Improvement Proposals for a Baggage Handling System

Faro Airport Case Study

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Abstract

On the past few years, there has been an increase of the low-cost carriers share on European airports. In case of airports located on regions where the tourism is greatly affected by seasonality, as Faro Airport, this increase is even more significant and it starts having repercussions on the airport infrastructure operations, of which stands out a reduction on the number of hold baggage that check in the baggage handling system (BHS) for departure flights.

In order to enable an adaptation to the previously presented paradigm, this masters dissertation main goal is to perform an analysis on different theoretically possible scenarios for the evolution of the number of baggages that check in Faro Airport's BHS and develop improvement proposals based on certain segments deactivation, therefore reducing operating and maintenance expenses while assuring that levels of service are not compromised.

It is used a methodology that consists in representing the BHS on a discrete event simulation tool, through which the system performance is evaluated for the different scenarios, and by formerly identifying the alternative segments parallel to main routes and admissible to be turned off.

Results allow to conclude that for scenarios closer to reality there are at least two stretches that can be deactivated and, in case of a strong decrease on the number of baggages that enter the system, there are two more segments that could be turned off without compromising the BHS proper operation.

Keywords: Airport, Baggage, Baggage Handling System, BHS, Discrete Event Modelling, Simulation.

1. Introduction

On 2003 the number of passengers that arrived in Portugal by air transportation was approximately 10 million, while on 2015 this number expanded to nearly the double, thus almost reaching 20 million (PORDATA, 2016). This massive growth on the number of passengers, registered not only in Portugal, consequently increased the quantity of hold baggage checked in and thereafter this also increased the number of lost baggage cases in airport terminals, which dilated from 22 million to about 24 million worldwide between 2013 and 2014 (SITA, 2015). These lost baggage cases have a profoundly negative impact not only for airport costumers but also for the entities responsible for organization, maintenance and management at airport terminals as they result in very high costs for those entities. Hence, the focus on development and improvement of airport baggage handling systems (BHS) has been increasingly considered and *Société Internationale de Télécommunications Aéronautiques (*SITA*)* disclosed that this focus has already saved 18 billion American dollars since 2007, in matters related to lost baggage.

Aeroportos e Navegação Aérea (ANA) is one of the entities aforementioned, responsible for the management and maintenance of Portuguese airports, and has demonstrated interest in exploring some improvement opportunities, mainly when it comes to upgrade and optimize the BHS at Faro International Airport. This airport has the peculiarity of being located on a region where the economic activities are strongly affected by seasonality, mostly because of beach tourism influence which has led to an increase in the interest of low cost carriers (LCC) to set up and operate in Faro in order to respond to the high tourist influx during the high season in the Algarve region. LCC such as Ryanair, Easyjet, Monarch and Transavia are already responsible for more than 70% of passengers that fly through Faro Airport.

A substantial proportion of the typical LCC passengers, such as short stay tourist and workers or businessmen with brief commitments in several countries, don´t usually carry large luggage. In addition, LCC themselves indirectly end up encouraging their costumers to give up on hold baggage due to taxes applied. Thus, unlike what is verified in most European airports, the number of baggages checked in Faro International Airport's BHS has been decreasing as the number of LCC operating rises.

At the time when the BHS for this airport was designed, it was assumed that the theoretically evolution trend for the number of baggages that enter the system was to increase along the years, like in the major European airports. Thereby, faced with a slight change in this trend, ANA finds an opportunity to be able to adapt to reality in the most appropriate way, optimizing the use of the BHS available resources and achieving advantageous reductions in operating costs, maintenance and human resources budget.

The main goal of this investigation is to perform an analysis on Faro Airport's BHS focusing on hold baggage from departure flights and, considering several possible scenarios for the evolution of the number baggages entering the system, develop improvement proposals based on certain segments deactivation, therefore reducing operating and maintenance expenses while assuring that levels of service are not compromised.

2. Literature Review

2.1. Baggage Handling Systems

The present investigation focuses on the BHS, which is divided into three main areas: arrivals, transfers and departures, the latter being clearly the most complex part of the system and the one studied in this dissertation (Abdelghany, Abdelghany, & Narasimhan, 2006; Ashford, Mumayiz, & Wright, 2011; Horonjeff, Mckelvey, Sproule, & Young, 2010). In addition, the set of several support areas directly related to luggage can also be considered as fourth part of a BHS (Airport Cooperative Research Program, 2010).

Baggages alluding departure flights enter the airport terminal through different public access points on the airport landside and are subsequently intended to board an aircraft. Baggage from arrival flights consists in luggage that entered the airport terminal on the airside, have recently left an aircraft and its destined to leave the airport via the common exits located on the landside. Finally, transfer baggages are the ones that disembark from aircrafts and enter the airport terminal through the access points on the air side and their goal is embark another aircraft in a short period of time (Wells & Young, 2004).

BHS can be divided in three categories based on baggage influx and processing capacity: systems from Category A are those where the number of baggages is equal to or less than 999 baggages per peak hour; in Category B are the ones whose process flows are characterized by being between 1000 and 4999 baggages per peak hour; Category C systems are those that process a number equal to or greater than 5000 baggages per peak hour (Bradley, 2010). As Ashford, Mumayiz & Wright also point out, Bradley also reiterates that the level of automation on a BHS must be higher as the number of processed baggages increase. In other words, at smaller airports such as the ones whose BHS are included in Category A the baggage processing can be done manually, while at larger airports such as those whose BHS are from Category C it's necessary to have automated baggage processing. Automation enables terminal to have significantly higher capacity and improve the quality of service provided (Kazda & Caves, 2000).

The security control areas constitute a system, which can be part of the BHS, and it is through this system that the baggage screening is carried out, with the least possible impact on the efficiency of the airport operations. However, following the terrorist attack on September 11th 2001 in the United States of America, this screening has undergone a major overhaul, with TSA (Transportation Security Administration) introducing significantly stricter and rigorous security controls in the baggage processing method and, consequently, directly affecting the planning and operations associated with BHS worldwide (Wells & Young, 2004). The set of different security control areas is called Hold Baggage Screening (HBS) and it's a system that, in case of European airports, is integrated on the BHS.

2.2. Discrete Event Simulation

The airport and its terminals compose such a complex system that encourage the use of different models, such as descriptive, performance, prescriptive-normative, analytical, numerical, simulation models and hybrid models (Ashford et al., 2011; Wu & Mengersen, 2013). In the present work, the most appropriate approach for the analysis and development of the case study is resort to a simulation model. As stated by Ashford, Mumayiz and Wright (2011), the simulation models are based on a computerized representation of reality and aim to portray different processes of a system as a function dependent on time, using mathematical, logical and numerical model that allow to anticipate the system changes occurring along the operating time. One of the great advantages of simulation models is that they allow to perform several and repeated analyzes of the same system, simultaneously changing operational conditions, which would be extremely expensive and a considerably longer process if these observations were made with the system itself repeatedly running in reality (Horonjeff et al., 2010).

As it was proposed by Horonjeff, McKelvey and Young (2010), a simulation model consisting of a network of point nodes united by paths will be constructed in order to represent and analyze Faro Airport's BHS. The paths will represent the conveyor and various merges and splits that exist in the routes where baggages are transported throughout the system, while the point nodes will portray the different components and services included in the BHS.

To help with the process of choosing the discrete event modelling software, the published work of Jadric, Ćukušić & Bralić (2014), Bardonet, Tewoldeberhan, Valentin & Verbraeck (2002) and Dias, Pereira, Vik & Oliveira (2011) was consulted and duly studied. Afterwards, the final choice lied on AnyLogic, which is a tool with several advantages that considerably facilitate the simulation process and that allows to insert maps to serve as the basis for models, to build the model in two dimensions but easily convert it into three dimensions, to program funtions using Java programming language and that, in addition, already contains a library of objects and entities related to the airport scope (Grigoryev, 2015).

3. Data and Methodology

3.1. Simulation Model

The first step to gather information about Faro Airport's BHS was to schedule a meeting with ANA, where it was provided a blueprint representing the whole baggage handling infrastructure along with some spatial referencing and some statistical data collected throughout the years related with baggage approval rates at different security levels, manual code destination reading, shoots occupancy rates, among other things.

Posteriorly, the methodology presupposes the construction of the discrete event simulation model based on the information and data previously gathered. First of all, the BHS blueprint was imported to the simulation software, AnyLogic, in order to provide some geographical referencing and make it easier to place a graphic scale on the model. Then, a network of point nodes and paths was drawn, where the paths represent conveyors that allow baggage transportation on the BHS and the nodes depict different services included on the system, such as:

- Baggage entrance and exit points from the system (check in collectors and shoot);
- Hold baggage screening location and process;
- Conveyors merge and embranchment zones;
- Areas where there is a change of speed between consecutive conveyors.

After this network of point nodes and paths is delineated, these elements must be configured to have physical meaning with the help of AnyLogic elements and Java programming language. Baggage injection is performed through programming diverse injection functions and each one is based on a probability distribution function with certain limits, which aim to recreate the variations registered in the inflow rate per hour and during a whole working day. The probability function adopted was the uniform distribution, whose lower and upper limits were defined based on an analysis previously performed on an Excel sheet which contains the results obtained in the scenarios formulation and later introduced in Anylogic through a programmed "Source" element.

Baggage transportation throughout the system was defined by applying constant speeds to "Conveyor" elements, considering not only information collected from ANA but also a visit made to Faro Airport's BHS. Besides that, in the model calibration phase there were still some adjustments at these speeds in order to portray reality as accurately as possible.

The security levels performance is portrayed through baggage approval rates, that is, for each vertical sorter included after a certain security check there is a "Select Output" element associated with it and which allows the definition of a probability for a baggage to be appointed as clean on that security level. Obviously, these probabilities are calculated based on statistical data collected on the BHS along the years.

Although is not essential for the present work since the BHS study and performance evaluation was focused upstream, the shoots were properly programmed with the objective of maintaining the coherence between the simulation model and reality. Thus, as the number of activated shoots depend not only on the period of the year but also on the period of the day, there are function that were defined in order to represent the variation of probability of a certain bag abandoning the system by a determined shoot. In other words, with each shoot a function was associated which indicates, for each moment of the day, the probability of a bag exiting the BHS through that same shoot.

There are a few bifurcation zones of conveyors which are also related to "Select Output" elements and that have been defined with a fixed probability value. These embranchments include the manual destination code reading, connections between different terminals, connections to areas for temporary baggage storage, among others. Most of them were defined with a null probability because in reality they are used very sporadically or simply because they are not useful for the present investigation purposes. The exception is the manual destination code reading that was defined like the security levels performance aforementioned.

Finally, a few bifurcation zones of conveyors correspond to system redundancies and operate as alternatives to main paths. These are the essential parts of this study and had to be previously identified and then duly programmed. The capacity of the main routes was determined and the alternatives were programmed through a function to be turned off at all times and only activate when the capacity of the main path was exceeded. This function also keeps records of the time during which the alternatives were turned on, in order to allow an afterwards evaluation of the system performance.

Obviously, after the definition of all these parameters there was a phase of calibration and validation. On this stage, based on all the statistical data collected, the goal is to ensure the simulation model represents what happens in reality. Therefore, all the parameters were analyzed in order to make sure the produced results were accurate, as well as the baggage movement throughout the system since the time bags spent along each stretch were counted and then compared and adjusted to times registered on the BHS itself.

3.2. Scenarios

This phase purpose is to elaborate theoretically possible predictions for the evolution of the number of baggages that enter the BHS of Faro Airport. As it's not available much statistical information directly about this topic, the scenarios are a result of an intensive search, analysis and processing of statistical data collected on these two subjects:

- Projections of the number of passengers at Faro Airport;
- Projections of the average number of hold baggage pieces carried by passengers at Faro Airport – baggage factor.

The tables shown below present a characterization of the different projections considered to build the scenarios.

Projection	Source	Characterization
Number of Passengers	INE (Portuguese National Statistical Institute)	Theoretical trend based on last years
	Boeing	Theoretical trend based on last years
	Own	Intention of building an aggressive scenario
Baggage Factor	ANA	Average of the last years
	ANA	Theoretical trend based on last years
	Own	Intention of building an aggressive scenario

Table 1 – Characterization of the projections considered to build the scenarios.

Combining the 3 projections alluding to the number of passengers with the 3 projections on the baggage factor, it resulted in a total number of 9 scenarios. Furthermore, there were considered two other scenarios through which the system performance was evaluated in case of deactivation of a whole baggage handling ring, what represents a significant potential containment of expenses.

The number of simulations is twice the number of scenarios because it's considered one for the high season period, in August, and another for the low season period, in December.

4. Case Study

Faro International Airport, which International Air Transport Association (IATA) code is FAO, is "the main gateway to the Algarve" (ANA Aeroportos de Portugal, 2016). The airport was inaugurated in 1965 and aims to serve not only the city of Faro but also the entire tourist region of the Algarve, in the southern part of Portugal.

The BHS of the Faro Airport is composed by two main areas: processing zone 1 (PZ1), consisting of ring 1, and the processing zone 2 (PZ2), which is constituted by rings 2 and 3, as it is identified on the next figure.

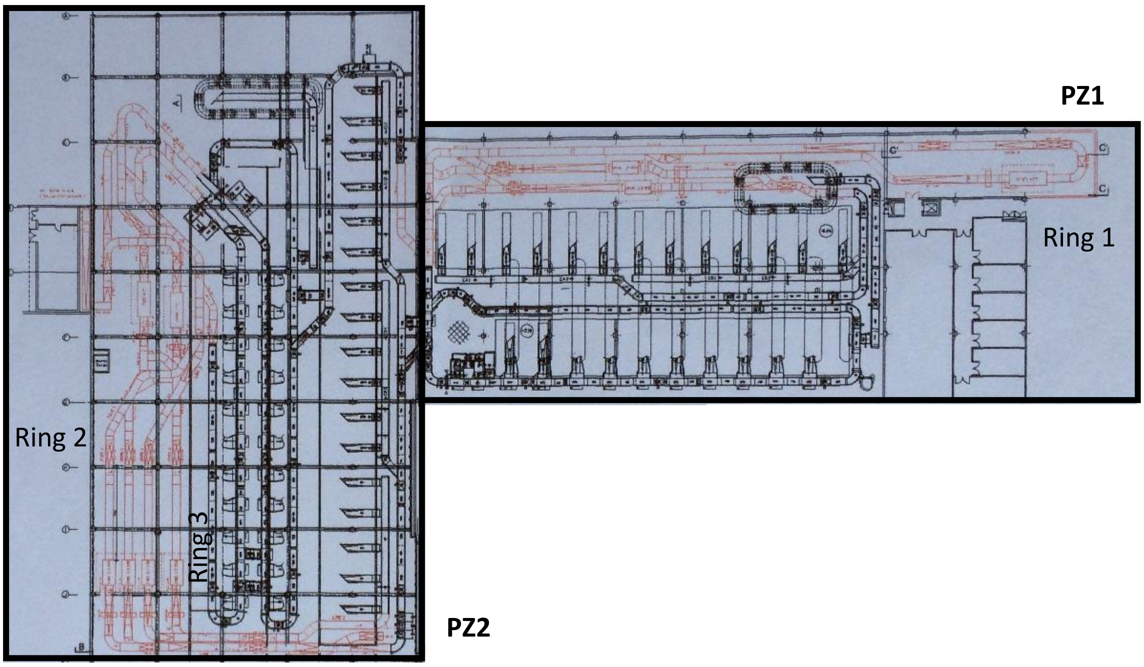

Figure 1 – The BHS of Faro International Airport.

During low season period, approximately between September and May, there is a significant decrease on the number of passengers and consequently on the baggage influx at Faro Airport's BHS. Therefore, during this season, PZ2 is deactivated and baggages are only processed through PZ1.

Moreover, this BHS has a particularity that distinguishes it from all others: the maximum allowable size for a baggage is bigger than what is defined in other airports due to the golf bags. Usually golf bags are processed as out-of-shape luggage although, due to the high number of golfers that visit the Algarve, Faro Airport's BHS is prepared to process these bags as a common hold baggage. Hence, the virtual window of each bag that enters the system is 1.30 meters, being 1.10 meter the maximum length acceptable for a hold baggage plus two 0.10 meters parcels corresponding to the necessary distance between two baggage circulating on BHS conveyors.

On the table presented below are exposed the monthly number of baggages that were obtained in the different considered scenarios formulated.

Scenario	Number Baggages Low Season (month)	Number Baggages High Season (month)
Scenario 1	76 228	386 937
Scenario 2	71 509	468 860
Scenario 3	58 133	295 085
Scenario 4	54 534	357 561
Scenario 5	27 662	140 410
Scenario 6	25 949	170 138
Scenario 7	55 050	289 283
Scenario 8	41 982	220 612
Scenario 9	19 977	104 974

On the following page, it is presented a figure with the identification of the alternatives taken into account on the present investigation and in which the results analysis and improvement proposals were based on.

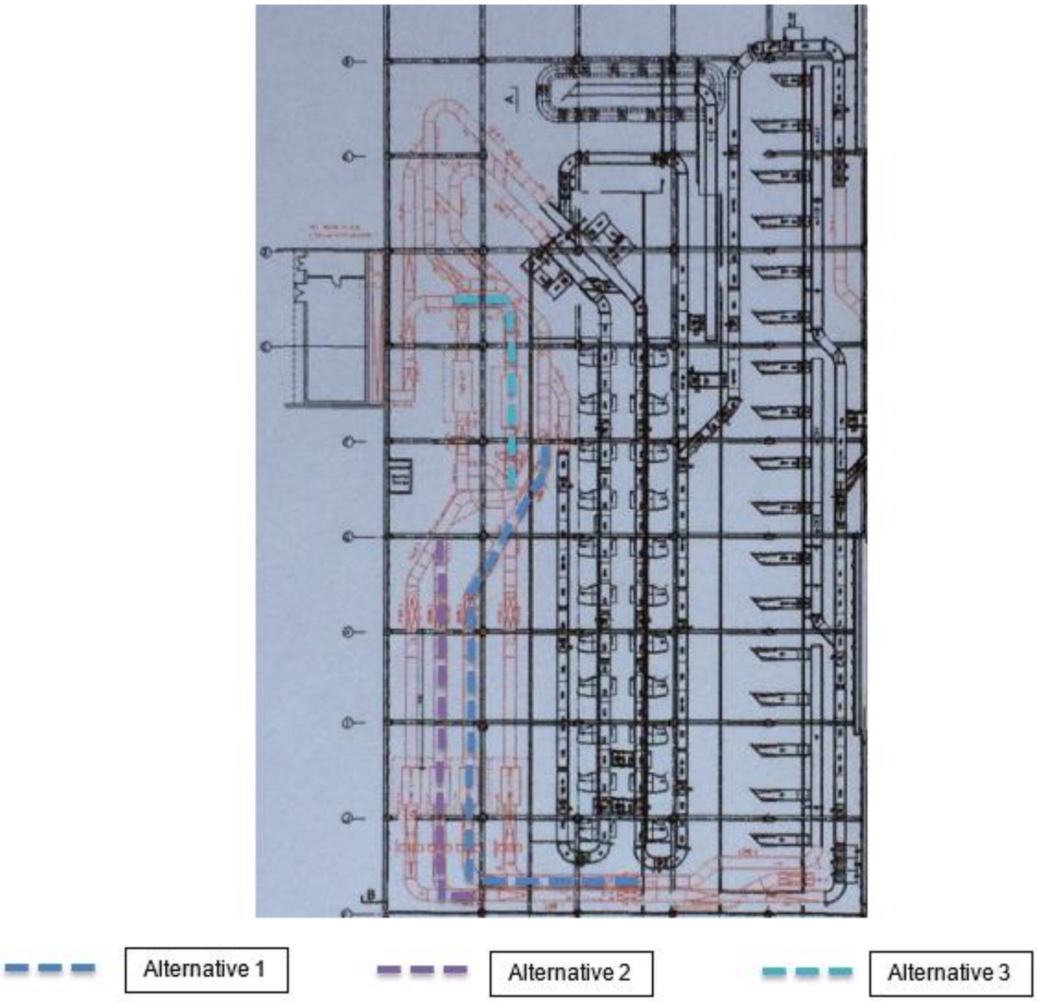

Figure 2 – Location of alternatives 1, 2 and 3 on PZ2.

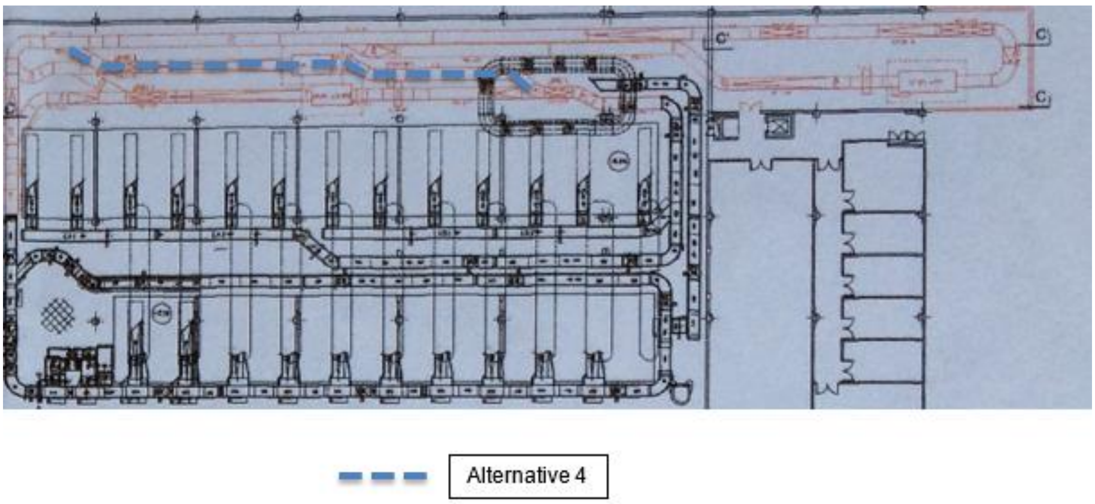

Figure 3 – Location of alternative 4 on PZ1.

5. Results

The simulation results are satisfactory and allow to withdraw some conclusions, which are presented on the table below.

Scenario	Alternative 1	Alternative 2	Alternative 3	Alternative 4	
				Low	High
Scenario 1	Deactivate	Keep turned on	Deactivate	Doesn´t apply	Turned on
Scenario 2	Deactivate	Keep turned on	Deactivate	Turned on	Turned on
Scenario 3	Deactivate	Deactivate	Deactivate	Doesn´t apply	Deactivate
Scenario 4	Deactivate	Keep turned on	Deactivate	Deactivate	Turned on
Scenario 5	Deactivate	Deactivate	Deactivate	Doesn´t apply	Deactivate
Scenario 6	Deactivate	Deactivate	Deactivate	Deactivate	Deactivate
Scenario 7	Deactivate	Deactivate	Deactivate	Doesn´t apply	Deactivate
Scenario 8	Deactivate	Deactivate	Deactivate	Deactivate	Deactivate
Scenario 9	Deactivate	Deactivate	Deactivate	Deactivate	Deactivate
Scenario 10	Keep turned on	Doesn´t apply	Deactivate	Doesn´t apply	Doesn´t apply
Scenario 11	Deactivate	Doesn´t apply	Deactivate	Doesn´t apply	Doesn´t apply

Table 2 – Conclusions withdrawn from the simulation results.

As can be seen in the table, results obtained to both alternatives 1 and 3 are very similar: these are dispensable paths that can be deactivated without compromising the BHS effectiveness and efficiency, for all scenarios in analysis, thus enabling a reduction on costs of operation and maintenance. The only exception is verified for alternative 1, which must be kept turned on if the characteristic conditions of scenario 10 are met at Faro Airport's BHS. This last conclusion was already expected because scenario 10 involves a high baggage influx and comprises turning off the whole ring 2, consequently overcharging ring 3 where the alternative 1 is located and subsequently making it absolutely necessary during peak hours.

In a general way, alternatives 2 and 4 also have analogous performances. On the one hand, for scenarios closer to reality, that depict higher numbers of baggages entering the BHS, these alternatives proved to be indispensable, mainly during peak hour. Therefore, most likely they can´t be deactivated neither for now nor on a near future. On the other hand, if in the future there is ever a considerable decrease in the baggage influx, as the one portrayed by scenarios 5 to 9, these two alternatives become unnecessary for the proper functioning of the BHS and can be turned off, in order to enable a reduction on operation and maintenance budgets.

6. Conclusions

This work allowed the author to perform an analysis for the Faro Airport's BHS, as it was intended by ANA. First, it began with a review of the literature already published on this theme in order to gather elements that increased the knowledge acquired on this topic and to understand the scientific advances already made in this field of study. Subsequently, the methodology outlined was applied through the construction of a discrete event simulation model that represents the BHS and through the formulation of theoretically possible scenarios for the evolution of the baggage rate that enter the system. Then, after having these work elements, this investigation proceeded to the simulations and results collection stage, which made possible the proposal of improvements for the baggage system in analysis.

Therefore, in general, the main goal of the present work was accomplished. The examination of the BHS of Faro Airport carried out proved to be opportune as the impact that LCC begin to have on airport activities, by reducing the number of baggages entering the processing systems, induces a need to consider some adaptations to the future paradigm. In addition, the topics discussed on the results analysis and on the improvement proposals have proved to be very convenient for Faro Airport management sector, since they allow a clear reduction of maintenance and operating costs, in case that similar conditions to those portrayed by the scenarios are verified in the future.

As this topic has not yet been adequately addressed at international level, there was experienced some difficulties in perceiving liabilities common between Faro Airport and other airports under similar conditions, which resulted in a highly personalized methodology for this specific case study. However, it's important to mention that this methodology can easily be adapted to other case studies, including cases in which the problem to solve is exactly the opposite: a lack of system capacity to process a number of baggages that is likely to increase. To do so, the phase for analyzing the existing redundant stretches should be replaced with a phase to design additional alternative paths to the system and, at the end of that investigation, it could be concluded whether or not there was a need to incorporate these designed sectors, taking into account considered scenarios.

It should be noted that the methodology developed in this investigation can also be applied to Material Handling Systems (MHS) in general, such as a set of transporting conveyors in a warehouse. In case of considerable decrease in the number of material units entering on the system in question to be transported, the methodology used for the BHS of Faro Airport may allow a containment of expenses in this same warehouse, providing answer as which sections should or could be disconnected, if the existing conditions permit so.

If there was an opportunity to extend this study, the first step would be to deepen the knowledge about Faro Airport. There was a lack of more accurate and reliable data to construct the simulation model as close to reality as possible. In the event of having time and monetary availability for a more extensive data collection and with more field visits, there was a prospect to improve the simulation model quality and consequently the quality of obtained results and interventions proposed for the BHS. Secondly, if this research could be extended, some time would be devoted to studying and building scenarios that would come closer and closer to the future reality and that would enable to achieve more reliable results and more easily transposed for the BHS reality. Finally, if the occasion allowed so, it would also be extremely useful to extend the phase of improvement proposals in order to have a more accurate and deep economic analysis that could quantify the benefits and turn these interventions into palpable values, which should be more perceptible to the community and more desirable for entities that manage airports, such as ANA.

Summarizing and concluding, the objectives were duly achieved. Depending on the evolution of the baggage entry rate registered in the future, this investigation identifies the direction to be considered, regarding the management of the baggage handling infrastructure of this airport. In addition, it was demonstrated the potential of the methodology used, which may be applied in other airports or material processing systems, in which is observed a similar situation to the one verified at Faro Airport.

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