concerning the passenger arrival pattern, which is sometimes correlated with flight characteristics.

In Figure 3, the random aspects of passenger arrival preferences are illustrated by means of empirical Cumulative Arrival Curves.

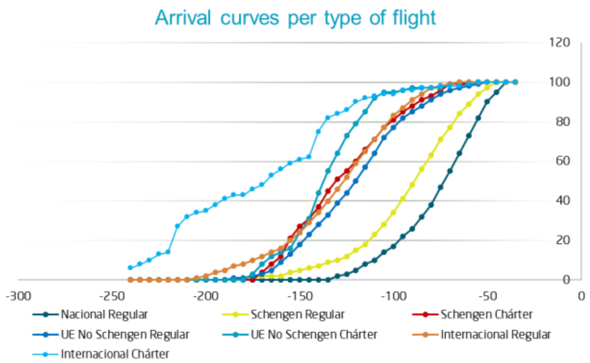

Figure 3: Empirical cumulative passenger arrival curves per type of flight

From this figure, it is possible to estimate the expected amount of passengers that will arrive, for a specific value or interval of arrival earliness.

Once passengers are in the terminal, there is also a random dwell time until they move to the SSC which depends on the type of check-in (Figure 4).

The stochastic model implemented considers different rates for each option correlated with certain relevant flight information such as the destination, departure time and flight occupancy.

Thus, an early flight with a business capital as destination (i.e. Brussels) will tend to show a higher rate of online check-in passengers than a flight to a tourist destination.

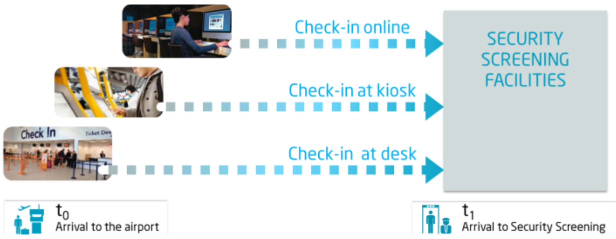

Figure 4. Passenger characterization

The combination of the different arrival pattern behaviors and type of check-in, produces a fluctuating demand that leads to idle capacity (Figure 5) during certain time period peaks and to the generation of queues during the peak periods (Figure 6), since sometimes the arrival of passengers exceeds the screening capacity.

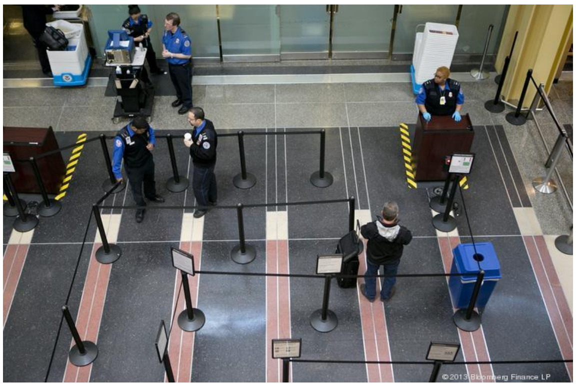

Figure 5: SSC Idle capacity periods between peaks of demand

Figure 6: Passenger queuing during peaks of demand at SSC

The problem of assigning passengers to a specific time window (*i.e.* Slot) to cross the SSC without queuing requires the proper modeling of the slot availability (Figure 7) which is dependent on prior passenger behaviors.

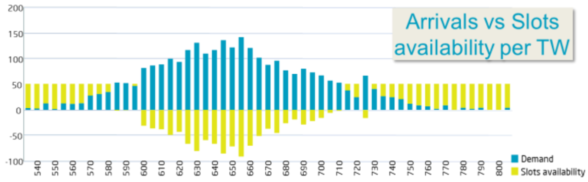

Figure 7. Demand vs capacity at SSC

The availability of slots is computed by means of the capacity (i.e. maximum workload possible in a time frame) and the total demand expected for each time window. The dark-colored bars represent the expected demand (always positive), while the light-colored bars show the availability. Thus, the light bars in the negative area represent the capacity shortages to be avoided by allocating passenger to the idle periods (i.e. light-colored bars in the positive area).

3. INPUT DATA AND THE ALGORITHM

The data inputs required for the causal simulation model implemented are summarized in Figure 8.

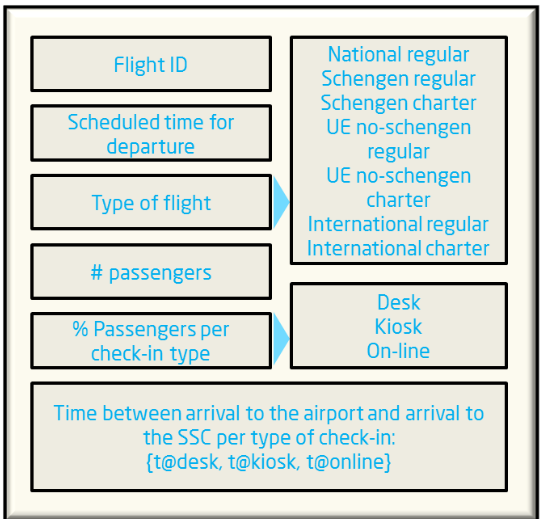

Figure 8: Data inputs to the algorithm

The input data are pre-processed according to the steps indicated in Figure 9.

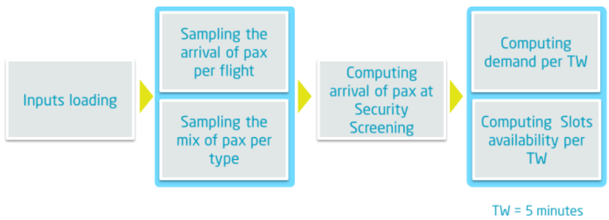

Figure 9: Data pre-processing steps

The outputs of the pre-processing allow the identification of demand peaks and compute the availability of Time Windows in the whole timeframe of the study (i.e. 3 hours or a complete day).

Based on these results the redistribution of the demand can be addressed. Thus, the outputs obtained after the pre-processing of the data allow the parameterization of the model. These outputs are summarized and illustrated in Figure 10.

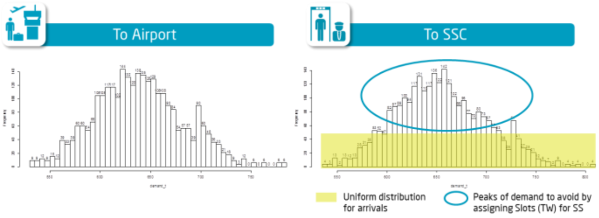

Figure 10: Outputs after the pre processing

On the left is the expected distribution of arrivals at the airport, and on the right, the corresponding demand at the SSC, with the peak to be redistributed being indicated by the ring, and the rectangular shaded area representing the desired demand distribution (i.e. uniform during the time frame and defined by the maximum workload allowed).

In order to measure the quality of the solution being developed, two indicators have been defined, both seeking to evaluate the impact of the solution on the quality service factor to the passenger.

By defining the passenger preference and adjusted earliness as:

Pax preference = time stamp for arrival at the SSC (pax arrives in a preferred slot)

Adjusted Earliness (AE) = (Scheduled Time for Departure – Slot proposed), that must be always bigger than 30 min

Two different KPIs have been designed:

Earliness = Scheduled Time for Departure – Slot preferred, that must be always bigger than 30 min

Pax preference deviation (PPD) = Slot proposed – Slot preferred

The passenger slot assignation has the form of a generic scheduled problem, and thus it can be formalized as a Constraint Satisfaction Problem, the structure relating the feasible Time Windows (i.e. slots) to the restrictions to balance the demand is illustrated as a matrix in the Figure 11.

Pax	TW1	TW2	TW3	...	TWn	Restrictions
P1	F(PPD, STD) @ P1					Sum =1
P2		F(PPD, STD) @ P2				Sum =1
P3						Sum =1
. . .						Sum =1
Pm	F(PPD, STD) @ Pm					Sum =1
Restrictions	Sum < = L	Sum < = L	Sum < = L		Sum < = L	

Where
L = maximum Load or demand allowed per TW
PPD = Pax preference deviation
STD = Flight scheduled time for departure

Figure 11: DSA in the Constraint Satisfaction Problem structure

The set of capacity constraints (*i.e.* work load defined as L) must be satisfied for all the time windows (columns 1 to n in the matrix) and the set of allocations must be restricted to one per passenger (*i.e.* the restrictions in the last column of the matrix).

Note also that the allocation is computed in the interval restricted by the Scheduled Time of Departure (STD) and the passenger preferences (PPD).

4. CASE STUDY AND RESULTS

Reward mechanisms to engage passengers in the use of slots to cross the SSC are highly dependent on the airport layout. Thus, centralized SSC layouts are usually placed before the commercial area of the airport, while in de-centralized layouts the commercial area is placed before the SSC.

The algorithm developed can be applied to centralized SSC layouts (Figure 12) or de-centralized SSC layouts (Figure 13).

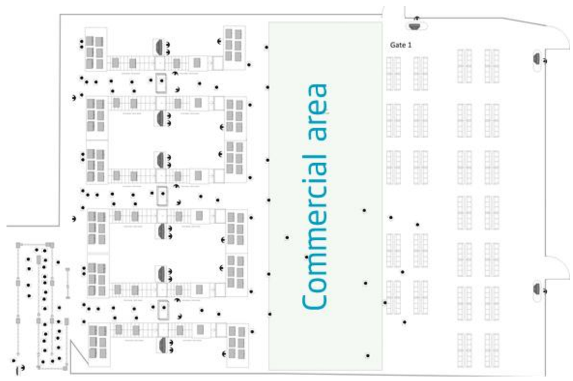

Figure 12: Centralized SSC facilities layout

Figure 13: Decentralized SSC facilities layout

To avoid idle capacity or capacity deficit, as illustrated in Figure 5 and Figure 6, the slot assignment service should consider new efficient mechanisms and layout redesign to allow the use of screening resources by normal passengers when there are no-show 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.

In Figure 14 a different approach has been represented based on a layout redesign (Buil 2011) 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.

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.

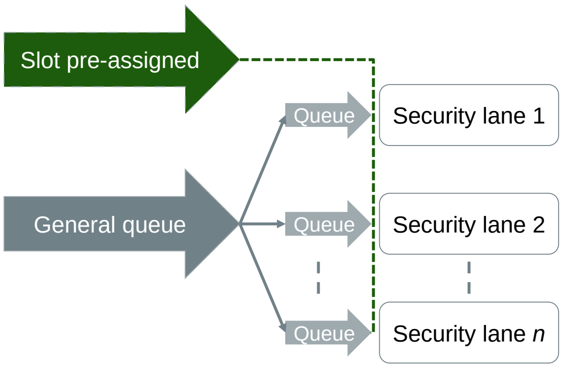

Figure 14: Layout redesign

In order to test the quality of the DSA results, it has been used a realistic scenario provided by AEGEAN airlines.

The scenario was tested assuming in the first case a Centralized layout. The scenario and results are summarized in Figure 15, in which it can be observed that the peak of 330 pax/TW has been reduced to 228 pax/TW.

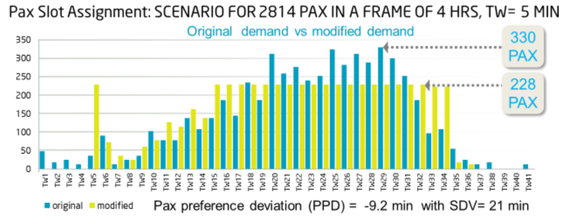

Figure 15: Original demand vs modified demand after passenger slot assignment (centralized)

The second analysis was performed assuming a decentralized layout. Figure 16 presents the expected arrival pattern at SSC.

As can be observed, the scenario can be separated into 4 time frames, as indicated in the figure.

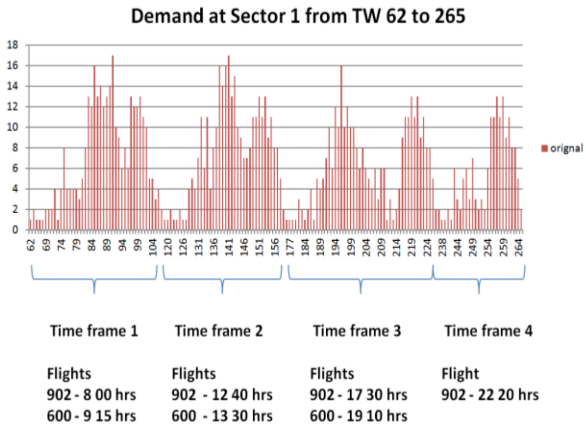

Figure 16: Original demand before slot assignment (decentralized)

For time frame 1, the original demand vs. the modified demand is illustrated in Figure 17.

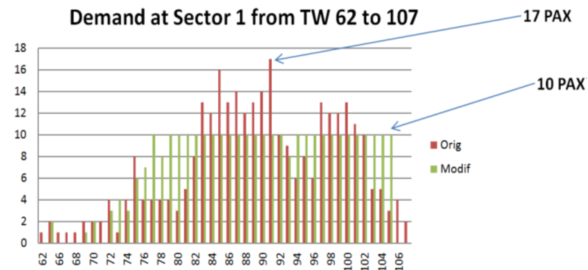

Figure 17: Solution obtained for time frame 1

After the slot assignment, the maximum workload is reduced by 41 %, (from 17 to 10 pax in the busiest TW) meaning that the workload is better balanced, uniformly distributed across almost the entire time frame 1 (light color bars).

In terms of KPIs, the solution obtained for time frame 1 addresses the demand peak redistribution with an average PPD of -0.25 min and standard deviation of 24.4 minutes, with the minimal earliness being granted in all cases.

For the full scenario (Figure 16), the proposed allocation of TW (i.e. Slots) provides a solution to decrease the idle periods by redistributing the passenger arrival. The peaks of demand are reduced between 30 and 40 %.

The overall comparison of original vs. modified demand is presented in Figure 18.

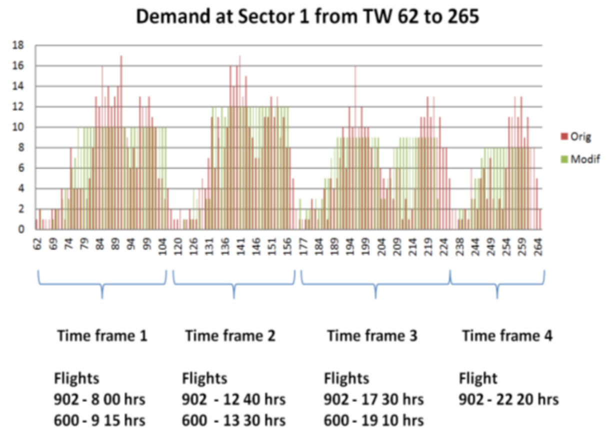

Figure 18: Original and modified demand pattern for the complete time frame (decentralized)

5. CONCLUSIONS

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

The algorithm developed relies on a socio-technological modeling approach (Nosedal 2014) to influence human behavior under a win-to-win approach in which:

- Passengers can have more control over the process as they will be able to better manage their time, which positively impacts the passenger buy-in
- The airport will avoid non-added-value operations such as idle resources at the security screening check-point
- The airline will be able to have better control of the location of their passengers in different time-lines

Passenger preferences may depend on different aspects such as cultural characteristics, type of travel, and ground access to the airport, among others.

The model developed must be properly parameterized to the boundary conditions of each airport. Thus field work is required in order to have a realistic prediction of the demand, together with a sample of passenger profiles.

The present socio-technical modeling approach, relying mainly on influence variables, can be extended with a system engineering approach in which control variables would allow fine-tuning of the times passengers wait at the kiosk or check-in counter.

It is expected that the right combination of control variables and influence variables could provide a new gap to integrate passengers in the expected time-stamp flow of activities considering available resource capacity.

Reward mechanisms are essential to engage passengers with the slot assignment:

- Priority boarding
- Free wi-fi
- Airlines' reward cards (extra miles)...

These reward mechanisms are independent of the layout of the airport (*i.e.* centralized or decentralized SSC). However, particular reward mechanisms should be properly designed by taking into account the facilities in the terminal.

5.1. Potential impacts and benefits

The proposed solution impacts mainly the passenger, airport, airline and the third party responsible for the airport security screening process.

The assignment of slots at security screening control will help better manage the security control resources as the peak congestions will be smoothed and the idle capacity decreased. This will increase the availability of security control resources and the management of passengers flow at the security control which will reduce the delays due to security control.

A reduction of the delays due to security control will increase turnaround punctuality (*i.e.* avoiding delays because of late passengers at gates). As well, the assignment of slots to pass through security screening will let airports (or the third party responsible for the security process) better manage the security resources, by smoothing the congestion peaks and reducing idle capacity. This improved management of resources will imply a reduction of the number of resources needed (including personnel), and thus could allow a reduction of personnel at the security point, meaning a reduction in the operating costs.

However, the current state of definition of the solution does not permit a solid cost benefit analysis. The areas directly impacted by the solution are Airport Terminal Operation and the particular stakeholder being mainly benefited from the implementation of this solution will depend mainly on the implementation itself. Different stakeholders may be able to implement the solution and accept the responsibility for it.

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AUTHOR BIOGRAPHIES

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