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Simulation of new policies for the baggage check in the security gates of the airports: the Logiscan case study

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Abstract

In recent years, the trend to mix in the same airports legacy and low-cost companies is heavily affecting the airport operations, stressing the security checks in particular. In fact, low-cost companies force the airports to add additional and strict rules for the hand baggage allowance, with additional checks in the security gates, introducing delays for all the passengers, including the legacy ones. Moreover, recent changes to the rules for hand luggage allowance introduced by legacy airlines are forcing the airport operations management to think of new strategies to automate the entire security check process.
One of the most advanced systems presently available to speed up the security operations is Logiscan, developed by Datalogic e Logital in collaboration with the "Aeroporto Guglielmo Marconi di Bologna S.p.A.", the company managing the Bologna Airport. The system automates the operations of size and weight measures and allowance checks and, in conjunction with a redesign of the queuing system, aims to improve the overall system efficiency in terms of accuracy and efficiency.
In order to check the new overall system, the entire process has been modeled and analyzed by means of AirSIM, a simulation tool for airport operations based on the well-known OMNeT++ Discrete Event Simulator. AirSIM is an object-oriented simulator able to describe the behavior of different passenger types, as well as to incorporate the logic of different flow management policies. In this paper we will show both how AirSIM can be used to analyze and choose the different parameters of the new security system of an airport, and how the overall system performances can be enhanced.

Keywords: Airport operations; simulation.

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Thus, it happens that the hand baggage of a passenger is rejected at the departure gate and the passenger must exit from the departure area, go back to the extra-pay desk and pass the security check a second time.

As mentioned before, Logiscan will automate the process of the boarding pass and the hand baggage checks. In this way the airlines can avoid the second check, speeding up the entire boarding process. The system after the introduction of Logiscan in represented in Figure 1(b). There is one Logiscan in line with every security gate. The security member is not necessary anymore, being the boarding pass check done directly by Logiscan. After the Tendiflex queue the passenger will approach the first Logiscan available (there is no buffer between Tendiflex and Logiscan). He puts his hand baggage in Logiscan with the boarding pass. If the boarding pass is valid and the hand baggage allowance rules of the specific airline are met, Logiscan gate opens, letting the passenger to approach the security gate. Otherwise, the baggage is rejected and he proceeds to a kiosk for paying the extra baggage. When the passenger is back, he can skip the Tendiflex by using an automatic gate. This gate is also used by the priority and the family passengers (their class is recognized by an automatic boarding pass reader).

3. AirSIM and the simulation model

AirSIM is a discrete event simulation environment specifically designed to reproduce airport operations. AirSIM is a joint project between the Operations Research and Optimization (ORO) group the Politecnico di Torino and BDS s.r.l., a consultancy company leader in the airport management sector. The aim of AirSIM is to identify and describe the interactions between the main actors in an airport (passengers, airlines crew, security devices, check-in desks, etc.) and model the basic operations. AirSIM is based on the OMNeT ++ simulation engine (OMNeT++ Consortium, 2012). Several simulation engines are available as commercial or academic products. The majority of the general purpose engines, as Arena, even presenting a large spectrum of applications and a user-friendly user interface, lacks of interoperability with other products, in particular from the point of view of the external code integration. On the other hand, software library engines have a larger flexibility, but require computer science skills. OMNeT++ is an academic project, which merges the possibility to access the simulation at the software library level with a user interface based on Eclipse. Moreover, differently from other academic projects, it has a large community worldwide developing additional modules, a commercial support, and interoperability with commercial and open source statistical packages, including SPSS, R and Octave. The core of AirSIM is a library specializing the simulation blocks, including passengers, different types of queues, check-in desks, and flow routers (implementation of different passengers' routing policies, security gates, and boarding gates). The library is fully integrated in the OMNeT++ interface in order to let a user with limited computer skills to model his system. Moreover, it integrates a series of statistical analysis tools specifically designed for the airport sector, and the Italian regulations in particular (Enac, 2002; 2009). AirSIM is integrated with other tools, including generic optimization software as Cplex Gurobi, and Xpress, as well as specific optimization software as AirCast, the DSS for passenger flows developed by ORO (Benedetti et al., 2012; Perboli et al., 2011). AirSIM, exploiting the modularity of OMNET++, defines a series of pre-built modules which describe the behavior of different actors of an airport (passengers, security staff, etc.), as well as specific machines and features (security gates, check-in, POS payments, manual and automatic baggage allowance, boarding gates, etc.), letting the user to easily define his specific case study. Moreover, a series of empirical distributions for different operations in an airport, derived from real data surveyed by BDS s.r.l., are integrated.

In the following paragraphs a description of the simulation model of the security system of the Bologna Airport is presented. The simulation considers the following basic blocks (see Figure 1):

- *Passengers*. They are the users of the system and they are characterized by passenger type, number of users to generate, distribution of arrival, time of the first passenger arrival. The passenger type is used by the other blocks to characterize some parameters, including their service times.

- *Security line*. In the case of the system in use, it is made by a capacitated queue connected to the security gate, while in the system with Logiscan it is made by one Logiscan machine, the capacitated queue and the security gate. The security line has a logic which automatically sends a message to the Tendiflex queue or to the automatic access gate queue in order to ask a new passenger. By default, the security line gives priority to the automatic access gate.
- *Tendiflex queue*. It is a queue without capacity characterized by a passenger management policy. The queue is passive, i.e., a passenger can leave the queue if and only if there is at least a security line after the queue and one of the security gates is empty or it completed the security checks. The policies can be passenger type dependent of global. The main policies are implemented, including:
  - Stochastic interaction with the security gates. The next security gate is randomly chosen by the user between the gates which have a residual capacity in their queue.
  - Proportional stochastic interaction with the security gates. The next security gate is randomly chosen by the user between the gates with non-zero residual capacity in their queue according to a probability which is proportional to their residual capacity.
  - Best allocation. The security gate chosen by the passenger is the one with the highest residual capacity
  - Priority passengers. Some types of passengers are redirected towards specific reserved security gates.
- *Boarding pass check*. This module is present only in the system without Logiscan. It is a server with a service time which is equal for all the passenger types.
- *Extra-bag payment*. This module models the payment of an extra-bag due to the rejection by Logiscan. The system is a multi-server with infinite capacity and service time independent on the passenger type.
- *Automatic access gate*. It is the gate used by specific passenger types (family and priority) and the passengers coming from the extra-bag payment. The gate is a passive queue waiting a signal from one of the security lines to send out another passenger.
- *Logiscan*. It is modeled as a server with one service time distribution for each passenger type. When it finishes in managing a passenger, and if there is room in the queue between Logiscan and the security gate, it enables the signal to the Tendiflex or the automatic gate queues in order to send out an additional passenger. Moreover, it has an hand baggage rejection probability which is passenger type dependent.
- *Security queue*. It is a passive queue introducing a delay on the passenger operations due to the process of preparing the different items for the security checks (e.g. open the hand-baggage in order to put the laptop in a different box). The queue waits a signal from its security gate for sending a passenger to the security gate.
- *Security gate*. It is modeled as a server with one service time distribution for each passenger type. When it finishes in managing a user, it gives the signal to the Tendiflex or the automatic gate queues to send an additional passenger and takes a user from the security queue.

4. Simulation model verification and validation

In this section we analyze the results of the system with and without the Logiscan. We first describe how the data for the simulation have been extracted and the model without the Logiscan validated by a series of tests. Then, we compare the results of the security check system with and without the Logiscan, presenting the advantages and disadvantages of Logiscan usage.

4.1. Testing environment

In order to test the system, some parameters had to be calibrated. In particular, we had to choose the specific test instances to use as test sets, to identify the unknown parameters and to determine them in order to build realistic instances. The following assumptions and parameters have been considered:

- *Simulation time* T. We considered simulations equivalent to one hour of real time. This is due to the fact that the available data about the airport schedules and the passengers arrival times at the airport have a granularity of fifteen minutes, while the schedules of the number of the opened security gates one hour. Moreover, from the point of view of passenger number, a simulation of one hour gives a good indication of the behavior of the system.
- *Passengers types*. The passengers are split in three main types: legacy, low cost and family. For each type of passenger, we identified the number of passengers as follows:
    - Airport schedule: full schedule list of one week in June, including airline and aircraft type;
    - Aircrafts loading factor: computed from the airline type (legacy, low cost, charter) and the ticketing data given by the Bologna airport;
    - Given the above mentioned data and using the empirical distribution of the time in which the passenger of each airline type arrives at the security gates (data taken from a previous analysis by the Bologna airport and BDS s.r.l.), we computed the number of passenger per airline type for each working hour of the security gates.
- *Weekly distribution of passengers arrival*. Given the number of passengers per hour, the weekly schedule of the security gates was categorized as high, medium and low passenger congestion (see Figure 2). Given the number of passengers per hour i and per passenger type j p_{ij}, the passengers have been assumed to enter in the system with an exponential distribution with parameter equal to the mean inter-arrival time T/p_{ij} .
- *Passenger scenario distributions*. We considered three reference hours taken from the weekly distribution of passengers arrival: heavy (black), mean (gray) and low (light grey) traffic.
- *Number of open security gates*. The number of gates was derived from the weekly schedule provided by the Bologna airport.
- *Security queue capacity*. The queues before the security gates have fixed capacity. All the queues have the same capacity.
- *Path connecting the Logiscan machines and the Extra-bag payment*. The path introduces a delay modeled as a triangular distribution. The parameters of this distribution have been obtained by tests performed at the Bologna Airport.
- Logiscan service time. The service time is a triangular distribution. The mean has been provided by Logital, while the remaining two parameters are the result of the calibration described later.
- *Logiscan rejection probability*. The probability of rejection for each passenger type has been provided by data on a similar system installed in the Stansted airport. In particular, the data provided are for the transient (inexperienced passengers, up to 6 months from the introduction of the system) and running (passengers after 6 months from the introduction) conditions.
- *Security gate service time*. The service time is a triangular distribution. The mean has been provided by the Bologna airport, while the remaining two parameters are the result of the calibration described later.
- *Initial passengers in the system*. The system is supposed to have, at the beginning of the simulation, a number of passengers already present in the system. They are computed as the mean number of

passengers observed in the actual system. These data have been collected by BDS s.r.l. during the periodic Italian Service Charter data collection (SAB, 2012).

- *Number of experiment repetitions*. For each combination of traffic scenario and Logiscan rejection probability condition (transient and running), we performed a set of 10 random repetitions.
- *Tendiflex queue policy*. The policy is the best allocation. We also performed tests with the proportional stochastic policy, but we did not observe substantial differences.

4.2. Parameters tuning and model validation

In order to validate the overall system and to tune up the parameters of the triangular distributions, we performed a series of tests in order to fit the real system behavior. In more details, we proceeded as follows:

- Following the rules by the Italian regulation in APT-12 and APT-31 (Enac, 2002; 2009), BDS s.r.l. performed a series of observations and computed the mean number of passengers in the system and the time of presence of the passengers in the security check system computed with a confidence interval of 90% for a set of 12 reference hours, equally distributed between high, medium and low traffic.
- The simulation model without Logiscan has been tested with different values of the lower and upper limits of the triangular distributions up we obtained a mean number of passengers and a presence time fitting the experimental data (error less than 10% in the worst case).
- The model with the best parameter settings has been used for the simulations with Logiscan.

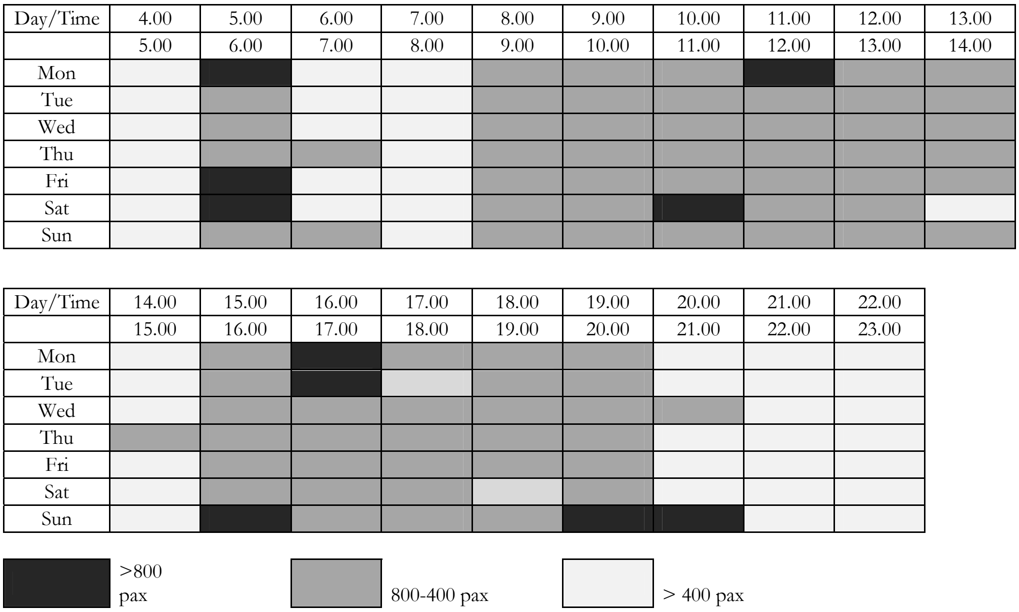


Fig. 2. Weekly distribution of passenger arrivals at the security check system

4.3. System simulation and analysis of the results

In what follows we analyze the results of the simulations of the different policies. Figure 3 presents the plot of the values of the mean time spent in the system by a passenger computed with a confidence level of 90%. According to the Italian Service Chart regulations APT-12 and APT-31 (Enac, 2002; 2009), the time spent by a passenger in the security check system is computed as the time between the arrival of the passenger in the Tendiflex queue and the time just before passing through the security gate. Thus, the security gate service time of each passenger is not considered in computing his time in the system (while it considers the service time of the passengers before him in the security queue). We decided to use this computation framework in order to make the results comparable with the existing and the past Service Chart data (SAB, 2012).

We can notice an initial consistent increment of the time spent in the system given by the initial unawareness by the passengers of the rules. In fact data collected by low cost airlines show how manual checks of hand-baggage imply a tolerance in the allowance rules which reduce up to 50% the rejected hand bags. This is mainly due to a larger tolerance on the weight, as well as the possibility that the crew members allow hand bags with a limited violation of the rules when the check is performed at the departure gate, in order to avoid that the passenger may miss his flight. On the contrary, in running conditions the parallelism introduced by the presence of automatic machines for reading the boarding pass, instead of having one employee before the security gates queue, not only compensated the time required by Logiscan to measure the size and the weight of the baggage (it is between 4 and 5 times the time for manually reading a boarding pass), but it is able to drastically reduce the time spent in the queues during the rush hour, with a mean reduction of about 50%. This compensates the slight increase of time in low traffic.

Also the number of passengers queuing (mean and maximum number) is reduced with the introduction of Logiscan (see Figure 4(a) and 4(b), respectively). In particular, the reduction of passengers is meaningful from a statistical point of view in the high traffic scenarios, with a reduction of about 50% in terms of passengers in the queues, while it is almost irrelevant in the medium and low traffic scenarios. This becomes more important by observing that the largest reduction is obtained in the peak values.

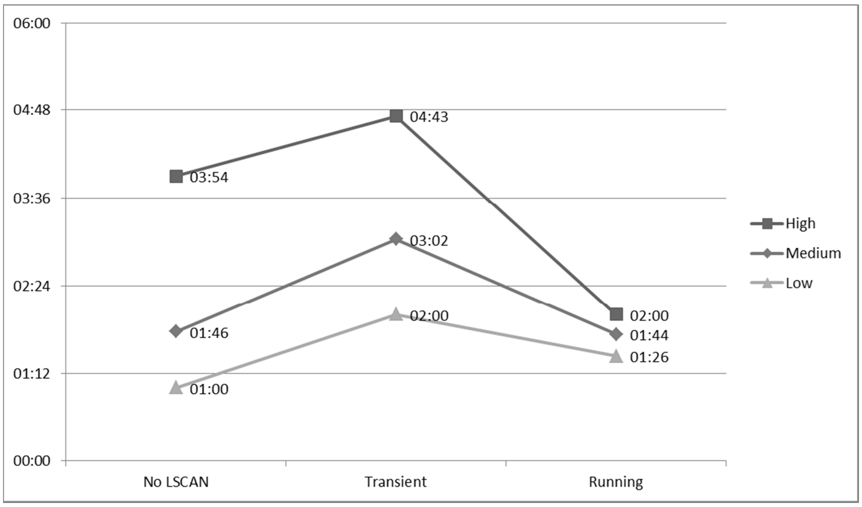
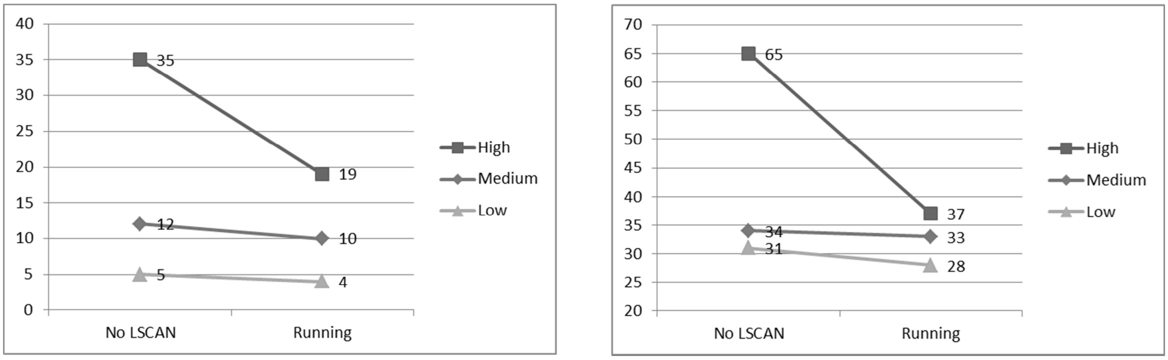


Fig. 3. Mean time in the system (confidence level 90%)



(a) (b)

Fig. 4. Mean and max number of passengers in queue in the security system

5. Conclusions and future developments

In this paper we briefly presented AirSIM, a simulation engine for Airport operations able to describe different operations scenarios. AirSIM has been tested in a real case study in the Bologna airport, based on the introduction of Logiscan, a machine for the automation of a series of the operations before the security gates. The results of the simulations show a large increase in service quality both in terms of reduction of the time spent by the passengers in the overall security check system and reduction of the number of passengers waiting in the different queues. Future developments include the integration of AirSIM with a timetabling tool able to change the security gates open during the week days, in order to reduce the number of employees involved in the security check while maintaining the same service quality level. An additional research direction is given by a multistage stochastic programming approach, which involve sequences of decisions over time, are usually hard to solve in realistically sized problems (Maggioni et al., 2013; Maggioni & Wallace , 2012).

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