Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 34 (2015) 106 – 111

www.elsevier.com/locate/procedia

9th International Conference on Axiomatic Design – ICAD 2015

Axiomatic Design to improve PRM airport assistance

Gabriele Arcidiacono, Alessandro Giorgetti, Michela Pugliese*

Guglielmo Marconi University, via Plinio 44, Rome 00193, Italy

* Corresponding author. Tel.: +393475572953.*E-mail address:*michypugliese@gmail.com

Abstract

Competition in the air transport market in recent years has prompted companies to search for products and services increasingly innovative and, at the same time, the decrease in development timing and the creation of resources devoted to the study of original technical solutions. One emerging important issue is to facilitate air travel for people with disabilities, elder and dependent people, setting the primary objective of preventing the emergence and spread of new barriers. This aspect is important both for the introduction of several mandatory requirements (rules, laws and regulations) and the increasing market share of this people category due to the aging of population. In this paper it is analyzed the study of the flow of PRM (Passengers with Reduced Mobility) departing, arriving and transiting through an airport terminal. The specific case study is based on the management process of passengers with special assistance for a major Italian tourist airport. The Axiomatic Design method is used to link the customers needs with all the process elements and boundaries: the infrastructure aspects, the limits imposed by security and the availability of appropriate resources (personnel and equipment). Finally some improvement suggestions are made to optimize the passage through the terminal and to ensure full accessibility of the considered environments.

Peer-review under responsibility of the organizing committee of 9th International Conference on Axiomatic Design

*Keywords:*PRM; Axiomatic Design; airport assistance

1. Introduction

The removal of architectural barriers is now one of the primary goals for a civilized countries. Indeed considering the increase in disability due to the incidence of diseases and the aging of the world population [1] the rights of people with reduced mobility are increasingly assuming a leading role in policies of companies worldwide.

A specific attention to the understanding of the requirements for accessibility and mobility has been placed by the transport system and numerous studies have been conducted [2].

In particular the development of the air transport market due to the increase of travelers and the growing competition has prompted companies to search for products and services increasingly innovative and with high quality. The design of an airport was assessed with a perspective to improve the quality, both through the Axiomatic Design [3] and through improved technique using the concept of level of service to indicate the interaction of time with space provision [4].

An emerging important issue is to facilitate air travel for people with reduced mobility, to ensure them conditions similar to those of all passengers without discrimination. To guarantee this, several rules have been developed and regulations are been dictated by the competent bodies in the field [5].

In this paper we analyze the process of managing the flow of Passengers with Reduced Mobility (PRM) within one of the main European airports.

The airport considered consists of three terminals divided between departures and arrivals T1, T2 and T3; plus T5, that is a dedicated terminal for sensitive flights departures with possible terrorist attacks risks. Each terminal consists of two areas: a landside area, where there are shops, toilets, check-in areas, security check and baggage claim belts, and the airside area, where in addition to shops and toilets there are passport control (flights No Schengen), boarding gates and runways / landing (Fig. 1).

In this paper it is not considered the assistance to PRM provided in flight by the airlines (on which studies have been conducted also with respect to matters to be taken for the

Peer-review under responsibility of the organizing committee of 9th International Conference on Axiomatic Design
doi:10.1016/j.procir.2015.08.012

safety in the cabin) [6], focusing on the ground assistance, which is a task due to the airport operator. In this case, the airport operator will provide trained personnel and resources and will design the assistance process in order to obtain the mobility of passengers safely and with greater satisfaction at the same time.

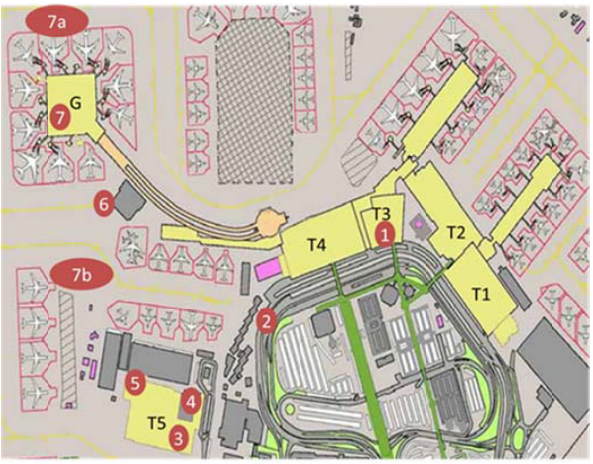

Fig. 1. Layout

The passenger satisfaction is one of the primary objectives for companies operating in this sector and it is one of the main subject of investigation [7].

Therefore the process considered is summarized in the following stages: PRM reception by an operator equipped with wheelchair, completing the acceptance operations and security checks and customs, loading/unloading of passengers and baggage claiming, satisfying all the needs of PRM during their transit through the airport.

The means available to staff are wheelchair, club car, vans, trucks and narrow chair. They must to be able to meet the demand growth for assistance of airports and the periods of air traffic peak.

The problem of PRM is previously been analyzed through the use of an algorithm with good solutions on smooth transport with short waiting times [8].

The purpose of this paper is to apply the theory of Axiomatic Design [9, 10] to the process cycle of assistance concerning PRM originating with sensitive flights, in order to learn about critical issues through the influence of the design parameters on the functional requirements and to propose improvement interventions. Further application could be found in literature [11].

2. PRM assistance and layout

To ensure full accessibility to air transportation to all customers with disabilities or reduced mobility the IATA (International Air Transport Association) has codified all types of PRM assistance with specific acronyms:

1. WHCR (wheelchair-ramp), passenger who can walk independently within the aircraft, and go up and down stairs, but who needs a wheelchair or other means of transport to move long distances inside the terminal;

2. WHCS (wheelchair stair), passenger who can walk independently within the aircraft, but that cannot go down or up the stairs and that needs a wheelchair or other means of transport to move around inside the terminal;

3. WHCC (wheelchair cabin seat), immobilized passenger, who needs a wheelchair to get around and needs assistance from the arrival at the airport until the end of the flight and out of the airport;

4. DEAF, passenger with hearing or hearing and speech impairment;

5.BLIND, passengers with impaired vision;

6. DEAF / BLIND, passengers with impaired vision and impaired hearing, and who need the assistance of an attendant to move;

7. DPNA, passenger with intellectual or behavioral issues.

In this paper it is examined, for quality assessment through the methodology of the Axiomatic Design, a process cycle of assistance to passengers with reduced mobility involving the more critical flight: PRM originating with sensitive flights.

The sensitive flights are all those destinations and / or air carriers affected by terrorist attack risk and where there are high-tech security control with specific machinery.

The terminal dedicated to the departures with sensitive flights is the T5 which is separated from the other airport terminals and to reach it you need to use a means of transportation on the road outside the city.

The cycle of assistance made by the airport operator for PRM originating from T5 can be divided into the following phases:

1. The passenger is greeted upon his arrival at terminal T3 (international) at one of the point designated by an operator PRM provided with suitable wheelchair;

2. The passenger is transferred through suitable van to terminal T5;

3. The operator PRM performs the acceptance operation for the passenger on the belonging flight at one of the check-in desk;

4. The operator PRM, the PRM passenger and hand luggage must undergo security checks required for the transition from groundside to airside respectively through the metal detector door, the manual control made by security operator and the RX line;

5. The passenger is subject to the passport control;

6. The passenger is carried through the boarding suitable van to gate G, where is the gate of the belonging flight;

7. The operator PRM accompanies the passenger to the gate and boards him on the flight. The boarding can be done in two ways depending on leased aircraft:

7a. From the loading bridge, if the aircraft is directly connected to the terminal by a finger;

7b. Remotely, if the aircraft is located in a parking lot for the takeoff / landing and must be reached by a van.

In case of passenger boarding by loading bridge the means used are wheelchair for the assistance of types WHCR and WHCS and with a narrow chair supported by the operator for the assistance of type WHCC. In case of remotely boarding, in addition to the van for the track's crossing, it an elevator will be needed to lift the portion of the base to the altitude where the aircraft door is located for the assistance of types

WHCS and WHCC. Then they will still use the wheelchair for assistance WHCR and WHCS and the narrow chair supported by the operator for assistance WHCC.

During the transition from goundside to airside the PRM will cross four main areas as shown in Fig. 2 and Fig. 3: terminal T3 and its reception points, check-in hall of terminal T5, boarding gate G and aircraft.

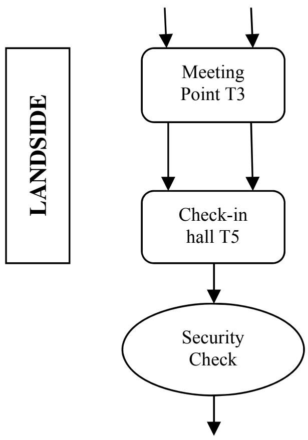

Fig. 2. PRM crossing areas: Landside

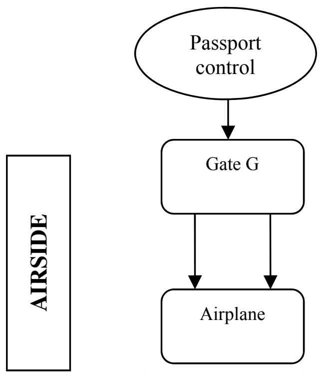

Fig. 3. PRM crossing areas: Airside

So the design in optical quality of the ground's care process for the PRM must ensure that passengers go through all the necessary procedures to bring them from groundside to airside and, subsequently boarding the aircraft as more as possible safely, in a comfort manner, and in the shortest time required.

The concept of improvement proposed in this paper is based on the analysis of the flow followed by the PRM and operators crossing these functional areas where we will evaluate carefully the construction and operational alleys.

The process object of study in this paper can be better summarized by a flowchart (Fig. 4) that chronologically describes all actions involving the PRM in order to provide the appropriate assistance throughout his time inside the airport.

Subsequently the phases of the process of assistance are inserted into the complex layout of the airport considered.

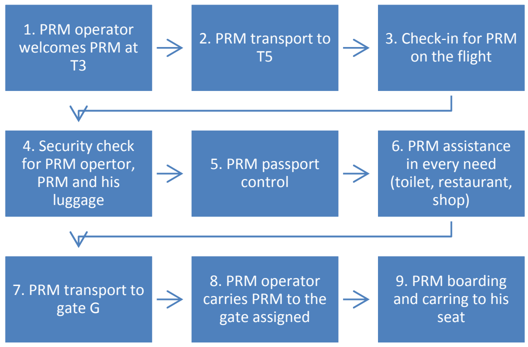

Fig. 4. PRM assistance flow chart

The airport operator has an adequate fleet for which operators rely PRM according to the phase of assistance and type of assistance.

These means are divided into three main categories of use. The first two apply to all PRM and the third on certain types and in specific cases:

- Support means (wheelchair and operator PRM);
- Transport (van);
- Vehicles or boarding (finger, narrow chair, PRM support operator, ambulift).

It should be stressed that the wheelchair and the PRM operator are present during the entire cycle of assistance to passengers with reduced mobility, because the use of the wheelchair must maintain the presence of the operator that manages it correctly and safely in accordance with the company practices.

3. PRM assistance and Axiomatic Design: design for operational excellence

Knowing in detail the management flow for passengers with reduced mobility assistance, in order to proceed with the analysis of the process is necessary to extrapolate the functional requirements (FRs) for each functional area and the design parameters (DPs).

Functional requirements must be deducted from the knowledge of the process in object and through a careful translation of the passengers needs with reduced mobility. All information obtained must be analyzed first through the Independence Axiom and then with the Information Axiom. According to the Independence Axiom the best design is an uncoupled one: in literature could be found some measures to establish the degree of coupling of a system [12].

The design parameters will be the means by which it will be possible to meet the process actions identified by the functional requirements, while remaining within the boundaries defined by the constraints.

Relations between the functional requirements and the design parameters characterize the Design Matrix. The Design Matrix is used to evaluate the interactions between rows and columns for each phase of the process.

Thus the FR's and the DP's can be interpreted as two vectors, while the mapping instructions are given by the Design Matrix.

For this process it has been built a Design Matrix for each level of the hierarchy, where with X will indicate a strong dependence, while x will indicate a lower dependence and O will indicate no dependence.

In the present case, proceeding to hierarchies and zigzagging, four levels of FR and DP have been identified. The first level of hierarchy or macro-level, respectively, provides the following FRs and its DPs:

FR 1: Secure the ground assistance to Passengers with Reduced Mobility originating from the terminal T3;
DP 1: Chain of PRM assistance operators and fleet.

Consequently the second level of the hierarchy consists of eight FRs and seven DPs:

FR 1.1: Meeting the passenger upon arrival at T3 near one of the meeting points;
FR 1.2: Move the passenger to T5;
FR 1.3: Fulfilling the acceptance operations for passenger;
FR 1.4: Perform security checks;
FR 1.5: Carry out passport checks;
FR 1.6: To accompany the passenger to the bathroom or to the refreshment;
FR 1.7: Proceed to the boarding area G;
FR 1.8: Board the passenger.

DP 1.1: PRM support means;
DP 1.2: Van;
DP 1.3: Check-in desk;
DP 1.4: Security check;
DP 1.5: Passport control stations;
DP 1.6: Layout;
DP 1.8: Means for PRM boarding.

The FRs>DPs because two different actions identified by FR 1.2 and FR 1.7 are carried out by the same DP 1.2, so it is preferred not indicate DP 1.7 and to indicate “Means for PRM boarding” with DP 1.8 to connect it to corresponding FR 1.8.

So the Design Matrix will be coupled (1)

$$\begin{Bmatrix} \text{FR 1.1} \\ \text{FR 1.2} \\ \text{FR 1.3} \\ \text{FR 1.4} \\ \text{FR 1.5} \\ \text{FR 1.6} \\ \text{FR 1.7} \\ \text{FR 1.8} \end{Bmatrix} = \begin{bmatrix} X & O & O & O & O & O & O \\ X & x & O & O & O & O & O \\ X & O & X & O & O & X & O \\ X & O & O & X & O & X & O \\ X & O & O & O & X & X & O \\ X & O & O & O & O & X & O \\ X & x & O & O & O & O & O \\ X & X & O & O & O & O & X \end{bmatrix} \begin{Bmatrix} \text{DP 1.1} \\ \text{DP 1.2} \\ \text{DP 1.3} \\ \text{DP 1.4} \\ \text{DP 1.5} \\ \text{DP 1.6} \\ \text{DP 1.8} \end{Bmatrix} \quad (1)$$

In the third level of the hierarchy there are three families of FR and three families of DP:

FR 1.1.1: Ensure short waiting times for passengers;
FR 1.1.2: Ensure accessibility to all passengers;
FR 1.4.1: Carry out security checks of the passenger;
FR 1.4.2: Carry out security checks of the PRM operator;
FR 1.4.3: Carry out security checks of luggage;
FR 1.8.1: Board the passenger through loading bridge;
FR 1.8.2: Board passenger remotely.

DP 1.1.1: PRM Operators;
DP 1.1.2: Wheelchair;
DP 1.4.1: Security Operator;
DP 1.4.2: Metal detector door;
DP 1.4.3: RX line;
DP 1.8.1: Means for PRM boarding with direct connection;
DP 1.8.2: Means for PRM boarding without direct connection.

The Design Matrix for the third level will be coupled (2)

$$\begin{Bmatrix} \text{FR 1.1.1} \\ \text{FR 1.1.2} \\ \text{FR 1.4.1} \\ \text{FR 1.4.2} \\ \text{FR 1.4.3} \\ \text{FR 1.8.1} \\ \text{FR 1.8.2} \end{Bmatrix} = \begin{bmatrix} X & X & O & O & O & O & O \\ X & X & O & O & O & O & O \\ X & X & X & X & O & O & O \\ X & X & O & X & O & O & O \\ X & O & O & O & X & O & O \\ X & X & O & O & O & X & O \\ X & X & O & O & O & O & X \end{bmatrix} \begin{Bmatrix} \text{DP 1.1.1} \\ \text{DP 1.1.2} \\ \text{DP 1.4.1} \\ \text{DP 1.4.2} \\ \text{DP 1.4.3} \\ \text{DP 1.8.1} \\ \text{DP 1.8.2} \end{Bmatrix} \quad (2)$$

Finally, the fourth level of the hierarchy has two families of FRs and DPs regarding the different ways of boarding PRM employees from leased aircraft and the type of assistance:

FR 1.8.1.1: Reach the aircraft;
FR 1.8.1.2: Board assistance type R or S;
FR 1.8.1.3: Board assistance of type C;
FR 1.8.2.1: Reach the parking of the aircraft;
FR 1.8.2.2: Board assistance type R;
FR 1.8.2.3: Board assistance of type S;
FR 1.8.2.4: Board assistance type C.

DP 1.8.1.1: Finger;
DP 1.8.1.3: Narrow chair with PRM support operator;
DP 1.8.2.2: Access ramp to aircraft;
DP 1.8.2.3: Ambulift.

Also in this case there are a number of FRs> DPs because of a failure to linear independence of certain functional requirements respect to the design parameters. Indeed, the FR 1.8.1.1 and the FR 1.8.1.2 are satisfied by the same DP 1.8.1.1, the FR 1.8.2.1 is satisfied by the DP 1.2 belonged to the second level and the FR 1.8.2.4 is satisfied by DP 1.8.1.3.

The Design Matrix for the last level will be coupled (3)

$$\begin{Bmatrix} \text{FR 1.8.1.1} \\ \text{FR 1.8.1.2} \\ \text{FR 1.8.1.3} \\ \text{FR 1.8.2.1} \\ \text{FR 1.8.2.2} \\ \text{FR 1.8.2.3} \\ \text{FR 1.8.2.4} \end{Bmatrix} = \begin{bmatrix} X & O & O & O \\ X & O & O & O \\ X & X & O & O \\ O & O & O & O \\ O & O & X & O \\ O & O & O & X \\ O & X & O & X \end{bmatrix} \begin{Bmatrix} \text{DP 1.8.1.1} \\ \text{DP 1.8.1.3} \\ \text{DP 1.8.2.2} \\ \text{DP 1.8.2.3} \end{Bmatrix} \quad (3)$$

Now, having evaluated carefully the relationships existing at each hierarchical level between the FRs and DPs, it is possible to perform a thorough analysis to choose the interventions of improvement that could turn the Design Matrix from coupled to uncoupled, in order to obtain a Best Design.

4. Solutions based on Axiomatic Design

The second level of the Design Matrix is a 8X7 matrix with off-diagonal elements. For the coupled Design Matrix proposal there are several measures to improve. The first project involves the DP 1.2 and the two FR 1.2 and FR 1.7. Integrating the terminal T3 with the equipment control present at the terminal T5 is necessary to perform the security checks of passengers and baggage belonging to originating sensitive flights, allowing the departure of these passengers including PRM, directly from the terminal T3, avoiding both road transport with the van to the terminal T5 and the transport on track with the van towards the boarding area gate G. The latter would be reached via a shuttle train with the departure station located inside the terminal T3. In addition, the van would become a mean used exclusively for embarking passengers with reduced mobility from remote and, therefore, would become a part of the category identified by DP 1.8.2. As a result the Design Matrix will become a 7X7 matrix.

The remaining off-diagonal elements show the correlation between the FRs, representing all phases of the process, satisfied by DP 1.1, representing the means of support for the PRM, and FR 1.3, FR 1.4 and FR 1.5are influenced by DP 1.6. Using the tool of *Reordering* it can get an array of second level decoupled. So by changing the position between FR 1.3 and FR 1.6 and the position of DP 1.3 and DP 1.6 it is possible to obtain a new Design Matrix (4)

$$\begin{Bmatrix} FR\ 1.1 \\ FR\ 1.6 \\ FR\ 1.4 \\ FR\ 1.5 \\ FR\ 1.3 \\ FR\ 1.7 \\ FR\ 1.8 \end{Bmatrix} = \begin{bmatrix} XOOOOOO \\ XXOOOOO \\ XXXOOOO \\ XXOXOOO \\ XXOOXOO \\ XOOOOXO \\ XOOOOOX \end{bmatrix} \begin{Bmatrix} DP\ 1.1 \\ DP\ 1.6 \\ DP\ 1.4 \\ DP\ 1.5 \\ DP\ 1.3 \\ DP\ 1.7 \\ DP\ 1.8 \end{Bmatrix} \quad (4)$$

The matrix of the third level is a 7X7 matrix with some off-diagonal elements. The improvement measures proposed concern the security checks that must undergo a PRM and that it may be done through a manual check performed by the security operator or by passing under the metal detector door depending on the mobility of the passenger. It could adopt metal detector doors that exclude the wheelchair from alarms using the same systems transmitters/receivers used to prevent theft inside the shops. Or it might be thought of providing airport wheelchair made of non-metallic materials, such as polycarbonate, which do not trigger alarms. In both cases it would be eliminated the DP 1.4.1.

In addition, providing to make a relay between operators PRM security check at the gates would generate a system where there are PRM operators fixed in groundside and PRM operators fixed in airside avoiding them security checks whenever passing from one area to another. Such action would lead to the elimination of FR 1.4.2.

The new Design Matrix for the third level will be (5)

$$\begin{Bmatrix} \text{FR 1.1.1} \\ \text{FR 1.1.2} \\ \text{FR 1.4.1} \\ \text{FR. 1.4.2} \\ \text{FR 1.8.1} \\ \text{FR 1.8.2} \end{Bmatrix} = \begin{bmatrix} X\ X\ O\ O\ O\ O \\ X\ X\ O\ O\ O\ O \\ X\ X\ X\ O\ O\ O \\ X\ X\ O\ X\ O\ O \\ X\ X\ O\ O\ X\ O \\ X\ X\ O\ O\ O\ X \end{bmatrix} \begin{Bmatrix} \text{DP 1.1.1} \\ \text{DP 1.1.2} \\ \text{DP 1.4.1} \\ \text{DP 1.4.2} \\ \text{DP 1.8.1} \\ \text{DP 1.8.2} \end{Bmatrix} \quad (5)$$

The fourth level Design Matrix is a 7X4 matrix coupled with off-diagonal elements. For this matrix it is possible to evaluate four possible improvements. The first two proposals concern FR 1.8.1.3 and FR 1.8.2.4, which are satisfied both by DP 1.8.1.

It might be thought to use a wheelchair model comfortable and small in width, so it can also go through the aisle of the aircraft without having to move the PRM from a wheelchair to a narrow chair.

In addition, if such wheelchair were integrated with a lifting system for the user it would not have the necessity of coming of another PRM operator to allow the PRM to sit in the place assigned. In this case it will no longer need to make a distinction between the stages of the process based on the types of assistance and so FR 1.8.1.1, FR 1.8.1.2 and FR 1.8.1.3 become one functional requirement.

The DP 1.8.2.3 must satisfy both FR 1.8.2.3 and FR 1.8.2.4; applying a stair lift with wheels directly to the wheelchair or implementing the access ramp to the aircraft with an handicap lift platform would eliminate this DP.

Finally, as a result of the improvements proposed at the first level, the van would be included in the means for boarding PRM, becoming a DP of this level.

The Design Matrix of the fourth level will become a square matrix 3X3 (6)

$$\begin{Bmatrix} \text{FR 1.8.1.2} \\ \text{FR 1.8.2.1} \\ \text{FR 1.8.2.2} \end{Bmatrix} = \begin{bmatrix} X\ O\ O \\ O\ X\ O \\ O\ O\ X \end{bmatrix} \begin{Bmatrix} \text{DP 1.8.1.1} \\ \text{DP 1.8.2.1} \\ \text{DP 1.8.2.2} \end{Bmatrix} \quad (6)$$

In this last level we have obtained an uncoupled Design Matrix with correlation elements only along the diagonal and no correlation outside of it.

Therefore we faced with a situation of optimum design.

5. Conclusions

The use of Axiomatic Design principles allows us to manage problems of the process of assistance to Passengers with Reduced Mobility originating from the airport considered as well as to highlight possible interventions for quality improvement of the cycle examined and therefore the service provided.

Having known in detail the whole process, the layout of the airport and the means available for the service and having studied the three key elements of AD (which are decomposition in design domains, *zig-zagging* to create the design hierarchy, independence axiom and *Reordering*) that are suitable to manufacturing environments and extendible across industries, it has been possible to analyze in detail each stage of production and find the weaknesses in quality perspective.

The cycle of assistance considered presented problems due to mainly: the movement of passengers with reduced mobility inside the terminal depending on the action to be performed, and issues related to the intense traffic of PRM departing from a stopover main connection. In most cases such movements were achieved by use of vans, causing an excessive exploitation with consequential accumulation of delays due to the simultaneity of actions and the large number of assistance requested.

Through the identification of the FRs and DPs and the construction of the Design Matrix, possible improvements have been identified: reduction of the van usage, reduction of for security checks time, advantages both for the PRM operator and for the passenger during boarding of the aircraft; the application of these solutions would lead to a decrease in the total service time, in compliance with the comfort and safety of passengers, as well as the use of systems, equipment and more cutting edge means that would increase the user satisfaction.

Furthermore, thanks to the performance of this work, it is possible to assert that the findings for the cycle considered is developable for other cycles implying the process of assistance to passengers with reduced mobility, leading to an overall improvement in the services offered by the airport operator and therefore customer loyalty.

In addition, the focus on resolving issues related to air transport for these particular groups of people is an important contribution to the removal of architectural barriers, as mentioned in the introduction.

References

[1] Guralnik JM, Fried LP, Salive ME. Disability as a Public Health Outcome in the Aging Population. Annual Review of Public Health. 1996 May; 17: 25-46.

[2] Alsnih R, Hensher DA. The mobility and accessibility expectations of seniors in an aging population. Transportation Research Part A. 2003 December; 37: 903-16.

[3] Rodriguez Pastor JB, Benavides EM. Axiomatic Design Of An Airport Passenger Terminal. Proceedings of ICAD2011 The Sixth Conference on Axiomatic Design. 2011 March 30-31; Daejeon.

[4] Ashford N. Level of service design concept for airport passenger terminal - a European view. Transportation Planning and Technology. 1988; 12: 5-21.

[5] Enac. Circolare Gen 02. Regolamento (CE) n. 1107/2006. 2006 Luglio 5.

[6] Chan Y. Cabin safety behavioral intentions of passengers with reduced mobility. Journal of Air Transport Management. 2012; 25: 64-6.

[7] Bezerra GCL, Gomes CF. The effects of service quality dimensions and passenger characteristics on passenger's overall satisfaction with an airport. Journal of Air Transport Management. 2015; 44-45: 77-81.

[8] Blander Reinhardt L, Clausen T, Pisinger T. Synchronized dial-a-ride transportation of disabled passenger at airports. European Journal of Operational Research. 2013; 225: 106-17.

[9] Suh N. Axiomatic Design: Advances and Applications. Oxoford University Press; 1990.

[10] Arcidiacono G. Axiomatic Design for Reliability. ATA Motor Car Engineering Journal. 53: 309-15 .

[11] Arcidiacono G, Delogu, M. The Integration of Reliability Techniques as an aid to the Design Optimisation of an earth moving machine, ASME International, Proceedings of International ME2001 Congress and Exposition, New York (USA).

[12] Arcidiacono G, Campatelli G, Lipson H. A Measure for Design Coupling, IMechE, Proceedings of the International Conference on Engineering Design ICED 01, Glasgow (Scotland, UK), pp. 45-52.