A Discrete Event Simulation to model Passenger Flow in the Airport Terminal

Conference Paper · September 2009

1 author:

Elpidio Romano
Università Telematica Internazionale UNIN…

A Discrete Event Simulation to model Passenger Flow in the Airport Terminal

GUIZZI G., MURINO T., ROMANO E.
Department of Material Engineering and Production
University of Naples "Federico II"
Piazzale Tecchio, 80 – 80125 Napoli
ITALY
g.guizzi@unina.it, murino@unina.it, elromano@unina.it, http://www.impianti.unina.it

Abstract: - The Paper describes the analysis of passenger flow in the terminal airport, from entrance to boarding. In particular this study develops a simulation model. Based on the *Discrete Event theory*, that can be used to build a structure that helps to predict delay and to produce a logical and rational management of check-in and security checkpoint inside the airport terminal. The proposed model, tested in the South Italian reality (Capodichino – Naples International Airport), has a modular architecture and interface, enabling quick and easy model building and providing the capability of being adaptable to the configuration and operational characteristics of a wide range of airport terminals.

Key-Words: - Decision support system, modeling, discrete event simulation and optimization, airport terminal analysis.

1 Introduction

An airport is an operational system comprising of a framework of infrastructures, facilities, personnel which collectively provide a service to a costumer. Each airport is to be:

- An ideal point of interchange among different means of inland transport (such as road and rail system) and air system;
- A services' centre, because it must provide the necessary services for ticketing, boarding, deboarding, documentation, control of passengers and goods;
- A point of connection between arrivals and departures, since it must ensure an easy transit from a system of continuous arrivals (which is the users flow) to a system of discrete departures (which are the scheduled flights).

The overall experience of a passenger at an airport can be demanding and time consuming. Delays occur with parking, checking in, security screening, and boarding. The less time the costumer spends in the systems, the higher the satisfaction. However, at the same time, the airport is obliged to hold standards that the passengers must meet. These standards include proper identification, limited luggage weight, and safety procedures at the security checkpoint [1].

Although passengers acknowledge the need for increased security, delayed boarding, cancelled flights, long waiting time have created an environment of passenger dissatisfaction. Therefore operational efficiency at an airport can have a direct impact on safety, user and costumer satisfaction and also at the financial performance of the airport.

In this respect there is a need for a decision support tool that will address complex processes and adopt a quantitative view and system thinking approach for airport terminal system analysis. The reminder of this paper is structured into six main sections. Section 2 provides a problem formulation relate to the functional area in the airport terminal and the prevalent criticalities. Section 3 provides a literature review of the existing model and tools for airport terminal performance analysis. Section 4 presents the overall methodological approach adopted. Section 5 provides data collection need to simulation model, Section 6 presents the architecture of the proposed simulation model. Section 7, finally, provides the critical results of simulation and optimization models tested on the Naples International Airport and some concluding remarks.

2 Problem Formulation

The terminal system can be decomposed into three functional areas representing activities related to the access interface, the process and the flight interface.

- **Access Interface.** Arrived at the airport with different transportation modes, passengers before taking part in the boarding process must perform different operations. The activities taking place in this area regarding the movement, parking of vehicles, bus and taxi station for loading arriving passengers and unloading the departing ones.
- **Process.** It is an area located just inside the terminal where all passengers and arriving and departing or in transit luggage-meaning that the passengers have a stopover at the airport and must continue their journey by plane- are processed. In order to ensure a correct sorting of passengers at the airport it is convenient to separate the arriving passengers flow from the departure one. In most new airports arrivals and departures are handled on separate levels, with departures generally located on the upper level. The main activities regarding the ticketing service, check-in passengers with its seats allocation, check-in baggage, inspection services and security control;

- **Flight interface.** This third component is representative of the passengers transfer from processing area to the aircraft through the grouping and carriage of passengers activities on board and back, loading and unloading of the aircraft itself.

The airport terminal for passengers represents the connecting interface with the air-side area, the place where the take-off and landing of aircraft take place. It is building that containing within it all that is necessary for the operations of boarding or deboarding passengers: check-in desks; documents control; customs; the security control facilities; all services related to luggage. The size of an airport terminal can be extremely variable, from a few hundred meters in the case of a domestic medium-small airport until to reach extensions of kilometers in the case of big international airports. Most of the airports, especially those of large size, shows complex traffic and congestion problems, both as regards the runways and parking areas (airside), both the airport where the public has access (landside). The main elements characterizing the capacity of an airside area are: the number and the length of runways; apron area; number of parking lots; taxiways; equipments for takeoff and landing. While the characteristics that affect the airport landside capacity refer to the following structures: number of check-in desks; number of gates; baggage handling system; Police filters; departing, transit and arriving passengers flow systems. All terminal operations (ticketing, check-in, passport control, security control) are obviously characterized besides a service time and a queue waiting time too. This last time cannot be too high, but so far we need to restrain it in order to ensure all passengers having regular ticket the observance of boarding time thus avoiding the flight missing. In most the reduced times are for travelers synonymous of high quality, key element in developing a good business image. For both reasons, therefore, is crucial for an airport during the years the infrastructure adaptation due to the increasing demand passengers transportation. In the airport passengers are subjected to increasing levels of congestion caused by three interrelated factors. In the first place demand fluctuations are considered. A second congestion cause is represented by network problems. The third and last reason is related to flights scheduling causing interacting of passengers addressed to different flights. To a variation of these elements the economic links must be added, which require airlines to make more and more tight turns. In this context, even the slightest delay can cause a cascading effect on all the activities: delays in connections, high time parking lot occupation, supply disorganization.

2.1 Boarding operations

The main planned phases before the flight for departing passengers essentially are three:

1) The check-in operations at check-in desks, where the passenger delivers the baggage and receives the boarding pass;

2) The transit at the security controls in order to proceed to the boarding halls with their hand baggage;

3) The boarding operations on the aircraft: the passenger must be show at the boarding gate of his flight with a boarding pass and a valid identity document. Generally, passengers must have completed the check-in operations:

- For domestic flights at least 35 minutes before departure;
- For international flights to Europe at least 45 minutes before the flight;
- For intercontinental flights at least 60 minutes before the flight.

Following the check-in the passenger, with boarding passes, valid identity document and hand luggage (weight and dimensions allowed by the company), passes through the expatriation controls and the metal detector where security operators perform a manual control on the person and on the hand luggage ascertaining the absence of improper weapons, real or other dangerous objects.

In recent years, airlines set up alternatives to the check-in desks thanks to the web check-in and telephone check-in, a real check-in procedure performed via internet. In these cases the practice is different from airline company to airline company, even if in most cases, the only constraint is required is traveling with only hand luggage only and therefore do not having baggage to check and also no need of special assistance. Some airports are also equipped with automated kiosks for check-in, at which the operation is carried out entirely by the passenger without staff operators.

3 Overview of existing models and tools

Many researchers have faced issues concerning the optimization of an airport terminal. In this section we show some of these works. The Nagoya University has conducted a simulation using the software Arena [2, 3, 4] on departing flow passengers from the International Kansai airport in Japan, in order to reduce the number of passengers, because of long waiting times in peak periods and because of unavoidable delays, they lose their flights [12]. Preliminary analysis on passengers waiting times showed that the total time spent by passengers in the airport: the 48% is spent moving from place to place within the terminal, the 25% is waiting and only the 4% is doing formalities such as process acceptance, embarkation, and so forth. In addition, it has been found that the time spent at the check-in desks in waiting queue is more than 80% of total time before boarding. This output highlights that the check-in should be considered as the main bottleneck. The simulation was conducted considering the condition of congestion based on flight operations of a regular working day, usually adjusted on a number of 100 flights and boarding operations of 70%. In particular, it refers to the airline's "A Company" which operates about 25% of all flights of the Japanese airport. The results of the simulation suggests that the number of passengers loosing their flights can be drastically reduced by the addition of a staff supporting the standard working group, and by the use of check-in desks different for passengers class, such as tourists, business and first class. This is a solution already adopted by many carriers both Italian and International. The departing passengers flow at the Buffalo International Airport (Niagara) has been studied by researchers from the Department of Industrial Engineering and Systems at the University of Buffalo [4]. Particular attention has been shown to the check-in process, considering that the waiting system times besides varying depending on week day and the time of the day, are function of different check-in available to passengers, the number of bags and the chosen airline to fly. The purpose of this analysis is to obtain specific information on the experience of passengers at the airport to identify the expectations and to create scenarios that will improve efficiency by increasing the customers perceived quality. The manners of check-in options available at Terminal 4 are considered. The check-in online and the kiosk are used only to accept passengers with no luggage, then the passenger having already obtained the boarding pass, can go directly to the security control, otherwise he should go to the inside check-in desks in order to send the luggage. Besides the inside check-in desks (which represent the classical solution) in the Buffalo terminal have the option Curbside (literally the platform, i.e. the area outside the terminal), where a number of agents accept passengers and their baggage, coming directly from parking lot or bus and taxi. Researchers referring to the airline "Sudwest Airline" have inserted the data collected for a couple of months during Mondays, Fridays and Saturdays, in a simulation model, which confirmed that the inside check-in desk is one of the slower process and it has the longest waiting time. It has been found that removing the possibility of the inside check-in desk, the whole process is adjusted on a lower waiting time. In order to realize such a scenario would be expected to encourage customers with little experience to use the express kiosks, perhaps by placing agents in their vicinity in order to provide at least the first time a useful support to conduct the formalities. In addition, the Sudwest Airline allows passengers using the online check-in to choose the seat on board the aircraft. It means that while substantially beneficial for travelers without luggage, this check-in method is used also by tourists having baggage, and therefore later they will be forced to get in line of the inside check-in desks, since they would like to choose the seat. As matter of fact, the simulated experiment shows that removing the option of seats allocating, the number of passengers using the online check-in significantly decreases.

It would be interesting to choose perhaps the best type of check-in depending on the referring day. For example, the express kiosk can be an optimal mode for on Mondays travelers, consisting in large part by business man class usually without baggage to be loaded, whereas it is not suitable on Friday and Saturday days, whose passengers are mostly for pleasure trip having a great number of bags to check. The Department of Civil Engineering of Surabaya in Indonesia has studied the services congestion carried out in an airport terminal building on the concept of temporal blocks. Data on passengers flow will be collected in time intervals divided into blocks of time dependent on size of service average time. In particular, periods of 10 minutes are considered, convenient choice since distributions on the arrival of passengers provided by IATA are based on 10 minutes time intervals [13]. Obviously the method adopted is based on a simplified procedure that does not take into account the service time variability. The periods of long delays and excessive waiting times are highlighted through the graphical analysis. The temporal blocks model, developed in Excel, is suitable to be applied to the case of several resources serving a single passengers queue, and the variables involved in calculating the number of resources are:

- Service time;
- Arrival curves;
- Configuration and typology of check-in;
- Cost of check-in area.

The model optimization is based on system total cost minimization. The costs considered include the cost of space, the operating cost and the cost of uneasiness endured by passengers when the waiting time exceeded the tolerable limit. The inclusion of the cost of space makes this methodology an useful tool for estimating the optimum size of the check-in area . Interesting is also the work proposed by the School of Mathematics and Statistics Carleton University (Ontario, Canada), where a linear programming model minimizing the total work hours at the check-in ensuring a satisfactory customer service level has been developed [11]. The output of this alternative method shows a significant performance improvement since it provides a shorter queues length, reduced waiting times and an increase in satisfied customers percentage.

4 The methodological approach

The simulation of passengers flow within an airport terminal allows the detection of any critical issues that could arise in the real flow management taking into account some key factors such as the traffic passenger volume and the type of the passengers themselves. All passengers behave differently at the airport, and the experience is certainly a key factor in the performance of their actions, difficult to predict a priori. The development of a simulation model therefore helps us to infer and predict, taking into account the available capacity and the fact that the volume of passengers depends on day time and the week day, the different passenger behavior. This study is to develop a simulation model able of optimizing in a logical and rational management all check-in desks and security control inside the terminal 1 at Naples airport. The importance of this model lies in the ability to identify, at any time of the year and depending on the airport traffic volume, the required number of check-in required and at the same time adequate to perform the check-in operations in full compliance and regularity of the scheduled flights ensuring a satisfactory service level for departing travelers. The close correlation between the check-in operations and the security controls allows to obtain in the same way the number of the security control accesses to be made operational during the referred period. Building the model is equivalent to virtually retrace the journey made by departing passengers studying the issues and highlighting all the available alternatives [7]. Essential to this development is the visit at the terminal, useful to understand in general the passengers approach and both in order to have all information needed for the continuation of this work. To fully clarify the issue we must know the number of check-in and the available security control checkpoints: these number are 56 and 12.Obviously at the changing flight destination varies the check-in time at desks which is usually an interval of 90 minutes for international flights and approximately one hour for domestic one. While as regards the security passengers control of any airline company can be served at any desk regardless flight destination, related to the check-in process is essential to examine how the airport operator assigns the desks to airline companies or handler. The airlines that operate more flights simultaneously adopt the solution of the common check-in (as the case of AIRONE company in our study), in which passengers on same company flights may be served on any desk regardless destination. Also the management queue can be different: in Naples airport, e.g., Airone airline manages several desks through a single queue, while other companies like Air France arranges passengers to many queues as much available desks. This clarification is crucial for an easier understanding of the logical model described in the next paragraph.

5 Data Collection

Today's airport terminals offer to tourists real business galleries, thus finished the check-in phase passengers are increasingly tempted to delay the next operation of security control since they prefer last shopping before departure or at least visiting other shops, always consistent with the remaining time for boarding. The landside of the Naples International airport consists of two terminals, Terminal 1 (T1) and Terminal 2 (T2). As the Terminal 2 is operating only in spring-summer season, and almost exclusively for charter flights, focus our study on passenger traffic on the only Terminal 1. The path related to passengers departing from Terminal 1 consists of two floors: on the ground floor we have the check-in desks, and on the first floor, accessible by escalators, the security control facilities and some shops and food services are located. On the other side of the ground floor besides the path related to arriving passengers there are the ticket office, the two currency exchange offices, several car rentals, and so forth.

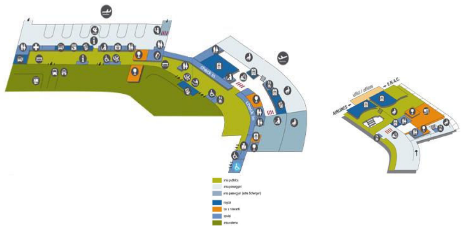

Fig. 1: Map of Terminal 1 at the Naples airport

5.1 Data Analysis

The most problematic phase of this study has been that on data acquisition. Sampling took place in the passenger terminal 1 at Naples International airport. After a thorough inspection of Capodichino airport it came out that passenger traffic peaks during the whole week were on Monday morning and Friday afternoon. Therefore the focus data collection phase was on three week days: Monday, Wednesday and Friday. The survey was repeated for several weeks by 2 people with different recognition tasks: the first one monitored near the check-in the passengers arrival at the counter to get the determination of so-called 'curves of presentation' and the service time of the check-in formalities, instead the second one has carefully considered the queue near the desks by defining the queue length and service time.

Data was grouped in the spreadsheets that shows some information such as basic information flight (the airline and destination), time of departure, time of opening and closing its check-in and finally the flight code. This information is important because from the flight code it is possible to know the type of the aircraft used for that flight and then the total number of aircraft available seats. As for the security control checkpoints (located on the first floor of the terminal), we used both historical data in our possession and new collected data. The survey in any case was simpler than the one made at check-in desks, because there is not flights distinction or other it is enough to consider the number of active locations and the time of queue clearing. In order to carry out a correct analysis of collected data it was necessary to make an appropriate data stratification for highlighting some key aspects. This was a crucial step in order to get to the distributions to be included in the simulation model to be validated. The stratification concerns different features:

- Airline. Mainly we focused on check-in desks number dedicated at Airone, the airline company currently operate the largest number of flights per day at Naples International airport (61% vs 39% for the others). In particular, the Airone company exploits its available desks through a mode called 'Common Check-in generalized', with which all counters are indiscriminately opened to any flight operated by the company itself, so at the same desk are recorded passengers to different destinations. For most other

airlines instead check-in is 'dedicated' to a specific flight.
- Flight destinations. The distinction between domestic (65%) and international flights (35%) is crucial in our study for the different approach that passengers show towards the second flight category compared to the next (eg arriving at the terminal generally more advance time) and for the different opening check-in desk times. The opening check-in desk times for the major airlines operating in Capodichino airport are:
  - AIRONE: for domestic flights from 1.5 h to 25 ' before departure and for international flights from 2h 30' before the flight;
  - BRITISH AIRWAYS: from 2h 30 ' before the flight;
  - AirFrance: from 2h 30 ' before the flight;
  - MERIDIANA: from 2h 30 ' before the flight;
  - LUFTHANSA: 2.5 h at 35 ' before the flight.
- Type of passengers. Important distinction is that which concerns the two main categories of passengers: tourist and business passengers, 80% and 20% respectively

6 Model Architecture

6.1 Development of logical Model

In this section, we will define our system in a logical model, with a level of sufficient detail to make significant further simulation. It's possible to think in terms of modular system, developing model through different sub models that make cleaner the understanding and allow for easier management of the whole. Three used sub models to represent whole system are: passengers generation; check-in and security control sub models.
In particular we considered it appropriate to divide the acceptance process depending on the type of servicing check-in: common desks and dedicated desks.

6.1.1 Generation passengers

Generated entities, representative the arrived passengers in the queue to check-in desks waiting to be processed, are suddenly separated by a decisional module, that is responsible for considering both types of check-in previously defined: common check-in maintained by a single line, and acceptance at dedicated desks, where it creates queue for each desk. In the assignment module, we define all the attributes (except luggage) with the respective probabilities, relieved by sample data, (common or dedicated, tourists or business, number of passengers groups), and used resources in model (check-in desks and security facilities).

6.1.2 Flights with common desks and flights with dedicated desks

Usually airlines dedicate a desk exclusively for business class (and first class) passengers.Moreover, the behavior of the latter differ not just from the common travelers. It's essential, therefore, to split business class from tourists class. It's assumed that business passengers are individual passengers, while those in the tourist category, it can assume that the same may occur in groups of 2, 3 or 4 people. For business class passengers, we have considered only the idea of having or not a single luggage, sufficiently representative of reality.

6.1.3 Check-in

We must distinguish common check-in from dedicated one. We start from common check-in event. We suppose to have at disposal desks, one of whom (nth), saved for business class passengers: obviously in case there aren't present business passengers, the n desks can be used to serve tourists, although desk's priority is always assigned to the first type of passengers. Two queues form: one of business near the n desk and a unique queue of tourist, assignable to (n-1) of n desks of acceptance. It's thought to simulate a occupation of a desk by a binary signal: supposing to label with value 1 free state of desk and with value 0 the occupied one. The decision-making form, that governs the wait can be represented in this way: at the beginning, all desks are free and so for each of them the attribute assumes value 1. Therefore, there is an equiprobability of choice among the n desks. In this initial phase, the passenger is forwarded to one of available desks, taking up it for a time equal to the servicing time, function of passenger type, of possibility that the passenger arrives in group, and of the number of luggage. During this time, the state of the occupied desk is changed in value 0.At the end of the process, the resource assumes again value 1, so the first user in queue can be finally served.
Now we examine the procedure for the case of dedicated desks. Arrived at the terminal and singled on the monitor the desks available for his own fly, the passenger queues up there where the number of users in wait is lower. In this situation there will be more queues, one of which is always dedicated to business class.
When all resources (check-in desks) are occupied, it's possible to conduct the arrive of the other users with functional blocks that simulate the accumulation of entities (queue blocks). These entities will be retained until eventuality that at least a resource unblock itself. To simulate the event to check-in by telephone o via web too, we consider a new generation of passengers that check-in on line.

6.1.4 Security Control

Differently from since happens during the procedure of acceptance, security controls are made one by one for each passenger, so groups that form during first sub model, are now separated. The entities are so doubled by some blocks of division in function of belonging groups. Depending on available time before time of departure, not all decides to pass the security control; someone, in fact, decide to utilize remaining time visiting commercial galleries, working at pc, reading a book, etc. For this reason, we face the event that the security control (C.S.) is referred. The queue near security control checkpoint is managed at just as common check-in, in other words only one queue for much more available checkpoint. This procedure is much more easier to model, since treating passengers singly and since being without luggage (as they are previously deposited at acceptance desk), it doesn't need to distinguish among service time. We have the same logical solution already adopted and so we attribute value 1 to the checkpoints with free status and value 0 to the others.

6.2 Simulation model

The passenger traffic flow at the airport is a discrete stochastic process. The simulation of discrete event [9] is often used to model systems characterized by complex processes, combined with infrastructure at limited capacity. The airports are therefore ideal places to work with simulations having these features. The software used for the case study of our study is Rockwell Arena [2, 3, 4, 5]. Retracing the considerations made in the logical model, the simulation has been developed in sub models allowing to obtain all advantages inherent to a modular system representation. Having discussed the model widely from a logical point of view, to avoid unnecessary repetitions, now we restrict the study in highlighting only some key aspects.

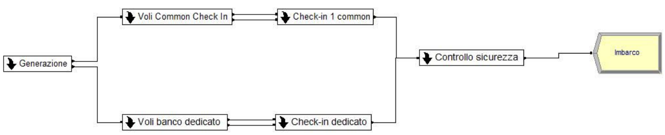

Fig. 3: Model representation

As already said, the available resources (check-in desks and security control checkpoints) are considered as variables with a value equal to 1, in the case of free state, and 0 if engaged. At this point the queues are managed through hold of scan for condition type, in which block the phrase allowing users to leave the queue and to continue the path is inserted.

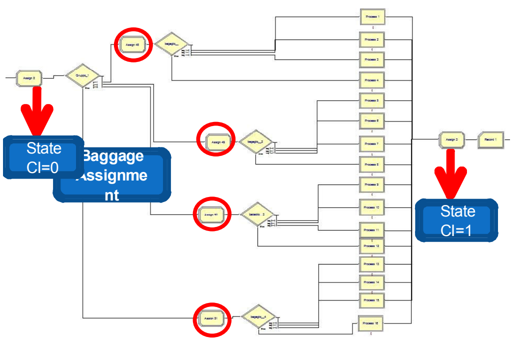

Fig. 4: Common Check – in management

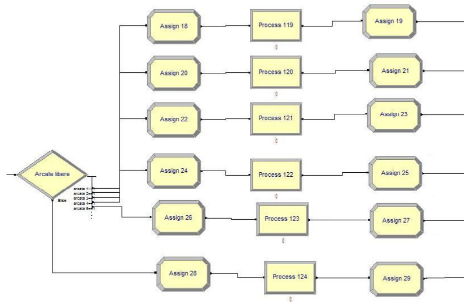

Fig. 5: Security Checkpoint management

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Coda A.Queue	0.3106	0,04	0.2516	0.4293	0.00001208	0.9017
coda Bd.Queue	0.02447783	0,01	0.01058678	0.04985998	0.00079936	0.08864483
coda4.Queue	0.0902	0,03	0.03910184	0.1457	0.00118771	0.3265
coda5.Queue	0.0903	0,03	0.03289742	0.1325	0.00005032	0.4291
coda6.Queue	0.08695318	0,03	0.04967483	0.1562	0.00017434	0.4000
Codabus.Queue	0.01748204	0,00	0.01181466	0.02965474	0.00001276	0.1225
CodaT.Queue	0.04333903	0,01	0.02537405	0.08383999	0.00004206	0.1613

Fig. 6: Hourly queue waiting time with all available resources

Number Waiting	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Coda A.Queue	21.7389	3,53	15.9816	32.5216	0.00	199.00
coda Bd.Queue	0.02260145	0,01	0.00132335	0.06232497	0.00	3.0000
coda4.Queue	0.6582	0,22	0.2151	1.0447	0.00	14.0000
coda5.Queue	0.6593	0,22	0.1933	1.0351	0.00	15.0000
coda6.Queue	0.6678	0,21	0.2856	1.1128	0.00	15.0000
Codabus.Queue	0.04970299	0,02	0.02615481	0.08802838	0.00	5.0000
CodaT.Queue	1.6089	0,48	1.0276	3.2907	0.00	48.0000

Fig. 7: Number of users in the queue with all available resources

As can be seen from Figure 7, while the number of users in the queue at check-in desk is quite low, which implies that too many desks are open, the values of the queue at the security control checkpoint is quite high therefore this scenario is not satisfactory to the customer. Then we add 2 more security control checkpoint in the model, initializing it with value 1 (free state) and we launch again the simulation.

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Coda A.Queue	0.1442	0,03	0.08273419	0.1898	0.00001713	0.4012
coda Bd.Queue	0.02710774	0,01	0.00849423	0.07885684	0.00482387	0.1219
coda4.Queue	0.1394	0,03	0.08541390	0.1838	0.00013671	0.4811
coda5.Queue	0.1325	0,02	0.0948	0.1881	0.00001231	0.5248
coda6.Queue	0.1316	0,02	0.08474739	0.1666	0.00018533	0.4373
Codabus.Queue	0.01880890	0,00	0.01524115	0.02770415	0.00014332	0.0915
CodaT.Queue	0.04046939	0,01	0.02104750	0.05911443	0.00000303	0.1521

Fig. 8: Hourly queue waiting time with 8 available security control checkpoint

Number Waiting	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Coda A.Queue	8.6206	1,91	4.5711	13.5705	0.00	130.00
coda Bd.Queue	0.01828298	0,02	0.00254316	0.08871395	0.00	3.0000
coda4.Queue	1.1504	0,21	0.8008	1.6249	0.00	17.0000
coda5.Queue	1.0865	0,22	0.6043	1.5284	0.00	19.0000
coda6.Queue	1.0870	0,20	0.6886	1.4993	0.00	19.0000
Codabus.Queue	0.06060394	0,01	0.04453302	0.0970	0.00	4.0000
CodaT.Queue	1.5202	0,39	0.7064	2.2537	0.00	48.0000

Fig. 9: Number of users in queue with 8 available security control checkpoint

In this new context, we remark that the queue waiting time at the checkpoint is noticeably reduced and in confirmation of what previously developed we found for the check-in desks the values similar to the ones previously found.

7 Costs optimization and evolving scenarios

The results obtained through Arena provide queue average values and waiting times as well as the related minimum

ISSN: 1790-2769

ISBN: 978-960-474-124-3

and maximum peaks in relation to the number of resources left open in the model [8, 10, 11]. Next phase is to optimize the model, and then to figure out the check-in desks and security control checkpoints best combination able to minimize costs. In order to achieve this goal it is necessary to define an objective function. Besides to consider the closing operating costs of each check-in desk and each security control checkpoints we took into account the inconvenience cost suffered from the traveler when the number of users in queue coming before(or just the same the waiting time) overcomes the limit considered tolerable. Thus the expression of the function cost is:

$$\sum_i C_1 x_i + \sum_j C_2 y_j + C_3 Max(NmqueueA\text{-}Nt,\ 0) + C_4 Max(NmqueueBd\text{-}Nt,\ 0) + C_5 Max\ [\ \sum_k (NmqueueK\text{-}Nt,\ 0)]\ + C_4 Max(Nmqueuebus\text{-}Nt,\ 0) + C_5 Max(NmqueueT\text{-}Nt,\ 0) \qquad (1)$$

where x is the check-in desks, and y the security control checkpoint, Nm the average number of users in queue, and Nt the maximum number of users assumed tolerable and k is the number of check-in desks open only for tourist.

C_1=12.5€	Cost of opening for single desk
C_2=10€	Cost of opening for single security control checkpoint
C_3=20€	Cost of inconvenience at security checkpoints
C_4=15€	Cost of inconvenience at check-in for business
C_5=10€	Cost of inconvenience at check-in for tourist

Tab. 1: Cost headings of resources

By OptQuest in Arena, starting from a first solution hypothesis the best solution has been identified in order to optimize, and then in our study, to minimize the function cost. Let start from the first considered scenario: 6 security control checkpoints

Minimize Costo_totale_euro	arcata 1	arcata 2	arcata 3	arcata 4	arcata 5	arcata 6	banco 1	banco 2	banco 3	banco 4	banco 5	banco 6	bancob 2	bancob
1033,01	1	1	0	0	1	1	1	1	0	1	0	1	1	1
311,008	1	1	1	1	1	1	1	1	1	1	1	1	1	1
306,011	1	1	1	1	1	1	1	0	1	1	1	1	0	1

Fig. 10: First scenario best solution

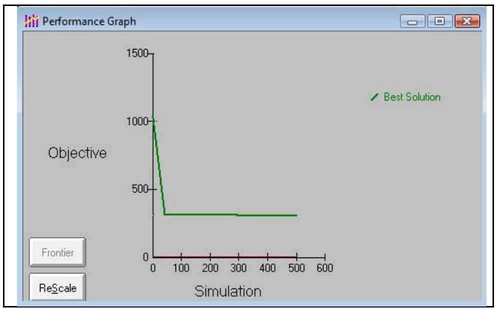

Fig. 11: Cost trend for first optimization

To deduce from Fig.6 OptQuest provides as best solution the opening of all security control checkpoints and the closing of two check-in (desk 2, desk b2). This solution is characterized from an average unit cost of 306,011 €. The same procedure has been carried out for a second scenario, adding 2 checkpoints for a total of 8.

Minimize Costo_totale_euro	arcata 1	arcata 2	arcata 3	arcata 4	arcata 5	arcata 6	arcata 7	arcata 8	banco 1	banco 2	banco 3	banco 4	banco 5	banco 6	bancob 2	bancob
461,974	1	1	1	1	0	0	1	1	1	1	0	1	1	0	1	1
149,282	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
143,227	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
133,337	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
214,043	1	1	1	0	1	1	1	1	0	1	0	1	1	1	1	1

Fig. 12: Second scenario best solution

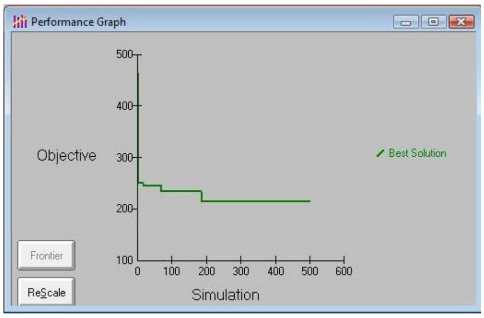

Fig. 13: Cost trend for second optimization

The optimal solution, for the input model data is the opening of 6 check-in desks and 6 security control checkpoints having a cost of 214,043 €. In the considered time period during the data analysis it is possible to hypothesize a solution with opening 6 out of 8 check-in desks and opening 6 out of 7 security control checkpoints. This solution allows to realize a right trade-off between costs and offered service levels.

Conclusion

The results obtained through Arena provide queue average values and waiting times as well as the related minimum and maximum peaks in relation to the number of resources left open in the model. It is possible to affirm that the proposed study, verified through a case study, even if robust for the vast amount of experimental used data, need to be reviewed during the verification of function cost and independent variables phenomenon relations (DOE analysis). Such approach, with the last proposed step, can be considered applicable to the different airport realities defining a general model able to provide an useful decision support for the design field, for airport terminal layout study, and the management field optimizing the available resources in function of demand variation.

References:

[1] Manataki I. O., Zografos K., A generic system dynamics based tool for airport terminal performance analysis, *Transportation Research part C,* Vol. 17 2009, 428-433.

[2] Joustra, P., and Van Dijk, N., 2001. Simulation of Check-in at Airports. *Proceedings of the 2001 Winter Simulation Conference*, 1023.

[3] Verbraeck, A., and Valentin, E., 2002 Simulation Building Blocks for Airport Terminal Modeling, *Proceedings of the 2002 Winter Simulation Conference*, 1199-1200.

[4] Appelt S., Batta R., Lin Li, Drury C., 2007. Simulation of passenger check-in at a medium sized airport. *Proceedings of the 2007 Winter Simulation Conference*, 1252-1260.

[5] Chun Wai Hon, Wai Tak Mak R., Intelligent Resource Simulation for an Airport Check-In Counter Allocation System. *IEEE Transaction on Systems, Man, and Cybernetics – part C: applications and reviews*, vol. 29, no.3, august 1999.

[6] Evans, W.A., 1994. Approaches to intelligent information retrieval. *Information Processing and Management*, 7 (2), 147–168.

[7] Sargent R., 2003. Verification and validation of simulations models, *Proceedings of the 2003 Winter Simulation Conferenc*e (WSC 2003).

[8] Park Y., Ahn S., 2003. Optimal assignment for check-in counters based on passenger arrival behavior at an airport, Korea *Transport Institute*, 2003.

[9] Rauch R., Kljajić M., 2006. Discrete Event Passenger Flow Simulation Model for an Airport Terminal Capacity Analysis.

[10] Ju Y., Wang A., Che H., 2007. Simulation and Optimization for the Airport Passenger Flow. *2007 IEEE*

[11] Cao Y., Nsakanda L. A., Pressman I., A Simulation Study of the Passenger Check-in System at the Ottawa International Airport, *SCSC 2003.*

[12] Takakuwa S., Oyama T., Simulation Analysis of International-Departure Passenger Flows in an Airport Terminal, *Proceedings of the 2003 Winter Simulation Conference,* pp. 1627-1634.

[13] Ahyudanari E., Vandebona U., Simplified model for estimation of airport check-in facilities, *Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 724 - 735, 2005*.