SIMULATION VS ANALYTICAL MODELS FOR THE EVALUATION OF AN AIRPORT LANDSIDE

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ABSTRACT

In this note we briefly present two models for evaluating an airport terminal comparing their relative merits. The proposed simulation model, AIRLAB, is a discrete-event simulation model of actions and decisions made by arriving, departing and transfer passengers in the airport terminal building, as well as their baggage movements. The proposed analytical model, SLAM, consists of a network of modules, one for each facility of the terminal. The objective of both models is to analyze any given facility, providing, among others, the estimation of the capacity of that facility, in terms of passengers/baggage per hour, and the level of service associated with it, compared to internationally accepted standards as those suggested, for example, in the IATA manual (IATA, 1982).

KEYWORDS

Airport terminal, Landside, Level Of Service, Capacity.

1. Airport landside facilities and Level of Service (LOS)

The airport landside facilities are divided into processing facilities (e.g., check-in, passport control, security screening, etc.), holding facilities (lounges, etc.) and flow facilities (e.g., corridors, stairs, etc.). The level of service (LOS) represents the quality and conditions of service of one or more facilities as experienced by passengers. Interrelationships exist among the typical measures of service level such as waiting time, processing time, walking time, and crowding. Typically both the waiting time and the available space influence the customer perception of the quality of service. Furthermore the same amount of time may be perceived as irrelevant, when waiting in front of a facility requiring a long service time, or exaggerate if the facility requires only a short processing time. Service level targets are the results of a compromise: higher LOS targets imply higher airport costs on one hand but a better “image” on the other. In fact, maintaining a particular level of service at an airport may contribute to attract new business and is also a reflection of the local or national community's goals. To specify the LOS, a set of letters from LOS = A (excellent) to LOS = F (unacceptable), are used. The levels of service are usually described in terms of flow, delays and level of comfort (see Table 1).

LOS	Level	Description
A	Excellent	Free flow, no delays, excellent comfort level
B	High	Stable flow, very few delays, high comfort level
C	Good	Stable flow, acceptable delays, good comfort level
D	Adequate	Unstable flow, passable delays, adequate comfort level
E	Inadequate	Unstable flow, unacceptable delays, inadequate comfort level
F	Unacceptable	Cross-flow, system breakdown, unacceptable comfort level

Table 1. IATA LOS standards

System managers and designers should specify, a priori, the desired or required level of service. Usually, level C is recommended as a minimum and level D is considered tolerable for crash periods. Multi-dimensional LOS standards should be specified for processing facilities; for example, for a check-in area LOS standards are specified both in terms of time (maximum tolerable waiting time) and of space (minimum available area per waiting passenger). See Table 2 for an example of space LOS parameters.

LOS AREA	A	B	C	D	E
Baggage Claim (sq. m.)	2.00	1.80	1.60	1.40	1.20
Flow-space (passengers per min. per m.)	20.00	25.00	40.00	57.00	75.00
Check-In (sq. m.)	1.80	1.60	1.40	1.20	1.00
Holding area (sq. m.)	2.70	2.30	1.90	1.50	1.00
Generic area (sq. m.)	1.40	1.20	1.00	0.80	0.60

Table 2. Space LOS parameters

Let us introduce a variable that we will call Index of Service (IOS), strictly related to the level of service (LOS). The LOS is a qualitative statement. To most of the LOS there correspond internationally accepted standards based on quantitative measurements. We will call index of service (IOS) such a quantitative measurement. For example, in a waiting lounge the LOS = B corresponds to 2.3 < IOS < 2.7 (m^2 per person).

2. AIRLAB

AIRLAB is a new discrete-event simulation model of actions and decisions made by arriving, departing and transfer passengers in the airport terminal building, as well as their baggage movements. This model is not the description of a particular terminal, but it may be customised to model any airport configuration by suitable parameter tuning. We refer the interested reader to (Brunetta and Romanin-Jacur, 2001) for an accurate presentation of AIRLAB.

The basic feature of this new model is the flexible implementation of behavioural models representing the way passengers make decisions in the terminal building on one hand, and of the decision policies related to the operations in the terminal facilities on the other.

Behavioural models are realised by a simple representation of the way passengers make decisions when moving in the terminal building (e.g. choose a ticket counter, spend time in a lounge, select a specific path, etc.). The same abstraction mechanism has been adopted to model the decision making and the policy of a specific facility within the terminal building by means of suitable “facility selectors”. For what concerns the layout of the terminal and the physical relationship among facilities, the user can define the location of each facility and the surface area of each lobby. The user does not need to define connectivity among the various facilities, since this information is implied in the definition of the behavioural model. The behavioural models represent the dynamic behaviour of the passengers in a very realistic way. In fact, as it happens in reality, passenger decisions are not made a priori, but rather are dependent on the situation of the facility at the time the decision must be made. Decisions like the selection of a check-in counter or a security gate they must go through are usually made at the time they are needed and past decisions may affect future actions. Also specific types of behaviour, like a longer stay in a lounge because of a delay announcement, can be easily represented. These are dependent on the on-line information on the flight schedule. This is implemented in AIRLAB by means of an information manager, which simulates the Flight Information Display System and the public address system within the terminal building.

AIRLAB is a new generation model that overcomes, on a low-cost platform, typical problems of the old packages, such as large data requirements and lack of flexibility. Our model stresses flexibility in the definition and implementation of alternative terminal building operating policies and in the modelling of passenger behaviour. It has been designed to be extensible (so that, in addition to the set of built-in behavioural models provided with the system, new policies can be incorporated seamlessly) and, at the same time, flexible enough to allow multiple, and possibly conflicting, policies to co-exist.

Model input data can be divided into four groups:

- *global parameters*, concerning characteristics of passenger and baggage movements (times, speeds, delays, etc.),
- *facility related inputs*, concerning characteristics of facility operations (locations, areas, times, servers, etc.),
- *traffic data*, concerning flight schedule and characteristics,
- *passenger routing*, concerning all passenger routes among facilities and related possible decisions.

Model output data can be divided into three groups:

- *processing facilities*, reporting information about queues, waiting times and service times
- *holding areas*, reporting information about people amount, time spent, congestion and level of service
- *passengers*, reporting information about times spent inside the terminal.

Note that all output data are given in function of time, i.e., their variation during the day or in different days are evidenced.

AIRLAB can model in a single run the landside of an airport of any size, including multiple terminal airports, since it has no internal limits on the number of facilities or the number of passengers it can accommodate. The model is coded in Simscript II.5 and runs on Windows 95/98/NT machines. It is equipped with an interactive Guided User Interface that allows the user to provide in an easy and reliable way: a) the system structure and behaviour parameters, b) the input for the simulation model, i.e., dynamic profile and characteristics of arriving and departing passengers. In fact, a standard relational database protocol is used to collect data and to check logical dependencies. It provides, among its outputs, colour-coded displays of LOS achieved at each landside facility over any specified period of time and animation of the operation within the terminal. Icons of the elements of the simulation are drawn with SIMDRAW. A wide variety of diagrams can be produced both at the end of each experiment and during run-time.

3. SLAM

We refer the interested reader to (Brunetta et al., 1999) for a deeper presentation of SLAM (Simple Landside Aggregate Model); here we just give an overview. SLAM is an intentionally simple model: the output produced by an aggregate model must be easy to understand and very fast to obtain. This choice is reasonable, since a detailed analysis can always be provided by a detailed model like AIRLAB. The input requested by the models is extracted from the data, usually collected by every airport Authority, that are typically provided to a detailed model.

The aggregate space model for a specific facility will consist of a simple formula, like the following:

$$\text{IOS} = \frac{\text{Area}}{\text{AP} * \text{ADT}}$$

that says that the index of service (IOS) for that facility can be computed dividing the *Area* by the product of the number of *Arriving Passengers* (*AP*) at that facility during one hour (the Peak Hour) times the *Average Dwell Time* (*ADT*) spent by a passenger in the facility. The IOS can then be used to obtain the space LOS of that facility. For example, if the Area in front of the check-in is 1500 m^2, the number of passengers arriving at the check-in during the Peak Hour is 3600, and the average Dwell Time is 0.15 (hours), then the IOS for that facility is 2.78 (m^2 per person), which means that the corresponding LOS is A.

SLAM uses “quick and dirty methods” to compute the Dwell Time (both its average and its distribution) at a processing facility: the time LOS of that facility can then be obtained, based on these quantitative estimates. We recall that the Input required by our model can be extracted from the statistical data that are typically available to an airport manager and that our analysis refers to the *peak hour* (PH). However, the time window to consider is typically greater than one hour, since we have to take into account all the flights departing or arriving that can possibly interact with the PH; for example, a check-in counter at the Linate Airport is usually opened two hours and fifteen minutes before the scheduled departure time.

In order to estimate the *Average Dwell Time* (ADT) spent by a passenger in a processing facility, SLAM considers two different approaches. The first one, based on classic Queuing models (M/M/s or similar), will not be discussed here. The second approach is suggested when the dynamic effects are too important to ignore.

In the following, for the sake of clarity, we shall refer to the check-in facility, instead of considering a generic processing facility. For each flight, the passenger arrival profile (which must be given as input) is a function of time that provides the number of passengers that have already entered into the system (i.e., the check-in facility). The profile of the passengers that have been served by the system (and therefore have left it) is again a function of time, but it also depends on the number of servers; this profile is not given as input, but can be inferred from the number of servers which are open and from the mean service time. The number of servers opened by a given air carrier is sometimes conditioned upon the carrier’s target level-of-service standards.

Let A(t) be the *number of passengers* that have *arrived* at the facility up to time t, and D(t) the overall *number of passengers* that have already *left* the facility by time t. Of course, A(t) and D(t) are non-decreasing functions.

Passenger profiles can be properly approximated by *piece-wise linear functions* (we represent time on the x axis and number of passengers on the y axis). Furthermore, the combined arrival profiles of the passengers of all flights assigned to the same Check-In counter (or block of counters) can be summed up by using the *arithmetic* of the piece-wise linear functions, thus producing an “overall piece-wise linear profile”. It follows that we can approximate A(t) and D(t) by piece-wise linear functions.

In figure 1 we represent a hypothetical A(t) and D(t) in the case where a single flight is assigned to a given counter.

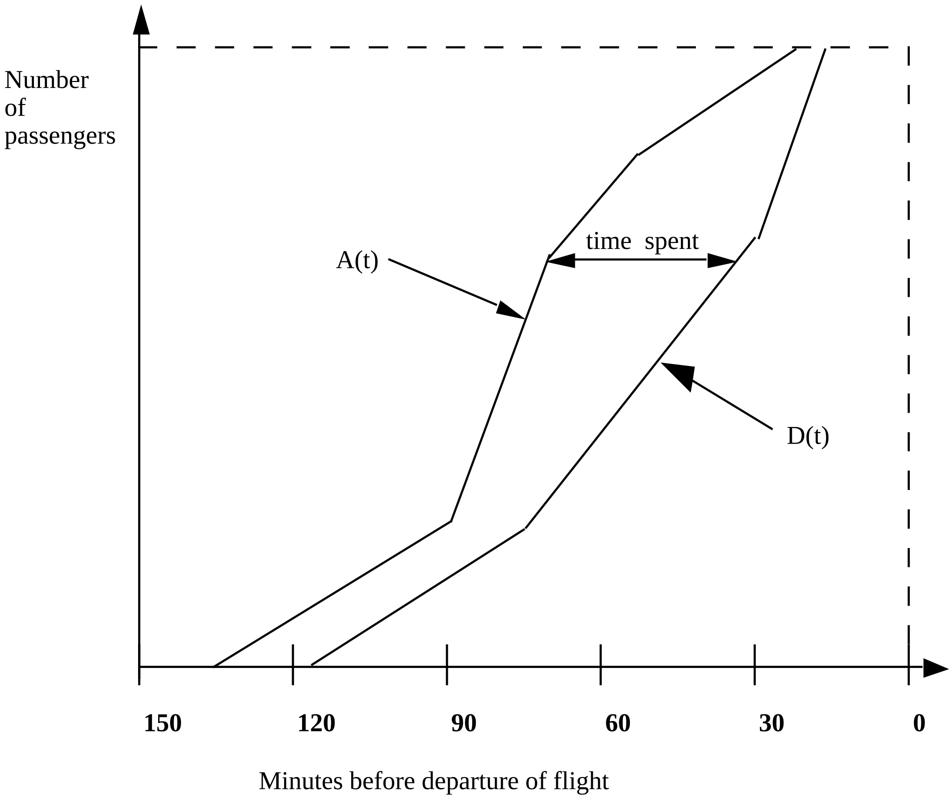

Figure 1. Piecewise linear functions (cumulative number of pax entering and leaving a counter)

If a passenger is the n-th passenger to enter the system, then his/her Dwell Time DT(n) can be computed as follows, under the natural assumption of a FIFO discipline:

$$DT(n) = D^{-1}(n) - A^{-1}(n),$$

where $A^{-1}(n)$ and $D^{-1}(n)$ are the inverse functions of A(t) and D(t). Considering A(t) and D(t) as piece-wise linear functions, their inverses are again piece-wise linear functions (and so is their difference).

SLAM can therefore provide information (rather unusual for aggregate models) such as the graphs, as functions of time, of the following quantities: cumulative number of served passengers, number of passengers in queue, number of passengers in queue per counter, number of counters together with number of passengers in queue per counter, number of counters together with expected queue time and an optimal allocation of the facility resources to reach a required level of service. Of course SLAM also estimates, during each period of interest, the average dwell time, the average waiting time, and the space and time LOS.

SLAM is made of a graphical user interface, called SLAM-Workbench (SLAM-Wkb for short) and by an engine (SLAM-Solver). The task of SLAM-Wkb is to assist the user in providing to SLAM the input data, then to start an elaboration, and finally to present graphical and textual output. The SLAM Solver is implemented in ANSI C, while the SLAM Wkb in JAVA. Both input and output files are text files composed by tables, so a person can read and manipulate them via any software package (e.g., *Excel* or *Access*) that can write a TAB spaced table; due to this fact both SLAM-Wkb and SLAM-Solver perform a specific input check.

The *input* of the program is composed by tables that contain: scheduling of the flights, terminal physical configuration, allocation of the terminal resources to manage the flights (policy data). A SLAM input has no large data requirements. A SLAM simulation (with over 800 flights) requires approximately 6 seconds of CPU on a PC Pentium 133 running under Windows 95. SLAM *output* is divided into 2 files: a textual and a graphical output file. In the *textual output file* there are the results of SLAM elaboration for each of the facility considered, while in the *graphical output file* there are the graph points and the LOS levels (where required) for plotting facility charts.

In both output files a summary table with the LOS provided by each facility is recorded. Results of a SLAM elaboration are provided for each facility or facility component. The facilities considered are: Departure Concourse, Ticketing, Check-in, Security, Passport control, Flow, Gate Lounge, Baggage claim, Customs, Arrival Concourse.

CONCLUSIONS

The validation of the models has already been conducted on the Milan airport terminal of Malpensa 2000 and on the Venice airport terminal "Marco Polo". In the current OPAL (Optimization Platform for Airports including Landside) research project, we will test the proposed models in six of the major European airports including Frankfurt, Toulouse, Madrid Barajas, the new Athens Airport and Amsterdam Schiphol.

Although both AIRLAB and SLAM model the same object, i.e., an airport terminal, they address different needs of an airport manager and may be considered as complementary to each other. AIRLAB is able to supply an extremely detailed description of all actor movements considered as a whole. Moreover the representation is dynamic, in that the evolution of system behaviour in time can be accurately reported. Therefore AIRLAB is best suited to answer tactical or operational questions and can best help in fine tuning the detailed parameters of selected facilities.

The main disadvantage of simulation lies in the amount of computation time. SLAM is a quick, simple and clear instrument to evaluate the system behaviour during its peak period of time from an aggregate point of view. The model can be usefully employed to detect and evidence the weak components of the system, and to quantitatively estimate the quality of service provided. SLAM is useful at a strategic level in the planning or designing phase when the main parameters of the considered facilities have to be chosen or when alternative scenarios have to be compared.

We think that the joint use of the two models can supply all necessary information to develop a correct and accurate analysis of any airport landside.

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