

AXIOMATIC DESIGN OF AN AIRPORT PASSENGER TERMINAL

Joan Bruno Rodríguez Pastor

joan.rodriguez@altran.es
Altran
Calle Campezo 1,
28022 Madrid, Spain

Efrén M. Benavides

efren.moreno@upm.es
Universidad Politécnica de Madrid
Department of Aerospace Propulsion
Pza. Cardenal Cisneros, 3
28040 Madrid, Spain

ABSTRACT

In architectural or civil engineering problems, like the functional design of an airport passenger terminal, complexity increases when the obligatory functional aspects of the infrastructure meets customers' needs. With the use of Axiomatic Design, this paper explores new ways of addressing the functional design problem of an airport terminal. Such buildings are characterized by the presence of a vast number of stakeholders interacting simultaneously, and whose necessities present a huge variety and variability. In such a framework, this paper shows how Axiomatic Design becomes optimal in order to find the minimum set of functional requirements that establish the basic topology of a passenger terminal at a small Spanish tourist airport.

Keywords: airports, passenger terminal, functional design, axiomatic design.

1 INTRODUCTION

The design of an airport passenger terminal requires the consideration of an enormous number of variables due to the number of stakeholders involved in all of the activities taking place in such an infrastructure. Apart from that, the passenger terminal must be optimized for a very wide range of air traffic densities that strongly depend on seasons, peak days, peak hours etc. Moreover, the infrastructure conceived must be valid for the current and the future air traffic demand which fluctuates around the predicted number of passengers and airplanes movements. Therefore, it is possible to establish that robustness should be a design target. On the other hand, passengers' needs are fulfilled when their transfer from the landside to the airside is optimally accomplished with the minimum process time and minimum emotional implications. Additionally, a large number of non-passenger stakeholders (such as handling companies, airlines companies, security companies, etc.) organize their activities to provide all of the processing facilities needed to ensure optimal management of passengers' departures and arrivals, while guaranteeing an excellent level of service with the minimum time required and the maximum security ensured. All of these aspects confer to the terminal design problem a high degree of complexity.

The preliminary stage of an airport's conceptual design, also called "quick dimensioning," can be performed by the use of formulae that can vary according to each national regulatory authority, airport manager or international

organizations [Ashford, 1988], such as the British Airport Authority (BAA), the Federal Aviation Authority (FAA), Aéroports de Paris, Aeropuertos Españoles y Navegación Aérea (Aena) or the International Aviation Transport Association (IATA). These formulae should ensure a certain level of service and serve as a guideline to establish the relation between typical design parameters such as level of service, peak day, peak departures hour, peak arrivals hour, busy hour, aircrafts movements per hour etc. and the infrastructure needed to satisfy them (number of check-in counters, restaurant surfaces, etc.) [FAA, 1988 and IATA, 2004]. Once the basic dimensions and infrastructures are estimated, their distribution and configuration are established according to architectural and functional criteria. Very often this task is done by selecting, among the solutions applied in other airports, the ones that best match the necessities identified. What needs to be mentioned here is that between the dimensioning step and the lay-out configuration stage, the passengers' necessities might be forgotten [IATA, 2004].

Traditionally, the airport engineering literature has studied the issue of the conceptual design of passenger terminals [Ashford, 1992 and Horonjeff, 1994]. In this paper, a new way of approaching the functional design of an airport passenger terminal is explored with the use of Axiomatic Design [Suh 1990 and Suh 2001], particularly, with the aim of solving simultaneously the dimensioning and the lay-out problem, and finding the minimal set of functional requirements that define the basic topology of the terminal building.

The case in this study is a generic, small Spanish tourist airport. This paper describes the results found for three main functional areas of the departures process: the departures curb, the departures concourse & the check-in hall and departures lounge.

In order to present the aforementioned results, this article describes in Section 2 the formulation of the design problem, where methodological aspects, definitions and restrictions are established. Further, in Section 3 the design of the three main functional areas is carried out, and the resultant topology of the terminal building is presented. Finally, conclusions and references close the study.

2 FORMULATION OF THE DESIGN PROBLEM

2.1 DEFINITIONS

Aerodrome: "defined area on land or water (including any buildings, installations and equipment) intended to be

used either wholly or in part for the arrival, departure and surface movement of aircraft.” [ICAO, 2004]

Airport: aerodrome where permanent facilities and services exist to regularly assist air traffic, to allow parking and repairs of aerial material and to receive and process passengers or freights.

Passenger Terminal: “primary processing interface that lies between the various modes of surface access and airside infrastructure systems.” [IATA, 2004] Therefore, the passenger terminal constitutes an exchanger of transportation modes that brings passengers from the landside to airside through a series of functional steps.

Functional Design: preliminary stage of the conceptual design where the basic topology of the airport and its basic dimensions are fixed. Given a passenger flux as a function of time, during the functional design the areas of the terminal used for accomplishing different functionalities must be sized, shaped and located side by side in order to ensure the correct connection between them. For example, the departures curb, the check-in hall and the departures lounge are functional areas to be defined, whereas the number of check-in desks, passport control positions and security screening check points are functional elements to be placed in the functional areas.

2.2 METHODOLOGY

The design of the departures functional areas must ensure that passengers go through all of the procedures needed to bring them from the landside to the airside in an optimal way and in the minimal time required. Figure 1 depicts the passengers’ departures process.

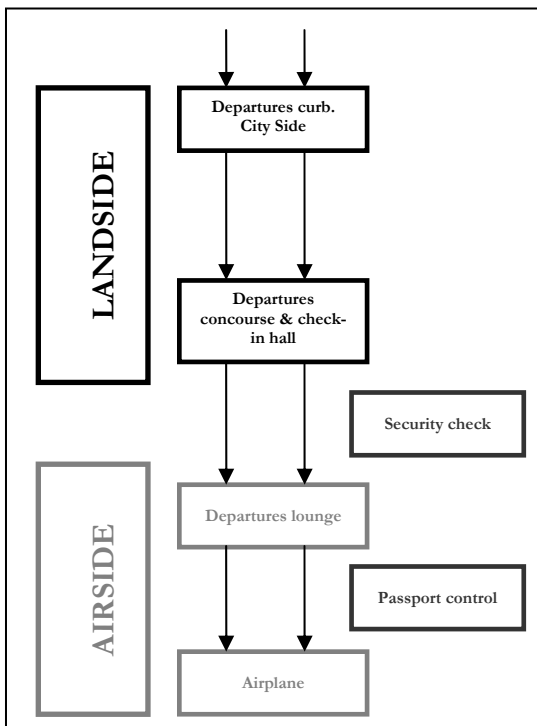


Figure 1. Passenger departures process.

As it can be seen, in their process from landside/airside passengers must go through three main functional areas: the departures curb, the departures concourse & check-in hall and the departures lounge. Obtaining the main characteristics

(shape, size, lay out) of these spaces is the object of the present study, and their design is presented in Section 3.

The concept of the solution proposed is based on the analysis of the path followed by each type of passenger in departures (tourist, non tourist, disabled, etc.). Indeed, in order to establish the list of functional requirements of each functional area, an inquiry was done to survey customers’ needs. All of the information obtained in the customer domain was analyzed with the use of the independence axiom first and with the information axiom later [Suh, 1990]. As a consequence, customers’ necessities were translated into the minimum set of independent functional requirements pertaining to the first level of hierarchy. This set should take into consideration the basic functions that each area should accomplish in order to fully ensure passengers’ satisfaction.

Generally, customers’ express their needs under a qualitative or vague formulation [Suh, 2001] that describes the way that they would like to feel during their time at the airport. The main objective of the mapping between the customer domain and the functional one is to translate passengers’ qualitative needs and emotions (that they may feel during any of the procedures at the airport) into the minimum set of independent functional requirements. This set of functional requirements should not only encompass all of their needs but should also be precise and easy to analyze and treat.

Additionally, customers’ needs may encounter other stakeholders’ requirements, such as the number of aircrafts simultaneously in contact positions, the capacity of security screening, the recommended standards of airport organisms, governmental regulations, etc. Therefore, in order to completely define the design problem, a list of constraints must be written. In the first level of the hierarchy, four main input constraints affecting all of the functional areas are taken into consideration: **1. - Existing infrastructures affecting the terminal building** (airfield infrastructure, urbanism, etc.); **2. - Environmental aspects;** **3. - IATA recommended values** and **4. - Air traffic data forecast.** The first one restricts the placement and orientation of the new building. The second one may limit its growth. The third one establishes the minimum infrastructure needed to accomplish a particular level of service. And the fourth one fixes the design point, i.e., the number of passengers per hour and aircraft movements per hour that have to be managed. It is important to note the traffic variation in Spanish seasonal airports. Over half of their demand might be concentrated in the summer months [Ashford 1988 and Aena, 2010]. Therefore, the terminal conceived must be able to adapt its infrastructure to huge differences in air traffic volumes during the year, with peaks of demand in the summer. This need is going to be called modularity. However, according to the definition given by Axiomatic Design for functional requirement, modularity cannot be considered as a functional requirement because it is not independent of other functional requirements such as accessibility or information. As a result, **modularity** appears as an important constraint to the design problem and its compliance will be checked during the design process. Additional constrains (introduced by particular passengers needs) may affect the individual functional areas and will be discussed in section 3.

Afterwards, the study discusses how the design parameters are obtained. These parameters are found in the physical domain with the aim of satisfying the list of functional requirements inside the boundaries framed by the constraints. In order to get an optimal design, the number of design parameters must be the same as the number of functional requirements, and each parameter should control only its corresponding functional requirement. Consequently, to meet the independence and information axioms, an optimal design is functionally uncoupled and contains the minimum information [Suh, 1990]. The relations between the functional requirements and the design parameters are characterized by the design matrix which is written for each functional area.

As a result, the design process used to solve the functional design of the airport terminal is based on the interaction between three main domains: customers, functional and physical [Suh, 1990 and Suh, 2001]. The application of the two axioms of design to the first mapping provides the minimum and independent list of functional requirements and the necessary list of constraints, whereas the application of the axioms to the second mapping provides the optimal set of design parameters. Figure 2 draws the three domains considered.

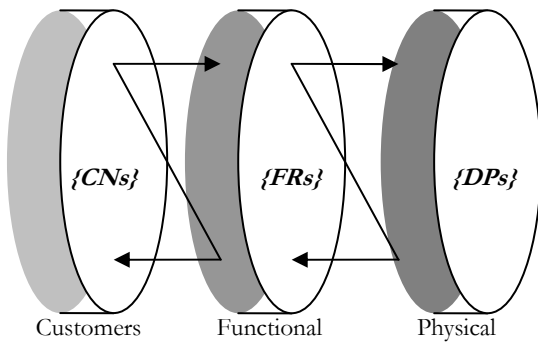


Figure 2. Design domains.

2.3 IATA RECOMMENDATIONS

IATA formulae relate the infrastructure needed to accomplish the correct processing of the estimated number of passengers according to a desired level of service [IATA 1995 and IATA 2004]. In this study it has been assumed that under IATA recommendations the desired level of service is not guaranteed. Therefore, such recommendations settled as a constraint: establish the minimum functional elements, lengths and surfaces required for ensuring the desired level of service. In addition, they provide design parameters' minimum values that decouple the functional requirements.

The IATA recommendations needed for the dimensioning of the three main functional areas considered are given by equations (1) to (7)

$$L = f \frac{a \cdot l \cdot t}{n \cdot 60} \quad (1)$$

$$S_1 = \frac{3}{2} f s \frac{t_1}{60} a (1 + o) \quad (2)$$

$$S_2 = f s a \left(\frac{1}{2} - \frac{t_2}{60} \right) \quad (3)$$

$$N_{cc} = f a \frac{t_3}{60} \quad (4)$$

$$S = a [p s_1 + (1 - p) s_2] \quad (5)$$

$$N_{cp} = a \frac{W}{y} \quad (6)$$

$$N_{pc} = f b \frac{t_4}{60} \quad (7)$$

Where the variables $a, b, L, S_1, S_2, N_{cc}, S, N_{cp}, N_{pc}, f, l, n, o, p, s, s_1, s_2, t, t_1, t_2, t_3, t_4, W,$ and y correspond to:

Table 1. Design IATA values.

	Description	Value
a	Originating passengers in the design hour	See Table 2
b	Originating or Arriving Non Schengen passengers in the design hour	
L	Length of the curb	Eq. (1) (m)
S_1	Surface of the departures concourse	Eq. (2) (m ²)
S_2	Surface of the queuing area (check-in hall)	Eq. (3) (m ²)
N_{cc}	Number of check-in counters	Eq. (4)
S	Functional surface of the departures lounge	Eq. (5)
N_{cp}	Number of security check positions	Eq. (6)
N_{pc}	Number of passport control positions	Eq. (7)
f	IATA recommendation for the error margin of 10%	1,1
l	Average curb length required by car or taxi	6,5 m
n	Average number of passengers per car or taxi	2
o	number of visitors per passenger	0,05 (international) 0,3 (national)
p	percentage of seated passengers	0,6
s	Space required per passenger	1,5 m ²
s_1	area required per sitting passenger (departures lounge)	1,7 m ²
s_2	Area required per standing passenger (departures lounge)	1,2 m ²
t	Average curb occupancy time per car/taxi (departures curb)	2 min.
t_1	Average occupancy time per passenger or visitor (check-in hall)	20 min.
t_2	Average processing time of 50% of the design hour passengers (check-in hall)	20 min.
t_3	Average processing time per passenger (check-in counter)	1,5 min.
t_4	Average processing time per passenger (passport control)	0,3 min. (departures) 0,5 min. (arrivals)
W	Number of hand baggage items per passenger	2
y	Capacity of X-ray hand baggage Unit	600 pcs/hour

3 SOLUTION BASED ON AXIOMATIC DESIGN

3.1 DESIGN POINT

The design point of the terminal is given by the air traffic demand values collected in Table 2.

Table 2. Air traffic forecast.

	Passengers	Aircrafts
Total	4 100 000	46 700
Busy day	33 300	317
Peak day	34 540	325
Maximal peak hour	3 550	25
Design hour	2 860	25
Arrival design hour	1 430	17
Departure design hour	1 430	16
National design hour	1 490	17
UE Schengen design hour	2 550	14
UE no Schengen design hour	2 550	14
Non UE design hour	600	3
Non tourist design hour	1 310	16
Minimal departure design hour	655	8

3.2 DEPARTURES CURB

The departures curb constitutes the interface through which passengers enter the Airport Terminal and where “vehicular flows become pedestrian flows and vice-versa” [IATA, 2004]. The design of this functional element has to consider all of the ways to get to the airport from the landside, such as rented cars, taxis, public transport, tourist buses or private cars. And, it must guarantee an optimal access to the airport terminal assuring a free-flowing traffic pattern.

Considering the reasons above, in the first level of the design hierarchy the main functional requirements are: 1.-“enough space to park for some minutes,” 2.-“minimal traffic congestion,” 3.-“optimal accessibility to the terminal,” 4.-“weather covered,” and 5.-“optimal information for travellers”. On the other hand, the design parameters that should satisfy the related needs are: 1.-“length of the curb,” 2.-“road layout,” 3.-“landside geometry of the terminal,” 4.-“weather protecting systems” and 5.-“signage system”.

The design matrix obtained for the departures curb is shown in Figure 3. In the design matrix the following notation is used: X strong dependence; - minor dependence; 0 no dependence.

$$\begin{pmatrix} \text{Park some minutes} \\ \text{Minimal traffic congestion} \\ \text{Optimal accessibility to terminal} \\ \text{Weather covered} \\ \text{Information for travellers} \end{pmatrix} = \begin{pmatrix} X & 0 & 0 & 0 & - \\ X & X & 0 & 0 & - \\ X & X & X & 0 & - \\ X & X & X & X & 0 \\ X & X & X & 0 & X \end{pmatrix} \times \begin{pmatrix} \text{Curb length} \\ \text{Road layout} \\ \text{Landside geometry} \\ \text{Weather protecting systems} \\ \text{Signage system} \end{pmatrix}$$

Figure 3. Departures curb design matrix.

The recommended value for the length of the curb in order to provide enough parking spaces for taxis and cars obtained is 171 m Eq.(1). As a result, the fulfilment of functional requirement 1 is achieved with any geometry providing a minimal of 171 meters of departures curb. Furthermore, this minimum guarantees the independence between functional requirements 1 and 2. We suppose that under this length, the main cause of traffic congestion is the

lack of space for vehicles to stop, whereas beyond this value, an appropriate road lay out could be primarily responsible for free-flowing traffic.

The achievement of the first functional requirement invites us to consider the simplest solution: 171 meters in a straight line with two lanes, a loading/unloading one and a through traffic one. This solution, however, couples the first and the second requirements. The flows of the cars circulating, restarting their motion and arriving at the terminal converge in a single lane. Thus, minimal traffic congestion is not guaranteed. Consequently, the systematic application of the axiomatic approach for the first and second functional requirements suggests the necessity of at least three lanes: one for loading/unloading, one for circulating and one that uncouples the two arriving and departing flows. This middle lane provides easy access to the stop lane and enables a fluent restart of the motion: it can be thought of as a manoeuvring lane (zone A Figure 4).

The fulfilment of functional requirement 3 requires the stopping lane to be placed closest to the main entrances of the terminal. That means that the architecture of the landside part of the building must follow the line drawn by the curb, and several main entrances to the terminal must exist along the whole landside perimeter. In this work, we propose three main entrances in the building façade, one in the middle and two others symmetrical and 60 meters distant from the central one.

Due to the necessity of optimal accessibility for all passengers, we will study the design solutions obtained for disabled passengers. First of all, the size of the parking places required for stopping vehicles with disabled passengers is bigger than the average size (6,5 x 2,5 m²). This circumstance adds a restriction to the design problem. For this concrete case, the fulfilment of the first functional requirement is assured by a 6,5 x 3,60 m² emplacement. The second functional requirement is guaranteed as we saw above by the existence of a manoeuvring lane. The achievement of the third requirement situates precisely the emplacement of the stopping area for disabled travellers. An optimal access to the terminal is only assured if the load/unload positions are placed in front of the main entrances. This conclusion obliges the designer to reserve at least three load/unload emplacements for disabled passengers: one at the beginning of the curb, one in the central position and one at the end. All of them must be placed in front of the three main entrances (zone B Figure 4).

Once the load/unload parking areas for disabled passengers are defined, the flow of public and tourist buses with the axiomatic approach is studied. In Spanish seasonal airports a big percentage of the foreign tourists arrive at the airport by tourist buses. This fact introduces a strong restriction to the design of the departures curb. Seasonal demand generates peak hours of bus movement. The achievement of functional requirement 1 forces the existence of a parking area for tourist buses with at least 20 parking spaces. Requirement 2 cannot be fulfilled if the tourist bus flows use the same lane as the average vehicles (Axiom 1). Consequently, the tourist parking zone must be placed in one of the lateral parts of the building. For that reason, the first and second requirements suggest a precise placement of the

parking zone for buses at the right side of the terminal (zone C Figure 4).

Functional requirement 3 cannot be achieved if a main entrance to the building is not placed next to the bus parking area. That is the reason for adding a fourth entrance on the right side of the building.

In addition, public transportation by bus must be also considered. Public buses arrive at an average frequency of 20 minutes. Based on the same considerations involved in the decision of the tourist bus parking area, the solution adopted for public buses is a bus stop next to the entrance on the right side of the terminal (zone C Figure 4).

For both the tourist and public bus traffic, the fulfilment of the second requirement forces the existence of a recirculation road around the bus parking. This road aims to avoid the presence of buses at the front curb and consequently the mixing of vehicles and bus traffic.

Finally we will study the flow of non tourist passengers. Even if Spanish tourist airports concentrate the majority of their air traffic during the summer season, a constant movement of national passengers exists throughout the whole year - passengers whose needs are completely different than the tourists' ones. This includes the need for a short term parking area connected directly to the terminal. For the predicted non tourist passengers in the departures area (655 pax/hour), a short term parking area with capacity for 230 cars is included.

Functional requirements 1 and 2 place a parking area in the South lateral side of the passenger terminal. The fulfilment of the third requirement (optimal accessibility) forces the existence of a fifth entrance on the left side of the building, symmetrical to the one previously defined on the right side (zone D Figure 4).

Therefore, the systematic application of Axiomatic Design to the different users of the landside curb provides a conceptual solution that satisfies everyone's needs. The achievement of the fourth and the fifth requirements (weather covered and optimal information) will be guaranteed with the use of shelters for the rain and with the implementation of an optimal signage system that conveniently informs travellers.

As a conclusion to the departures curb design we collect the results obtained: 171 meters curb with three lanes for cars and taxis: one for loading/unloading, one as a manoeuvring and a through traffic one. Additionally, five entrances are needed for the passenger terminal: three in the main and frontal façade and two in both of the lateral sides. On the right side, parking for buses (public and tourist) with a proper recirculation road is proposed whereas on the left side a short term parking area for non tourist passengers is suggested. As it can be seen, the structure drawn by the application of the axiomatic approach provides a quasi-symmetrical solution that can adapt its infrastructure to the fluctuant demand during the different seasons. Indeed, in the winter season when tourist bus traffic is reduced to a minimum and air traffic demand decreases, the symmetry allows both sides of the terminal to be used for the same purposes, and therefore satisfies the whole winter demand with half of the infrastructure, reducing costs and time in process. Figure 4 describes the solution adopted.

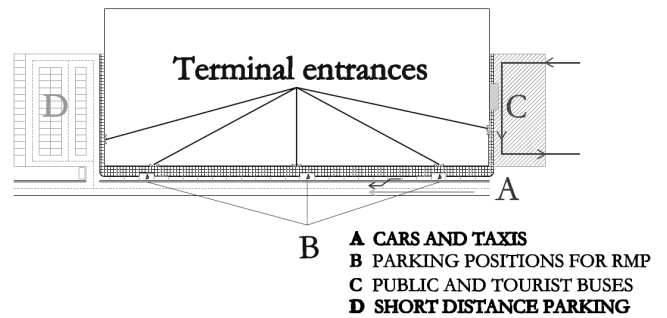


Figure 4. Departures curb.

3.3 DEPARTURES CONCOURSE & CHECK-IN HALL

“The airlines acceptance of passengers and their checked baggage takes place at the check-in facility, which consists of a number of check-in counters with appropriate outbound baggage conveyance facilities” [IATA, 2004].

Functional requirements chosen for this system are: 1.- “minimal time in the check-in process”; 2.- “enough surface for functional elements”; 3.- “accessibility to security or passport check” and 4.- “optimal information for travellers”. The design parameters to cover all of these requirements are: 1.- “number of check-in counters”; 2.- “departures concourse & check-in hall surface”; 3.- “interior geometry of the building”; 4.- “signage”. It has to be mentioned here that functional requirement 2 includes enough area for passengers, baggage trolleys, information points, queuing areas and visitors. Figure 5 shows the design matrix obtained.

$$\begin{pmatrix} \text{Minimal time in check - in process} \\ \text{Surface for functional elements} \\ \text{Accessibility to security check} \\ \text{Information for travellers} \end{pmatrix} = \begin{pmatrix} X & 0 & 0 & - \\ X & X & 0 & 0 \\ X & X & X & - \\ X & X & X & X \end{pmatrix} \times \begin{pmatrix} N \text{ Check - in counters} \\ \text{Surface} \\ \text{Geometry} \\ \text{Signage} \end{pmatrix}$$

Figure 5. Design matrix check-in hall.

Firstly, the axiomatic approach is applied to the election of a centralized/decentralized check-in concept [IATA, 2004]. The fulfilment of functional requirements 1, 2, 3 and 4 is better achieved with a decentralized check-in concept, combining a gate check-in for non tourist flux (constant the whole year) with a central area for tourists during the summer season. A gate check-in permits easier access to the security check and reduces queuing times. Moreover, the decentralized concept permits a separation of the different flows according to each type of air traffic, and as a consequence, facilitates the accessibility to the security check (especially for the gate check-in) and the information system inside the terminal.

However, this solution is not in compliance with the constraint of modularity. Considering the specificity of the seasonal demand (peak days of non regular flights of different types of traffic such as UE Schengen, UE Not Schengen, etc.) and according to the definition given of modularity (capacity of adjusting to the demand) a decentralized system cannot offer flexibility. Indeed a modular terminal cannot be obtained if each part of the check-in hall cannot adapt itself to the concrete necessities of the demand. This argument becomes essential when the desired modularity is expected as a progressive adaptation to the increasing demand from the

beginning of the tourist season. Therefore, in order to satisfy the restriction imposed, a centralized concept is chosen.

Next, the axiomatic approach will be applied to the goal of drawing the optimal check-in layout with the aim of discriminating between an island type and linear type check-in.

Seasonal demand introduces a strong restriction in the design of the check-in layout. Peaks of tourists produce long queues in the check-in counters. A layout based on an island concept can satisfy functional requirements 1 and 2 with enough check-in desks and with enough functional queuing areas, but it doesn't satisfy the rest of the functional requirements. Perpendicular to the main landside façade, check-in islands would produce long queues that would block the free flow of passengers. Parallel to the mentioned façade, they would demand a wider queuing area and consequently longer distances to cover. In both configurations, the requirement of accessibility is not fulfilled. Thus, the frontal linear layout is chosen.

For this type of configuration and according to the predicted number of originating passengers, the recommended number of check-in counters is 40 Eq. (4) and the minimal area needed for the departures concourse and the queuing area is 1 927 m² Eq.(2) and Eq.(3). In order to fulfill functional requirements 1 and 2, 42 check-in counters are chosen and a wider functional area is guaranteed (minimum 30 meters in the queuing sense). The fulfillment of functional requirement 3 obliges the designer to facilitate the access of the passengers to the security check. To achieve this need, the set of 42 check-in counters is divided into three groups of 14. The distance between each group will be large enough to permit the passenger to circulate (zones F1, F2 and F3 in Figure 6). With this configuration, the fourth functional requirement will be satisfied if an optimal signage system is installed. In such a solution, modularity is assured: the proposed layout allows three design points: 14, 28 and 42 check-in desks.

Finally, the same method is applied to determine the number of desks intended for disabled passengers. The first and the second functional requirements are largely fulfilled if one counter of each group of 14 is prepared for attending reduced mobility persons. The fulfilment of the optimal accessibility requires the designer to reserve the desks located at the end of the group. Therefore, desks 1, 15 and 42 would be adapted to the service of disable passengers (lateral sides of F1, F2 and F3 in Figure 6).

Finally, automatic check-in counters are considered. Considering the needs of the passengers, 10 auto checking counters would be enough to satisfy the first functional requirement. The second functional requirement is automatically achieved if a minimum queuing area is considered. The independence of the third requirement places the mentioned counters in the lateral part of the terminal in order to uncouple the flows of passengers using automate check in and not. Functional requirement 4 is directly achieved with an optimal signage system, and the fulfilment of modularity implies the existence of two groups of automate checking counters, in both sides of the terminal (zones G1 and G2 in Figure 6).

As a conclusion, a schema of the solution is presented in Figure 6. As it can be seen, a circulation area around the

check-in counters is defined in order to satisfy the optimal accessibility of passengers and in order to maintain an uncoupled design, by maintaining the independence of the queuing area with the circulation of travellers (zone E in Figure 6).

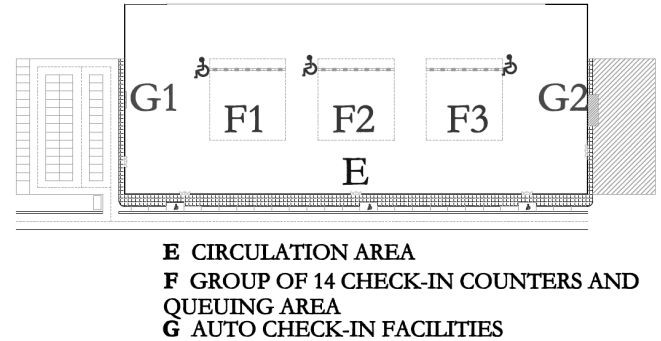


Figure 6. Departures concourse & check-in hall.

3.4 DEPARTURES LOUNGE

The departures lounge accommodates the passengers who have already checked-in and still await their boarding gate details. According to IATA, “[a]t small-scale airports, it may not be cost-effective to provide separate departure lounge and gate lounge facilities” [IATA, 2004]. Hence the departures lounge integrates the common hall and the boarding gate facilities. The set of functional requirements is: 1.-“enough surface to accommodate the number of passengers in the design hour”; 2.-“leisure and entertainment offerings”; 3.-“accessibility to aircraft” and 4. - “optimal flight information.”. In order to achieve all of these necessities, the design parameters are: 1.-“functional surface”; 2.-“leisure time surface”, 3.-“geometry” and 4.-“signage system”. The resultant design matrix is shown in Figure 7.

$$\begin{pmatrix} \text{Enough surface for departure passengers} \\ \text{Leisure and entertainment offer} \\ \text{Accessibility to aircraft} \\ \text{Optimal flight information} \end{pmatrix} = \begin{pmatrix} X & X & 0 & 0 \\ X & X & 0 & 0 \\ X & 0 & X & X \\ X & X & X & X \end{pmatrix} \times \begin{pmatrix} \text{Functional surface} \\ \text{Leisure surface} \\ \text{Geometry} \\ \text{Signage} \end{pmatrix}$$

Figure 7. Design matrix of departures lounge.

The design of the departures lounge is subject to a strong restriction introduced by the minimal airside perimeter required to park the number of estimated aircrafts. The predicted number of aircraft movements per hour and the characteristics of a seasonal demand invite a solution of 5 boarding bridges combined with remote parking positions. An average distance of 55 meters between each bridge implies the need of a 220 meters airside perimeter. On the other hand, the minimal recommended area in order to accommodate passengers and leisure concessions is 2 860 m² Eq.(5) (leisure concessions surface is dimensioned as 30% of the departures lounge functional area). The fulfilment of functional requirements 1 and 2 is assured by any geometry that provides the minimal needed area. For example, a 220 meters linear façade or a 110 meters pier would both suffice. However in this precise case, the axiomatic approach draws a close geometry. As it has been studied in Section 3.3, modularity and accessibility demand the availability of all of the check-in counters for all types of traffic. Assuming that the security check serves as an interface between the landside and airside,

the geometry that satisfies a 220 meters airside perimeter and that provides the optimal accessibility to all the boarding bridges from a concrete point is a 70 meters radius semicircle centred in the security check (zone H2 in Figure 8). As it can be seen, this geometry largely satisfies the recommended area, and implies shorter distances to the boarding gates than linear or apron concepts. The functional requirement “demanding easy orientation and information” is also achieved by this geometry and must be accompanied by an optimal signage system. Finally, modularity is also satisfied. Indeed, the proposed geometry permits each boarding bridge to be individually operated. Besides, an optimal isolation system could keep closed a desired part of the departures lounge during the winter season.

In order to satisfy travellers’ needs, a relaxing/waiting area could be defined following the airside perimeter close to the boarding gates (zone J in Figure 8). Additionally, in the centre of the geometry leisure concessions are placed (zone I in Figure 8).

Even though the present study is not analysing either the security check or the passport controls needs in detail, a succinct commentary will be included here. It can be noted that IATA formulae recommend 5 security check positions and 7 passport control desks Eq.(6) and Eq.(7). In order to satisfy modularity and accessibility, passport controls are placed at the entrance of each boarding bridge (K1, K2, K3, K4 and K5 in Figure 8) and two additional mobile ones are defined in order to cover the possible necessities of remote position departures. The security check is placed after the check-in counters, and it is given a wide queuing area in order to ensure accessibility. It also constitutes the main entrance to the departures lounge.

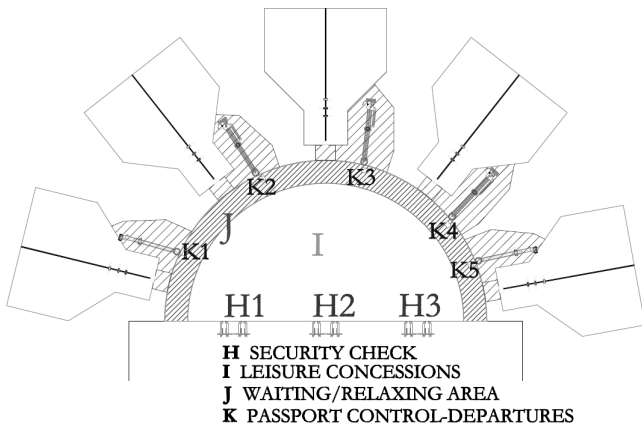


Figure 8. Departures lounge.

3.5 THE WHOLE SYSTEM

The design of each functional area has been detailed individually in the previous sections. The resultant system is presented here. Figure 9 shows the solution obtained.

Two comments must be made about two main characteristics of the design achieved. First, it is crucial to emphasize the importance of accessibility as a functional requirement in the definition of each functional area. Indeed, thanks to the presence of such a functional requirement in the design matrix, the resultant design for the whole system is constituted by three main sub-systems optimally linked to

each other. This characteristic is optimal from the perspective of travellers who see their time in process and walking distances reduced. Second, the importance of modularity as a constraint must be underlined. Modularity served to reject solutions not coherent with the specificity of seasonal demand, and above all, was the main cause of the symmetry of the solution. In fact, the compliance of modularity suggested that symmetrical shaped terminals can better adapt to fluctuating demands.

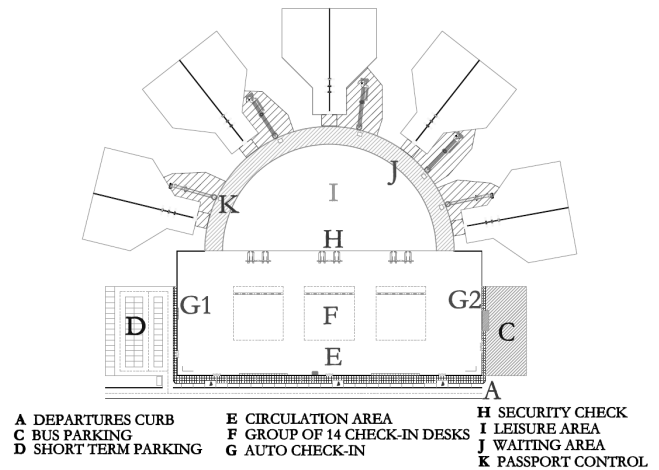


Figure 9. Departures functional areas.

4 CONCLUSION

This paper shows how Axiomatic Design has been applied in order to obtain the optimal functional design of an airport passenger terminal. It has been demonstrated that an appropriate selection of functional requirements and constraints permit, with the guidelines of the independence and information axioms, to shape and size the terminal that optimally responds to the identified needs of the different interacting stakeholders.

Indeed, Axiomatic Design allows the designer to face the design of an airport passenger terminal from a global perspective without breaking the creative process and avoiding the loss of crucial information between each step of the design process. In other words, Axiomatic Design solves the dimensioning and the lay-out of the terminal as a unique problem, obtaining the minimum set of functional requirements that define the basic topology of the Terminal building.

Future research will consider the airport as a large and complex system, increasing the number of stakeholders involved and implementing dynamic models of passengers’ flows and air traffic demand with Axiomatic Design.

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