Queuing model for improving airport passengers treatment process

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Abstract

The objective of this work is the optimization of the passenger treatment chain at Fez-Sais airport. Our approach is articulated around a systematic analysis of the passenger treatment process in order to detect its constraints, illuminate the possible improvements and develop a method to improve the process. For that reason we have used the flow and process diagram as well as the queuing theory.
The discounted result is the enhancement of the passenger's service quality, while decreasing the time of waiting and eliminating bottlenecks, via the improvement of the forecasting, scheduling and resources affectation processes at the level of different modules of the chain.

Keywords
Passenger flow; Waiting time; Flow diagram; Queuing theory; Process improvement

Introduction

Passengers at the airport expect a smooth and personalized treatment, but the multitude of actors and occupations with divergent interests, different constraints and priorities, and consequently divergent and autonomous processes, make the fast service expected, sometimes perceived as unpleasant and this due to the multiplicity of controls, the cumbersome registration procedures and queues that passengers confront.
The speed and fluidity of treatment with a better quality of service constitute strong demands from passengers. So how can we reconcile the fluidity expected by passengers and the divergency of airport processes?
The systematic analysis of the passenger treatment process will be our approach to detect the constraints, to enlighten the possible improvements and to develop a method in order to enhance the process. To this end we use the flow diagram and the queuing theory.
Our goal is to improve the quality of passenger service by reducing waiting times and eliminating bottlenecks through improving forecasting, planning and resource allocation in the various components of the system.

1. Service Quality at Airports (Passenger Terminal)

1.1. Service quality dimensions

Airports have become more than just a port that people travel through on their way to their destination, with many now operating as hubs that send passengers around the world. These Hubs work to create economies of scale by pooling demand for destinations and regular flights.
Airport customers are considerably varied and involve passengers, airlines, employees, concessionaires, tenants and others. Despite their differences, however, all these customers are at the airport for the sole purpose of transferring from ground based to air modes of transportation (Fodness and Murray, 2007). In this study, we chose to focus on

air travelers – the end users of airport facilities and services- since their satisfaction is the key to business success(Jagoda and Balasuriya, 2012) (passengers' satisfaction is increasingly important that may affect reputation and long term profits of airports). This satisfaction occurs when airport service quality fulfill or exceed the passenger expectation. Airport service quality is become important and be an index or benchmark for passengers to take in count as a destination.

The terms of airport service quality are hardly to be defined. Dimensions to study airport service quality are different due to every airport operation and design is slight different. Thus, (Fodness and Murray, 2007) stated the nature of expectations underlying airport service quality perceptions is unclear. Airport receives air travelers from different countries around the world; different countries possess different types of culture. Therefore, passengers will have different perceptions with a same situation which increases the difficulty for airport management to tackle passenger satisfaction.

In assessing the quality of airport services, some authors ((Chou and al., 2011) and (Erdil and Yildiz, 2011)) developed criteria according to the classical dimensions of the SERVQUAL methodology (tangibles, responsiveness, reliability, assurance and empathy): (Erdil and Yildiz, 2011) assessed quality according to 22 criteria, while (Chou and al., 2011) supplemented the quality dimensions with the flight pattern group of criteria and used a set of 28 criteria (Pabedinskaitė and Akstinaitė, 2014). While (Lubbe, Douglas and Zambellis, 2011) claim that the main measure of assessment of airport operations is the opinion of passengers, hence it is highly important to analyze passengers' expectations in respect of airport services. It is they who must define and evaluate services. Based on the model proposed by Fodness & Murray (2007), the authors conducted a study at the O.R. Tambo International Airport (South Africa), during which they investigated three areas of services provided by the airport. The first area is the interaction described by the speed of processing complaints, individual attention, and the speed of responding to queries. The second one is the function made up of two groups of parameters: one of them described effectiveness (exterior signs, airport service signs, physical layout, the variety of means of transport ensuring accessibility, convenient location of baggage trolleys, availability of connecting flights), whereas the other group of criteria characterizing efficiency covered luggage waiting time, registration speed, duration of unloading of passengers from the aircraft. The third area of assessment of airport operations, namely, diversion, consisted of three groups of criteria: maintenance (retail supply, supply of restaurants offering local cuisine, supply of stores reflecting traditional local culture), décor (the environment consistent with local culture, various artistic expressions, interior) and productivity (services of conference organization, the presence of business centers, the presence of silence zones) (Pabedinskaitė and Akstinaitė, 2014). Based on a functional approach, and according to the viewpoint of the passenger, the main groups of activities in the airport terminal involve (Popovic et al., 2009): process activities (that cover, in the case of departing passengers for example, the passenger flow from check-in, security screening, until boarding) and discretionary activities (which comprise what the passengers are able to do with their slack time in the terminal). Passenger perception of quality regarding the processing activities, has been commonly related to the efficiency of the processes, short waiting times, and the positive attitude of the service staff (Caves and Pickard, 2000; Fodness and Murray, 2007; Rhoades et al., 2000). As for the discretionary activities, a set of factors must be taken into consideration including passenger perception of leisure/convenience alternatives and airport servicescape, i.e., the physical setting in which a service is performed, delivered, and consumed (Bitner, 1992; Bogicevic et al., 2013; Mari and Poggesi, 2011; Bezerra and Gomes, 2016).

1.2. Waiting time as a factor of Service Quality at Airports

In this work, we have chosen to study the first category of activities which is the process activities by addressing more specifically the waiting time of the passengers at the various modules of the chain.

While some passengers perceive waiting times as an opportunity for relaxation, something that enables them to escape the fast paced routines (Vannini, 2012) by doing a variety of things, such as shopping, eating, watching movies on a computer, using the restrooms, working, etc ..., others consider it a waste of time. This contradictory perception can be justified by the nature of traveler (for example Western cultures often celebrate 'being busy' and inscribe 'being idle' with negative Associations (Ehn and Löfgren, 2010)), the financial situation of the passenger (While some travelers deal with waiting by using the paid services of the airports, less affluent travelers are not always able to afford airport services), by the waiting place (queuing at security checkpoints requires travelers to follow strict procedures and rules regardless of how uncomfortable and annoying it may be and participants feel uncomfortable and stressed at the security check, which is seen as the most unpleasant experience while waiting in an airport (Blichfeldt, Pumputis et Ebba, 2017)), etc...

The International Air Transport Association (IATA) links quality of service at an airport terminal to its ability to handle customer requests for a specified period of time. The quality of service is transcribed by IATA in the form of a valuable scale in 6 levels:
Level A: excellent level of service, free flow conditions, no waiting time, and excellent level of comfort.
Level B: High level of service, stable flow conditions, very short waiting times, and high level of comfort.
Level C: Good service level, stable flow conditions, acceptable waiting times, and good level of comfort.
Level D: suitable level of service, unstable flow conditions, acceptable delays for small periods, and suitable level of comfort
Level E: insufficient level of service, unstable flow conditions, unacceptable delays, and insufficient comfort level.
Level F: unacceptable level of service, crossing of flow conditions, system breakdown, unbearable delays, and unbearable comfort level.
Also IATA considers the waiting time to different modules of treatment as a key factor of the quality of service.

Table 1. Maximum waiting time recommended by IATA

<table>
<tr><th rowspan="2">Module</th><th>A</th><th>B</th><th colspan="2">C</th><th>D</th><th>E</th></tr>
<tr><th colspan="3">Waiting time
Short to acceptable</th><th colspan="3">Waiting time
Acceptable to long</th></tr>
<tr><td>Check in Economy</td><td colspan="3">0 – 12 minutes</td><td colspan="3">12 – 30 minutes</td></tr>
<tr><td>Check in Business Class</td><td colspan="3">0 - 3 minutes</td><td colspan="3">3 – 5 minutes</td></tr>
<tr><td>Security</td><td colspan="3">0 - 3 minutes</td><td colspan="3">3 – 7 minutes</td></tr>
<tr><td>Passport control Inbound</td><td colspan="3">0 – 5 minutes</td><td colspan="3">5 – 10 minutes</td></tr>
<tr><td>Passport control Outbound</td><td colspan="3">0 – 7 minutes</td><td colspan="3">7 – 15 minutes</td></tr>
<tr><td>Baggage Claim</td><td colspan="3">0 – 12 minutes</td><td colspan="3">12 – 18 minutes</td></tr>
</table>

Source: Capacity of passenger terminals technical guide, technical service of civil aviation France

Table 1 shows the maximum wait times, in minutes, recommended by IATA for each processing module based on quality of service. This time depends on a complex airport system by its actors, its structure, and its processes. So understanding this system will help us to optimize this time in order to improve passenger's service quality.
As reported by (Wu and Mengersen, 2013) airport models can be classified into four groups : capacity planning, operational planning and design, security policy and planning, and airport performance review and can be analytic, simulation, and hybrid approaches as well. They require different levels of detail (e.g. macroscopic, microscopic, and mesoscopic) and have deterministic and stochastic characteristic (Wu and Mengersen, 2013) and (Zografos and Madas, 2006)). The models capture different performance metrics for 'operational efficiency', including service time, queue length, and congestion (Alodhaibi and al, 2017).
Queuing Theory that we used at the level of this work has been widely applied within the airport system to optimize processes. Analyzing a system using queuing theory provides insight into the queue lengths and waiting times according to the passenger (Dwet, 2010). From the viewpoint of a service provider it involves the number of employees and technological equipment which are needed to maintain queue parameters at acceptable level (Vokáč, Lipták, and Lánský, 2016). This theory is a mathematical approach based on the study of automatic telephony equipment carried out at the beginning of the 20th century by the Danish telecommunications engineer, A. K. Erlang. Queues form when clients arrive randomly to get served. Several general approaches for the performance approximation of time-dependent queueing systems are discussed in literature (see the overviews in (Ingolfsson and al; 2007) and (Stolletz; 2008)). In our case we have chosen to use "Infinite" Population Queue Model.
The data necessary to feed the model are obtained following a meticulous analysis of the passenger's treatment process. Thus, and as an example, the amount of time at each stage where the passengers wait for available counters or booths, where they are to be processed, when they move, or kill time are examined for all international departure/arrival passengers.

2. Modeling, Measurement and Analysis

Upon arrival at the airport, the passenger initiates a treatment process, consisting of formalities and a transport or delivery service of the luggage. This process is characterized by the multiplicity of actors. The diversity of their interests and responsibilities complicates the chain organization; however each of their individual interventions contributes to the success or failure of the passenger treatment process along this chain.

This process can be broken down into two sub processes arrival and departure, given the particularity of each treatment phase. Mastering the weak link, the organization of interfaces and the involvement of each actor are essential to the success of the overall performance.

2.1. Departure sub process

The Departure sub process is a succession of processing modules, namely registration; immigration and boarding that allow passengers to make the necessary formalities to access the plane (see figure1). This sub process is linear where each passenger obtains the same basic service by moving through a series of standardized steps and from one operation to another according to a predetermined sequence. For the analysis of this sub-process, we will firstly use the flow diagram in order to trace the flows, according to which the passengers pass through the sub-process, and secondly the process diagram whose aim is conducting a temporal diagnosis of the steps and operations, grouped into five main categories: Operations, Move, Inspection, Waiting and Storage. The objective is to have quantified data, understand the progress of activities and detect all the interesting detail in order to deduce the phase or step that must be subject of future consideration to improve the sub process (see table2).

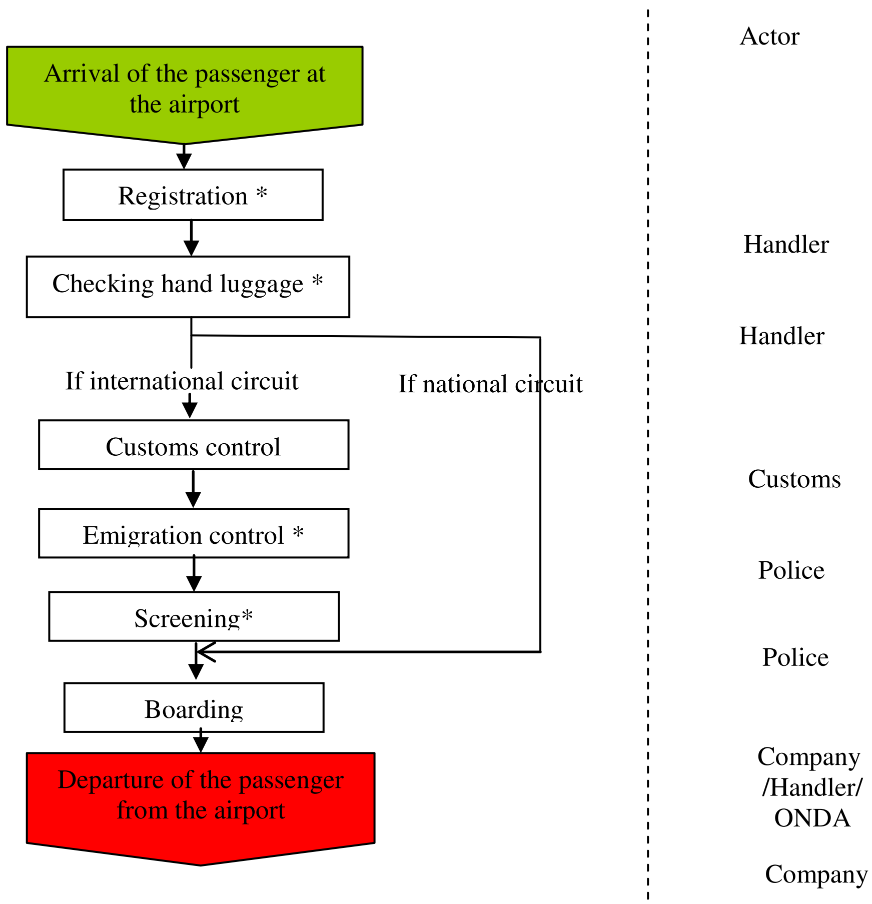


Figure 1: Flow diagram of passengers on departure

* Critical to the success of service delivery (contact staff, allocated resources, service capacity, waiting time, capacity of the waiting area).

Table 2. Diagram of the sub process Departure

Sub process :	Treatment of passengers at departure
Object :	Ensure the continuity and the necessary facilities for passengers traveling to another country or another city
Start :	Arrival of the passenger at the airport
End :	Boarding

Activity		**Number of steps**	**Duration minute**	**Distance meters**
Operation	⬭	**5**	**1,76**	
Move	➡	**5**	**0,91**	A few meters
Inspection	▣	**0**		
Waiting	D	**5**	Several minutes	
Storage	▽	**0**		

Step n°	**Average duration (second)**	**Travel Distance (Meter)**	⬭	➡	▣	D	▽	**Step description**
1	20s	few meter		X				the passenger arrives at the airport and shows up at the registration room (queue)
2	Several minutes					X		the passenger waits his turn at the queue
3	56s		X					the passenger arrives at the check-in counter to register
4	20s			X				the passenger is directed to the control hand luggage interface
5	Several minutes					X		the passenger waits his turn at the queue
6	12s		X					checking hand luggage
7	5s	few meter		X				the passenger shows up at the emigration room
8	Several minutes					X		the passenger waits his turn at the queue
9	40s		X					the passenger carries out the emigration formalities
10	5s	few meter		X		X		the passenger moves to the security check post
11	12s		X					an Inspection is performed by the police
12	5s	few meter		X				the passenger moves to the boarding lounge
13	Several minutes					X		the passenger is waiting to be embarked
14	10s		X					Checking boarding passes

The summary of this diagram shows that the waiting time of passengers at the different stages before each operation is several minutes, while movements and operations do not exceed 3 minutes. This waiting time is mainly due to resources put in place for each operation, since the travel time between these operations is negligible. We can conclude that the challenge is how to manage a variable demand by adopting a methodical approach based on capacity planning (resources) appropriate to the situation, to loads (temporary demands) at the various modules and interfaces of the departure sub-process.

The trigger element of the sub-process is the presentation of the passenger to the module registration; it is the capacity of this module that allows defining the capacity of the other modules by the flow that it generates.

This flow is one of the determining factors of the resources to be set up at the level of the other modules in order to avoid bottlenecks, especially if the passenger treatment rate at the hand baggage control interface or at the module control emigration does not match with the registration rate, a queue will then form between the location of these two operations.
The waiting time for passengers at Registration is bound to the passenger arrival rate, thus the allocation of resources at this level is a decisive factor in decreasing this time. For that, and to infer the rate, we conducted a count of passengers waiting to be registered for 80 minutes (the time reserved for recording) at intervals of 20 minutes for a sample of 29 flights. The analysis of results of these observations allowed us to deduce the percentage of passengers arriving at the registration area during the first hour period (see figure 2).

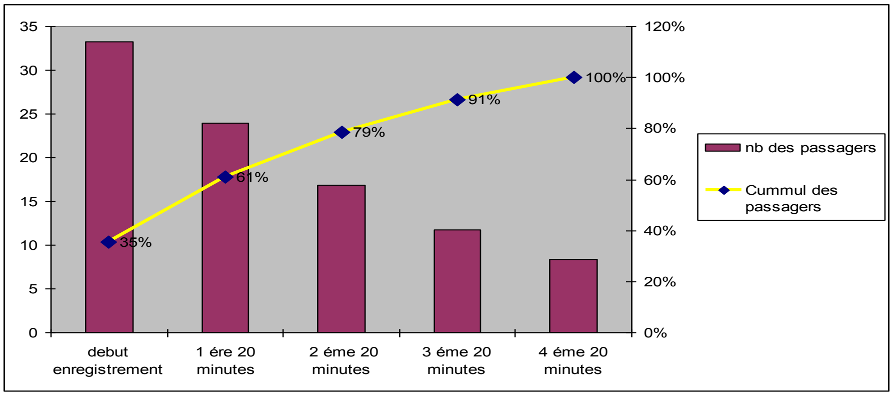


Figure 2. Number of passengers waiting for 20 minute time intervals

Analysis of this histogram shows that 90% of passengers arrive at the registration post in the first hour, and that 10% of passengers arrive in the last twenty minutes. Based on the registration rate, and assuming that a large percentage of passengers registering, are moving to checking hand luggage (as we have had great difficulty in identifying the behavior of passengers this level), it is possible to calculate the duration (in minutes) and the number of passengers in queues in front of the hand baggage check station and of course in front of the emigration control post.
The following formula calculates the number of passengers and the duration of their waiting time:

$$\textbf{Waiting Time} = \frac{\textbf{Passenger flow} \times \textbf{average duration of checked hand luggage}}{(\textbf{Number of checks} \times 60)} \quad \text{(During 10 minutes)}$$

Number of passengers in queues = (maximum duration × passenger flow) / 10 (During 10 minutes)

Table 3. Number of passengers in queues and waiting times at the hand baggage control interface

Number of registration counters	1	2	3	4	5	6	7
Waiting time / 10 minutes *(with a single checkpoint)*	3mn	5mn	8mn	11mn	13mn	16mn	19mn
Waiting time / 10 minutes *(with two checkpoint)*	1mn	3mn	4mn	5mn	6mn	8mn	9mn
Number of passengers in queues / 10 minutes *(with a single checkpoint)*	3	11	26	46	72	103	140
Number of passengers in queues / 10 minutes *(with two checkpoint)*	1	6	13	23	36	52	70

Table 3 shows that, based on the counters used, the number of passengers in queues and waiting times decreased by 50% with two hand baggage checkpoints, that with only one checkpoint.
From the hand baggage-checking rate, the number of passengers in the queues and the duration of their waiting time in front of the emigration control post are given in Table 4.

Table 4. Number of passengers in queues and waiting times for hand baggage checkpoints

Number of emigration control counters	1	2	3	4	5	6
Waiting time / 10 minutes (with a single hand bag checkpoint)	32mn	16mn	11mn	8mn	6mn	5mn
Number of passengers in queue / 10 minutes (with a single hand bag checkpoint)	128	64	43	32	26	21
Waiting time / 10 minutes (with two hand bag checkpoints)	64mn	32mn	21mn	16mn	13mn	11mn
Number of passengers in queue / 10 minutes (with two hand bag checkpoints)	512	256	171	128	102	85

Data analysis shows that as the number of counters used increases, the number of passengers in queues and waiting times decrease (see table5).

Table 5. Number of passengers in queues and waiting times in the Posts of Inspection/ Filtering (PIF)

Number of emigration counters	1	2	3	4	5	6
Waiting time / 10 minutes (with only one PIF)	3mn	6mn	9mn	13mn	16mn	19mn
Number of passengers in queue / 10 minutes (with one PIF only)	4	16	35	63	98	141
Waiting time / 10 minutes (with two PIFs)	2mn	3mn	5mn	6mn	9mn	9mn
Number of passengers in queue / 10 minutes (with two PIF)	2	8	18	31	49	70

2.2. Arrival sub process

The sub-process arrival is a succession of two treatment modules, namely immigration, and luggage delivery (see figure3). Also for the analysis we will follow the same steps as for the sub-process departure (see table 6).

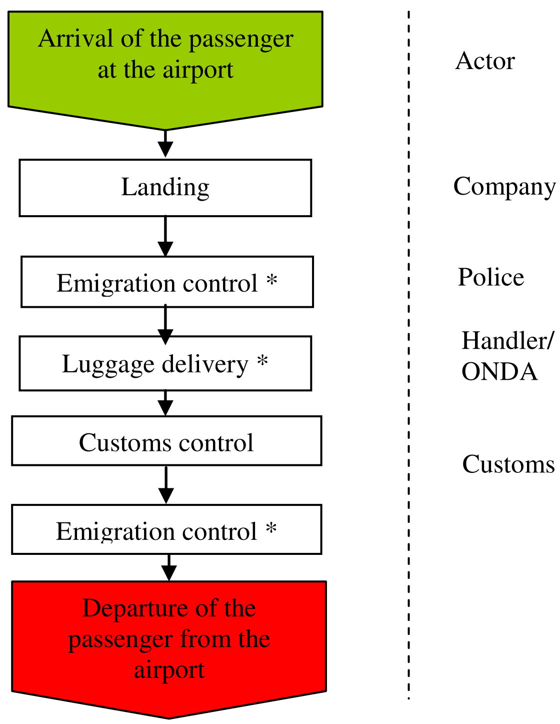


Figure 3. Flow diagram of passengers on arrival

* Critical to the success of service delivery (contact staff, allocated resources, service capacity, waiting time, capacity of the waiting area)

The summary of this chart shows that the waiting time for passengers at the immigration control and luggage delivery stages is several minutes, while moves and operations do not exceed 3 minutes. The flow of passengers at the immigration module level increases in proportion to the open immigration counters (see table 7). Thus, in order to reduce the waiting time, the luggage delivery operation must be accelerated.

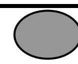
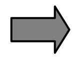
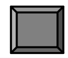
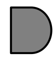
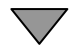
Table 7: Flow of immigration counters

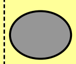
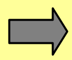
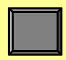
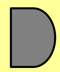
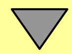
Number of immigration counters	1	2	3	4	5	6	7	8	9	10
Passenger flow / 15 minutes	19	38	56	75	94	113	131	150	169	188

The waiting time variable, which is the most important element in ensuring passenger quality, is directly linked to the resources allocated to all modules. So a good fit capacity is the only solution to ensure better passenger satisfaction.

Table 6. Diagram of the sub process Arrival

Sub Process:	Treatment of passengers at arrival
Object :	Ensure the continuity and the necessary facilities for passengers coming to another country or another city
Start :	Arrival at the airport
End :	Departure from the airport

Activity		**Number of steps**	**Duration (minutes)**	**Distances (meters)**
Operation		2	0,96	
Moves		3	1,16	few meters
Inspection		0		
Waiting		2	Several minutes	
Storage		0		

Step n°	**Average duration (second)**	**Distance to be traveled (meter)**						**Step Description**
1	60s	Few meters		X				the passenger arrives at the airport aboard an plan and joins the arrival room (immigration control)
2	Several minutes					X		The passenger waits his turn at the queue
3	48s		X					the passenger carries out the immigration formalities
4	5s			X				the passenger moves towards the luggage delivery room
5	Several minutes					X		The passenger awaits the delivery of his luggage
6	5s	Few meters		X				the passenger moves towards customs control
7	10s		X					the passenger undergoes customs control

3. Improvement and optimization

The process of handling passengers covers several operations and their useful capacity is often different because the resources allocated by each actor are not always coordinated with the other ones in the chain but judged according to its interests, constraints and priorities. This creates either bottlenecks (therefore an unacceptable waiting time for passengers and a degraded quality of service) or an unoccupied resource and then a lost value for the entity and also for the airport that can be deployed to another module to improve the service quality.
Our optimization reflection consists of a dynamic management method based on the theory of the queue whereby and from the forecast of the passenger's number per flight, we will deduce the resources to be set up at each module in such a way to reduce wait times and eliminate bottlenecks.

3.1. Queuing Theory

3.1.1. "Infinite" Population Queue Model

Several models of queues are available to managers to design systems for the production of goods or services or to represent a real system in order to analyze their performance. Among these modules: the Multiple Servers module and exponential service time. Table 7 shows the symbols and terminology used for models with infinite population.

Table7. Symbols and terminology for models with infinite population

λ :	Client arrival rate
μ :	Service rate
A :	System utilization rate
Na :	Average number of clients waiting to be served
N :	Average number of clients in the system (customers waiting and customers being served)
1/μ :	Service time
Ta :	Average waiting time in queue
T :	Average waiting time in the system (queue waiting time, plus service time)
P0 :	Probability of zero unit (client) in system
Pa :	Probability that there are n units (clients) in the system
S :	Number of servers

3.1.2. Basic relationships

The main relationships for determining the desired performance measures are presented in the table 8:

Table 8. Main relationships for determining the performance measures

	File for a server	**File for S servers**
The system utilization rate	A = λ/μ	A = λ/sμ
Probability of empty system (P0)	1-A	$\frac{1}{\sum_{k=0}^{S-1}\frac{A^k}{k!}+\frac{A^S}{S!}\frac{1}{1-A/S}}$
Probability of waiting (Pa)	A	$P0\cdot\frac{A^S}{(S-1)!(S-A)}$
Average number of clients in the system (<N>)	$\frac{A}{1-A}$	$A(1+\frac{Pa}{S-A})$
Average number of clients waiting (<Na>)	$\frac{A^2}{1-A}$	$A\cdot\frac{Pa}{S-A}$
Average number of clients in service (at the counter) (<Ns>)	A	A
Average time spent in the system (T)	$\frac{1}{\mu}\cdot\frac{1}{1-A}$	$\frac{1}{\mu}\cdot(1+\frac{Pa}{S-A})$
Average waiting time (T_a)	$\frac{A}{\mu(1-A)}$	$\frac{Pa}{\mu(S-A)}$
Condition of achievement of balance ("without congestion")	$\frac{\lambda}{\mu}<1$	$\frac{\lambda}{S\mu}<1$

Source: Operations Management: Products and Services 3rd Edition, William J. Stevenson, Claudio Benedetti, 2011

These models only apply to non-congested systems. There is no point in analyzing systems in which λ>sμ because it is obvious that in such cases they are congested

The average number of clients waiting in queue (Na) is the key element in determining other system performance measures, such as the average number of clients in the system, the average time in queue and the average time spent in the system. Therefore, when solving problems with queues, the first performance measure to consider is Na.

3.2. Chain optimization

The analysis of the two diagrams Departure and Arrival sub-processes showed that the only factor affecting negatively the passenger's service quality at the various modules and interfaces of the chain is the waiting times given the tangible character he reflect.
Our optimization approach then, aims to define a procedure that will bring the necessary and sufficient improvements to the processes by acting on its temporal aspect. The time factor is directly related to the number of servers set up and their treatment capabilities. To do this we use the principles of queuing theory to develop a dynamic tool that will allow us to forecast, plan and allocate resources optimally at each module level.
We will use the Microsoft Excel calculation software and apply the formulas of the above-mentioned queuing theory (see table 9)

Table 9. Application of queuing theory formulas

REGISTRATION MODULE

Treatment at the 1st hour

Insert number of passengers	**177**
Passenger arrivals / hour	**159,30**
Rate of service in number of passengers / hour	**64,29**
A	2,48

Number of control points to be set up: **3**

Occupancy rate **83%**

NB of counters	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Average number of passengers in queue / hour			3,275	0,509	0,12433	0,03217	0,00809
Average number of passengers in the system / hour			5,753	2,987	2,6023	2,5102	2,4861
Average time spent in the system / hour			0,036	0,019	0,016	0,016	0,016
Average wait time in queue / hour			0,0206	0,0032	0,0008	0,0002	0,0001

Treatment in the last 20 minutes

Number of passengers expected	17,7
Rate of arrivals passengers / hour	53,10
Rate of service in number of passengers / hour	64,29
A	0,83

NUMBER OF COUNTERS TO BE ESTABLISHED: **1**

OCCUPANCY RATE 83%

NB of counters	**1**	**2**	**3**	**4**	**5**	**6**	
Average number of passengers in queue / hour	3,921	0,170	0,021	0,003	0,00033	0,00004	0,00000
Average number of passengers in the system / hour	4,747	0,996	0,847	0,829	0,8263	0,8260	0,8260
Average time spent in the system / hour	0,089	0,019	0,016	0,016	0,016	0,016	0,016
Average wait time in queue / hour	0,074	0,0032	0,0004	0,0001	0,0000	0,0000	0,0000

CONTROL HANDBAG INTERFACE

Passenger flow / hour	**192,86**	**Number of control points to be set up:**	**OCCUPANCY RATE**
Rate of service / hour	**240,00**	**1**	**80%**
A	0,80		

NB of control points	**1**	**2**
Average number of passengers in queue / hour	3,287	0,155
Average number of passengers in the system / hour	4,091	0,958
Average time spent in the system / hour	0,021	0,005
Average wait time in queue / hour	0,017	0,001

Our main entry data is the number of passengers planned for a flight or given flights. The output data are the resources to implement. For a departure flight the resources will be:

- The number of registration counters to open at the first hour and the number of counters to open the next 20 minutes;
- The number of checkpoints for hand luggage and the number of emigration counters;
- The number of PIF (Inspection /Filtering posts);
- The average number of passengers waiting in queues and system and the average waiting time in queues and system.

For a flight or several flights on arrival, the output data will be:

- The number of immigration counters to be set up;
- The average number of passengers waiting in queue and system;
- The average waiting time in queue and system.

As a result (screenshots below) we can simulate the resources to be implemented in such a way as to reduce the waiting time to the maximum.
Analysis of the results of this tool shows that at the level of:

- The registration module, we do not need to retain the same human resources after the first hour of treatment. They can be redeployed in boarding module for control of boarding passes and the preparation of passengers for flight.
- The emigration module, the minimum number of resources to be used is 4 counters (i.e. 4 agents) given the passenger flow from the baggage checkpoint.
- The immigration module, with a passenger number exceeding 120, we have to use all the resources (the 10 counters) because all the passengers show up at the arrival room within 10 minutes after the arrival of the flights.
- The luggage delivery module, the flow from the immigration counters is very large, so luggage delivery must be very fast to avoid congestion and excessive waiting time especially in the case of simultaneous flights.
- The RMP (Reduced Mobility) counters must be used for more performance considering the limited percentage of RMP passing through the airport. If a PMR is present, it must have priority in terms of formalities.

Conclusion

The tool we have proposed provides help in making decisions on resources to implement at each module, in order to reduce passenger waiting time. However, it remains inadequate without close cooperation between all actors in the airport chain.
To attend this co-ordination, it is necessary to give each actor a vision of his / her role in the achieving of the overall performance, bringing the different actors together in a working group or a think-tank to share information, make decisions and solve problems related to each flight

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