

# BOARDING GATE PROCESSES COMPUTER MODELING

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**Abstract.** With the air traffic growth in the last few decades, the term of airport capacity has become very important. For many bigger airports world wide is still harder to expand due to lack of space or environmental politics. According to this, they have to find a space for capacity growth without building a new runways, aprons or terminal halls. One possibility is optimalization of current systems using computer simulation.

This paper deals with terminal hall operations and describes basic terminal subsystems. Terms like static and dynamic capacity are defined. In the second part of the paper is shown an example of simulation on the boarding system model. Results of the simulation experiment are analyzed and the best variations are selected.

**Key words:** dynamic capacity, static capacity, terminal hall subsystem, simulation element

## 1 Introduction

Terminal hall is the busiest point in terms of capacity. A big amount of passengers, baggage, information, staff and other technical devices moves in many directions. A terminal hall consists of many subsystems which capacities are supposed to be harmonized together to provide whole system fluent behaviour.

There are three basic subsystem types in the terminal hall:

- Reservoirs
- Processors
- Connecting links

Reservoir is a place used for gathering passengers, cargo, baggage or information. Reservoir is defined by static capacity.

Processor is an active element defined by dynamic capacity. Its ineligible setup or peak hours failures can affect whole terminal hall capacity.

The last terminal hall subsystem type is connecting link. It connects reservoirs with processors. Connecting links are represented by corridors, escalators, lifts, moving pavement etc. (Table 1).

	RESERVOIRS	PROCESSORS	CONNECTING LINKS
ARRIVAL	<ul style="list-style-type: none"><li>▪ Arrival hall</li><li>▪ Passport control queue area</li><li>▪ Custom control queue area</li><li>▪ Immigration control queue area</li><li>▪ Etc.</li></ul>	<ul style="list-style-type: none"><li>▪ Passport control</li><li>▪ Secondary processors</li><li>▪ Custom control</li><li>▪ Immigration control</li><li>▪ Etc.</li></ul>	<ul style="list-style-type: none"><li>▪ Aircraft – terminal hall transport system</li><li>▪ Corridors</li><li>▪ Pavements</li><li>▪ Escalators</li><li>▪ Boarding bridge</li><li>▪ Lifts</li><li>▪ Etc.</li></ul>
DEPARTURE	<ul style="list-style-type: none"><li>▪ Departure hall</li><li>▪ Departure lounge</li><li>▪ Waiting area</li></ul>	<ul style="list-style-type: none"><li>▪ Check-in</li><li>▪ Passport control</li><li>▪ Security control</li><li>▪ Boarding control</li></ul>	<ul style="list-style-type: none"><li>▪ Aircraft – terminal hall transport system</li><li>▪ Corridors</li><li>▪ Pavements</li><li>▪ Escalators</li><li>▪ Boarding bridge</li><li>▪ Lifts</li></ul>

Table 1 – basic subsystems examples

Earlier were mentioned two capacity types:

- Static capacity
- Dynamic capacity

Static capacity shows ability of a subsystem to take amount of passengers. It depends on flooring and required space per one passenger. By constant flooring, static capacity is determined by required space per one passenger. This variable shows comfort level. For example, in peak hours more passengers gather at some area than in non-peak hours. Static capacity than increases but comfort level gets lower. Static capacity is defined by formula (1).

$$C_{stat} = \frac{flooring}{required\ space} \quad (1)$$

An ability of a subsystem to process some amount of passengers or other system element per time unit is shown by dynamic capacity. In terms of flow through the terminal hall, it represents each subsystem permeability. Dynamic capacity of whole linear system is given by subsystem with the lowest one. Formula (2) expresses dynamic capacity.

$$C_{dynam} = s_{processing} \cdot n_{devices} \quad (2)$$

Where:

$s_{processing}$  – processing speed

$n_{devices}$  – number of devices (processors)

Boarding system is a chain link connecting terminal hall and apron. It consists of reservoirs, processors and connecting links. In terms of capacity, there are defined both, static and dynamic capacity. Static capacity is given by waiting area, a place where passengers gather before embarkation. Dynamic capacity is defined by dynamic capacities of processors or connecting links.

## 2 Boarding gate processes computer simulation

The whole boarding system can appear like black box with input and output represented by passenger flow and their time distributions. An optimal boarding system can be considered one with capability of processing all passengers with desired comfort level. Simplified, to ensure fast and comfortable boarding, basic subsystems harmonization is required. In the real traffic is necessary to cope with irregularities in turnaround times, number of passengers or type of flight.

For purposes of optimization or proposals of a new system is useful computer simulation. Especially in case of large and complicated systems can be computer modeling really helpful. There are four basic steps to follow in our example simulation:

- Simulation model assembly
- Input data – model setup
- Simulation experiment
- Measured data analysis

### 2.1 Simulation model assembly

For building up our model were chosen software Witness 2007. It's based on simulation of discrete events. This product of Laners Group Company is useful instrument for design and optimization of logistic and manufactures systems.

First of all, it is necessary to have an outline of future model. Presented model example is a boarding system with loading bridge, waiting area and security control. It is simple copy of boarding system used at Prague – Ruzyně airport to board flights to countries outside the Schengen area. Model is built by simulation elements, the Witness 2007 building blocks. There are three basic groups of them:

- Physical
- Logical
- Graphical

Witness allows simple insertion of elements and connecting them by links. Following the outline, model can be assembled in the layout window (Figure1). All used elements are shown in Table 2.

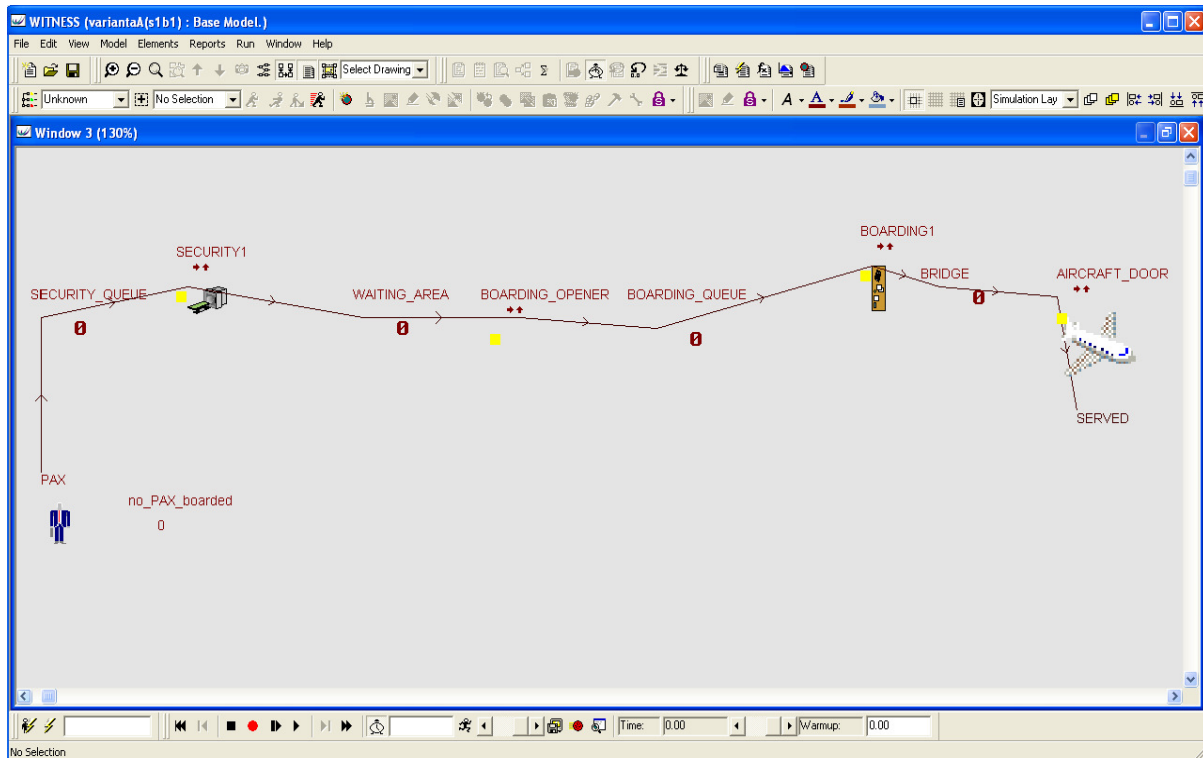


Figure 1- layout window with model of the boarding system

TYPE	NAME	ELEMENT FUNKTION
entity	PAX	Input flow 1 entity PAX represents 1 passenger
queue	SECURITY_QUEUE	Queue infront of security control
	WAITING_AREA	Gather passengers before boarding
	BOARDING_QUEUE	Queue infront of boarding control
	BRIDGE	Simulates gate corridor between boarding gate and aircraft door
activity	SECURITY	Security control
	BOARDING_OPENER	Auxiliary activity – opens gate in desired time before departure
	BOARDING	Boarding control – boarding pass control
	AIRCRAFT_DOOR	Output activity – simulates reaching passengers seat on the board
timeseries	QUEUES	Shows graph of each queue extend and its time behaviour
variable	noPAX_boarded	Number of passengers which went through the model

Table 2 - Used elements and their description

## 2.2 Input data – model setup

To provide proper run of model, it requires „feeding“ it by input data and making setup. In case of our example model, there is need of defining following:

- Definition of the time
- Number of arrived passengers
- Passenger arrival time distribution

- Dynamic capacities of activities (processors)

First important thing is to define a time scale in which will our model run. There is time running in Witness 2007 during the simulation in undefined simulation time unit. For purposes of our example model, simulation unit definition will be following:

***1 simulation unit = 1 minute***

The moment in which is simulation time equals zero is moment when the security control starts to process passengers. 30 minutes after security control start, boarding control begins to process passengers to the bridge.

Number of passengers which comes to board their flight is related to aircraft capacity. As example aircraft type was chosen Boeing 737-800 with capacity 189 passengers in economy class.

Passenger arrival on security control depends on boarding time, which is in our case 30 minutes before departure. It is obvious that passengers don't come at one moment or in even distribution. The truth is probably somewhere in the middle. At the beginning, 60 minutes before departure when security control is opened, it comes only few passengers. We suppose that most of them proceed to security control about 35 minutes before departure and again only few passengers come after the boarding time. To define this more exactly, a table of time distribution from literature [2] was used and modified. The whole 60 minutes process was divided into 30 intervals. In each 2 minutes interval comes exact amount of passengers. The sum total of all intervals is 189 passengers. Element PAX is supposed to behave like input passengers flow. By simple insertion of modified table it is programmed to control this flow following the table or graph (Figure 2).

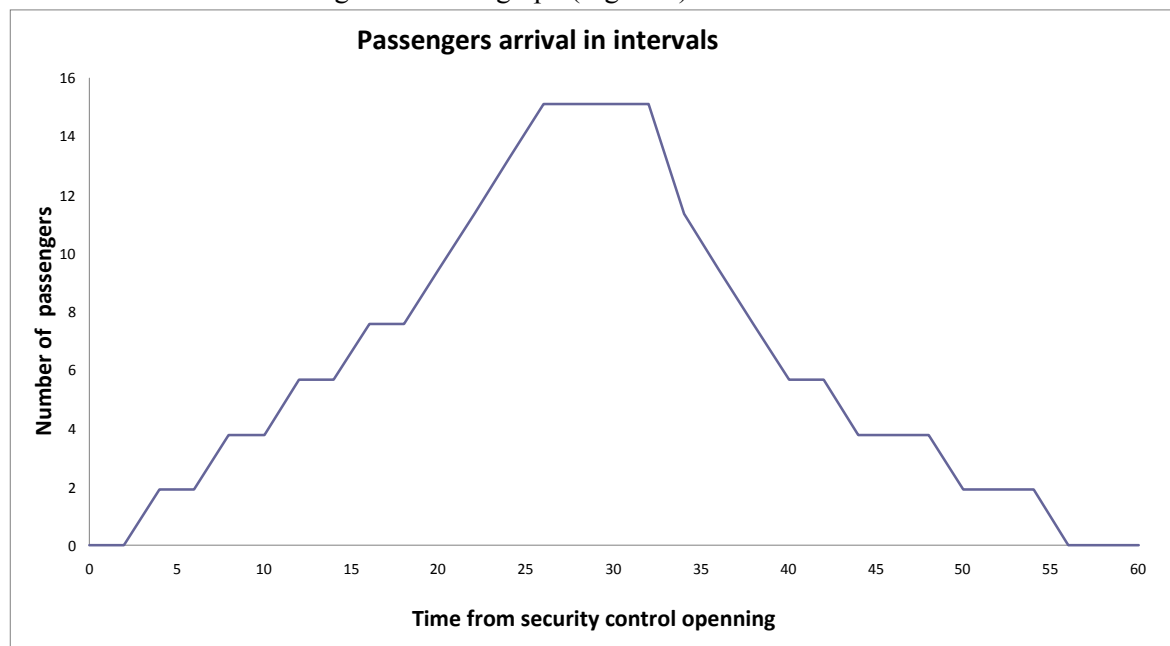


Figure 2- graph of passengers arrival intervals

Last step is definition of processors dynamic capacities. Element type activity allows setup a duration of the process. It can be simply inserted time of process duration in simulation time units or there is a choice of many statistical function and distributions. For our purpose I decided to choose the triangle function. It consists in definition maximal, minimal and medium process duration. Than the process duration is one of those three values in random sequence. Setup values for activities are in Table 3.

	MINIMUM	MEDIUM	MAXIMUM
SECURITY	0,2	0,3	0,7
BOARDING	0,13	0,16	0,21
AIRCRAFT_DOOR	0,11	0,12	0,13

Table 3 – activity setup values

Data used in Table 3 are partially result of survey made by Prague – Ruzyně airport Security control department and partially by my own private survey for purpose of diploma thesis.

### 2.3 Simulation experiment

Before start of the simulation, there is convenient to know which parameters should be observed. Their brief summary is following:

- Total time of gate occupation
- Time of closing aircraft door
- Maximal number of passengers in the waiting area
- Maximal security queue extend
- Maximal bridge queue extend
- Average delay on security control

For this purpose, 6 variants of model were created. Variants differ in number of element *SECURITY* (1,2,3) and *BOARDING* (1,2). All combinations are in the Table 4.

SECURITY	BOARDING	VARIATION
1	1	A
1	2	B
2	1	C
2	2	D
3	1	E
3	2	F

Table 4 – simulation variations

Each variation will be tested now and required parameters will be recorded. Results of simulation experiment are presented in Table 5.

variation	Gate occupation	Time of closing A/C door	Max. in waiting area	Max security queue	Max. bridge queue	Average delay on security
A	83,92	84,05	52	87	1	17,31
B	83,93	84,05	52	87	20	17,31
C	61,29	61,41	85	32	1	2,58
D	53,24	53,36	85	32	42	2,58
E	61,29	61,41	97	7	1	0,16
F	53,36	53,48	97	7	54	0,16

Table 5 - measured data

### 2.4 Measured data analysis

Analysis consists in examination of affect changing number of *SECURITY* and *BOARDING* elements and best variation selection.

After short look at measured data in Table 5 is possible to claim that number of element *SECURITY* affects following parameters:

- Maximal security queue extend
- Average delay on security control
- Maximal number of passengers in the waiting area

Element *BOARDING* affects only parameter:

- Maximal bridge queue extend

Two remaining parameters, total time of gate occupation and time of closing aircraft door, don't directly depend on *SECURITY* or *BOARDING* elements. Provided that except the number of *SECURITY* and *BOARDING* elements are other variable constant, these two parameters depends on element with lowest dynamic capacity. In fact, they represent dynamic capacity of whole boarding system.

To select a best variation is necessary to designate following conditions:

- Time of closing aircraft door < 60 minutes
- and minimal number of passengers in waiting area
- and average delay on security control

According to previous conditions, the best variations are D and F. Although variation D has higher delay on security control, there is less passengers in the waiting area which provides higher comfort level. Variation F has an advantage in minimal time which is necessary to spend in security queue. This can make some passengers disturbance. Higher dynamic capacity of variation F allows processing 63 passengers per hour more than variation D.

### **3 Conclusion**

This article refers about capacity problematic of transport airports with focused on terminal hall processes. There were defined terms like static or dynamic capacity or terminal hall subsystems. In second part of the article is shown a computer modeling example of terminal hall processes. For this purpose was used simulation software Witness 2007. A boarding system model was assembled, programmed and 6 variations were tested and analyzed.

Today computer simulation is in really wide use in many industrial or scientific disciplines. It is really helpful in those systems which are too spread out or their testing on real models is too expensive.

Example in this article is just simplification but it shows a possible ways to go by design of new systems or optimalization of current ones. With support of wide terminal hall processes survey can be assembled very exact models.

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