Functional Analysis of the Implementation of an iBeacon System in an Air Operator

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Abstract

Airline companies are making great efforts to find ways to optimize various processes. Such as in maintenance to ensure high safety standards and directly to customer service. Economic pressure is increasingly high, and it is a business model with a low payback rate. The goal of this paper is to leverage the use of existing resources - iPads - to simplify processes currently inefficient. The adopted technology starts from the assumption that it will be the iBeacon since it takes advantage of the technology owned by Apple for the transmission of signals. It was integrated into the iOS and it enables an iPad or iPhone to perform two functions - transmitter and receiver. Furthermore, a review of various real-time location system technologies is conducted, and their applicability in the context of an airline operator is evaluated. In this paper, three different case studies on processes where technology can be advantageous are addressed: crew check-in at the presentation terminal; pre-flight procedures inside the aircraft; tool inventory management in maintenance. A proximity-based solution was proposed for each case, using different technologies. The most popular solution has been the adoption of Quuppa technology. It is Bluetooth based, with its protocol allowing more precise positioning (first and last case). For the second case, simple RFID technology is proposed. Lastly, financial and functional analysis of each solution was undertaken, by calculating the benefits of their implementations.

Keywords: Optimize, iBeacon, real-time location system, Quuppa, RFID.

1. Introduction

Airlines strive to perform more efficiently every day. Very efficient processes and procedures are necessary just to keep normal operations running smoothly. However, the quest for ever more efficiency is not sustainable without major changes. In a post-pandemic era, congestion at airports is reaching a tipping point and shows no signs of abating as passenger traffic continues to grow. The air travel industry takes passenger satisfaction seriously.

In a global market where the possibility of choice is becoming more available to the consumer, the management of companies goes through a continuous process of optimization. This is a complex and non-trivial process that aims to spend as little money as possible, without compromising the quality of the final product. Thus, it is essential to find a reasonable balance between these goals, which are hard to obtain.

Portugália has multiple technologies already deployed in the field, there is a great interest in exploring them to their maximum capabilities. One of those technologies is the iBeacon which is integrated in the operating system of the iPad used by some staff members. iBeacon system is a communication technology that allows applications to identify their position on a local scale. It enables the delivery of customized data to users based on that location. Tracing its roots to the Bluethooth Low Energy (BLE) system, this is a low-power, low-cost wireless communication system used within medium and short-range.

A priori it is considered and studied as a low investment system. However, it is necessary to analyze the procedures involved in flight operations in order to assess if the acquisition and implementation of this technology will potentially save wait times and data overlap. The goal is to achieve an overall improvement in efficiency and inherent processes in any situation - *e.g.* crew check-in.

Portugália has been facing growth. Its fleet is expected to increase to 19 aircraft by the end of 2022. This growth brings new challenges and emphasizes others that had not yet been overcome. It also leads to the need to introduce more human resources, leads to more material entering and leaving the workshops and logistics, greater maintenance dynamics, *etc.*

In the initial, phase in-depth research on existing technology and bibliography was carried out. Secondly, a survey was performed in order to confirm what could or could not be useful for this specific case. Subsequently, it was time to get to know the various departments, map the main challenges and find a way, using technology, to overcome those challenges, making the processes more efficient.

This paper aims to use technology to minimize the impact of the raise of challenges the company faces daily. With that in mind, the company intends to optimize operational processes with the help of different technological solutions. As the work evolved, there was a focus on the issues related to crew tracking and tools and parts tracking. In terms of crew control (exact time which the crew members go through some strategic locations along their route, which starts with individual check-in), while in terms of controlling items in workshops and warehouses (check-in and check-out of parts).

The research developed in the course of this paper is heavily supported on existing papers describing studies performed for real-time location technologies in industries other than aviation, specially in construction sites. The goals of such papers and studies are very similar to the goals of the aviation industry.

There are many attempts to automate data collection on production resources and status using sensor technologies, such as passive Radio Frequency Identification (**RFID**) [1], Bluetooth Low Energy (**BLE**) [2], and Global Positioning System (**GPS**) [3], among others. A real-time tracking system can be used for identifying value-adding time of construction resources. The fundamental issue is how real-time tracking does not only improve production control but also enables measuring of the performance level of site operations. Waste can occur in many ways, such as waiting, transportation, or movement. The crucial requirement for a tracking system is to identify these non-value-adding activities, which are not often noticed in the project [4].

2. Background

This section provides information which is necessary in order to understand this work.

2.1. Portugália Airlines (PGA)

PGA is a portuguese based airline. It is a subsidiary of TAP Air Portugal. PGA works within a group logic, it is a flight capacity supplier by hiring its aircraft to TAP Air Portugal. Portugália thus is the feeder-defeeder of the TAP Group. Hence, in 2016 TAP's subsidiary Portugália Airlines was commercially rebranded and started operating under the TAP Express banner.

2.2. IATA Delay Codes

IATA has developed a group of business standards upon which the air transport trade is built. They assist airlines by simplifying processes and increasing traveller convenience. In that sense, IATA created a list of delay codes to standardize the reporting system by airlines of commercial flight departure delays. The flight delay reporting format was standardized by using codes that clearly identify the cause for the delay and the responsible entity. This is a very important model, to solve any dispute between possible responsible entities.

Like other airlines and aircraft ground handling, TAP Group has the common practice of having contracts based on a bonus-malus system, penalizing the causative agent for the delays caused. The delay codes cover nine categories sets according to their cause. Each category sets can be described using a two-digit or a two-letter alpha code. Most airlines, and TAP, use the numeric format and subdivide the IATA codes with additional characters, for more granular delay analysis, but they are not standardized. The relevant codes for this work are the ones that determine Portugália's responsibility for the delay, since those are the ones which this work aims at solving/reducing.

2.3. Real Time Location System (RLTS)

RTLS is a type of system that is capable of locating in real time. This is used to automatically identify and track the location of assets or people in real time, usually within a building of other contained area. Wireless RTLS tags are attached to objects or worn by people, and in most RTLS, fixed reference points receive wireless signals from tags to determine their location.

2.4. Radio Frequency Identification (RFID)

RFID technology uses electromagnetic fields to identify labels or identifiers - tags - with a portable reader or fixed - with an antenna. Its main advantage is that the tags can be passive, not depending on any energy source. In this way, the tags can be placed on any object.

Sometimes when one talks about RFID it refers in particularly to passive RFID. However, RFID encompasses active tag technologies (*e.g.* Bluetooth, UWB, *etc.*) and passive tag technologies (*e.g.* NFC, RAIN RFID, *etc.*).

2.5. Quuppa

The Quuppa Intelligent Location System$^{\text{TM}}$ is a technology owned by a Finland-based company that specializes in the field of real-time location tracking. It is a RTLS technology platform for location-based services and applications. It provides accurate and real-time tracking for tags and devices using unique direction-finding methods and advanced proprietary algorithms. Assets, people, and mobile devices are tracked in real-time using Bluetooth-compatible tags, which send location data to the locators. The data is then computed through the Quuppa positioning engine, using advanced positioning algorithms to display an accurate dot on the map.

3. Operational Flight Analysis

The operational flight data analysis was crucial to sustain the application of the solutions presented in this work.

3.1. Data Filtering

To forecast the operation for the next years and analyse the flight data on flight delays, the data from the operator's database was used. It had flights from 29 May 2016 to 12 June 2022. Being a total of 176674 flights for analysis. It starts from a database with **176674** flights and **54** parameters per flight, since some of this data is not populated on all flights, the set of actual data was **6016912**.

To simplify the analysis, and since not all parameters were necessary, preliminary filtering was carried out, broken down into two steps. Firstly, all the unessential parameters were deleted - remaining the ones were: leg_no, ac_subtype; ac_registration; dep_ap_actual; arr_ap_actual; dep_sched_dt; offblock_dt; arr_sched_dt;

arr_dt; leg_state; leg_type; delay1_code; delay1; delay2_code; delay2; delay3_code; delay3; delay4_code; delay4; change_reason; ops_remark; pax_flown; isvalid; captain; previous_leg_no; next_leg_no. The second step was to filter the only relevant flights. The relevant flights follow a specific set of characteristics listed in Table 1.

Table 1: Relevant filters of the parameters.

Parameters	**Characteristic**
dep_ap_actual	LIS
leg_type	(C or G or J)
leg_state	ARR

Lastly, a set of **48707** flights remained to be analyzed, with **26** parameters each, giving a total of **878578** data effectively filled in.

3.2. Movements and Delay Analysis

A detailed analysis was made with the set of **48707** flights, implementing some new parameters, to the filtered data. Overall each flight ended up with a set of **34** parameters. Overall there was a sample with a total of **1303044** data effectively filled in. With the new set of information, it was possible to extract some relevant intermediate data for the analysis, showed in Table 2.

Table 2: Relevant data for the analysis along this document.

Variables	**Value[min]**
Tot_Dly	807942
Tot_Dly_15	689094
Tot_PGA	190732
Tot_PGA_15	172742

The new parameters helped classifying the flights regarding their delay codes. Figure 1 summarizes the distribution of the percentage of flights according to their type of delay. The yellow data represents around 9.29% of the commercial flights, and charters, with a delay greater than 15 minutes caused by PGA and departing from the Lisbon Airport.

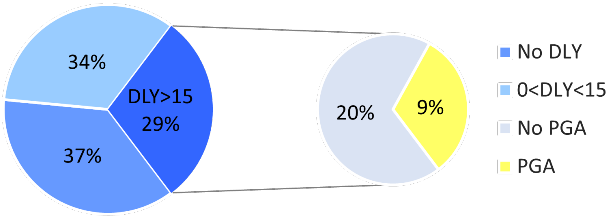


Figure 1: Percentage of flights according to their OTP.

In Figure 2 is possible to come up with a visual conclusion about the top ten PGA delays, with the heaviest impact on the overall OTP.

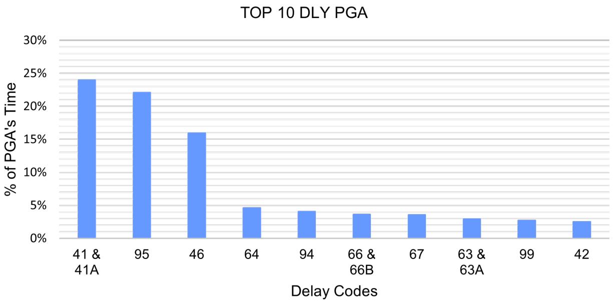


Figure 2: Top 10 delay codes - responsibility of the operator - with the most occurrences in PGA.

The codes from the Figure 2 were decoded to understand their particular reason inside the operator. This detailed information was the bottom line to begin a plan of action. Decide which area is the most effective to minimize the problems and understand what can and cannot be changed. From that one arrive at the following conclusion:

Since aircraft and maintenance delays are not easy to prevent, codes 41 & 41A, 42, and 46 were dismissed for this work. Delays 95 and 94, as the 64 and 67, were also dismissed since they are reactionary delays. To prevent a reactionary delay it takes preventing a primary delay. In this sense, for the purpose of this work, delays 63&63A and delays 66&66B were considered.

Code **63&63A** refers to entire late crew Boarding Procedures other than connection and Standby.

Code **66&66B** refers to late cabin crew departure procedures other than connection and standby.

3.3. Flight Forecasting

A predictive analysis of the flight data had to be carried out. The current and historical facts were analyzed to make predictions about future events. It uncovers relationships and patterns within large volumes of data that can be used to predict behaviour and events. Unlike other BI technologies, predictive analytics is forward-looking, using past events to anticipate the future [5].

Since PGA is in the phase-in process of some aircraft (A/C) - three Embrear190 and three Embraer195-, until the end of the year, the calculation of the following data will helpanalyze and assess the impact of the acquisition of one A/C in the overall scenario.

The entry of a new Embrear190 will add a_90=2.35 departures per day form Lisbon Airport during its first month, and one Embraer195 will add a_95=2.55 departures per day in the same conditions, during the same period.

The following part of the analysis considered the normal behaviour of a constant fleet. The average departed flights per day per A/C, by model was calculated for each month through the years, but some data was dismissed. For the model E190 all data before November 2016 was dismissed since it was the phase in of the new fleet. Hence, the total number of operational E190 aircraft was 9, for the calculations. For the case of the E195 model all the data before September

2017 was also dismissed, for the same reason, considering 4 E195 A/C for the calculations. Other data was also dismissed, considering the Covid-19 pandemic.

After analysing all data, it was possible to obtain the following chart in Figure 3. This chart has the graphical evolution of the number of flights for the next three years. It forecasts the flights from June 2022 until December 2025, by type of aircraft. The light blue bars represent the E190 model and the dark blue the E195 model. For data before June 2022 the actual values were considered.

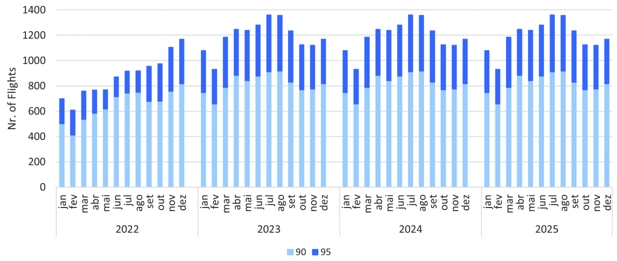


Figure 3: Monthly distribution of forecast flights - Jun 2022 until Dec 2025.

This graphic verifies that after integrating all the new aircraft, the model assumes a cyclic behavior over the years, since the fleet has a constant number of A/C. It is obtained an overall scenario of around 14 000 Flights per year, for the next three years.

4. Case Studies

Three central case studies covered in this thesis:

1. Pre-flight procedures at the TTA;
2. Pre-flight procedures at the A/C;
3. Maintenance department and its logistics.

4.1. Case Study One - Pre-flight Procedures at the TTA

During the pre-flight procedures at the Areeiro Crew Terminal(TTA) many information is not reported automatically and impartially. That leads to unclear data or even a lack of it when figuring out the cause of some delays. Therefore, it is sometimes difficult to determine whose responsible for the delays with codes 63&63A and 66&66B (between PGA and the handling company). Lack of proof makes it hard for the operator to sustain its defense and the handling company's fault. This may lead to the operator being unfairly held responsible for some delays.

In this case study the implementation of a RTLS solution was proposed, aiming at automatically report the monitored information. Quuppa technology was chosen because the mobile devices are already equipped with Bluetooth radio which allows the devices to get their own location. With an application running on the personal electronic device (PED), it is possible to emulate it as a Quuppa tag. Also in terms of accuracy, Quuppa technology meets the needs of the industry demands. With Bluetooth UWB technology - which at the moment is not yet standard - it would be required to attach an UWB tag to each device.

This solution suggests the setting up of two Bluetooth antennas - one at the input of the terminal, and one at the output of the terminal, as described in Figure 4.

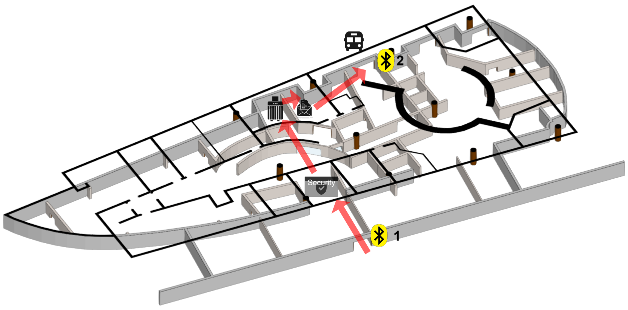


Figure 4: PNC check-in proposed solution

By introducing antenna **1** at the entry of the terminal, the antenna will interact with the crew member's PED (iPad) when detected, and triggered an interaction. Instead of doing the check-in on the networked computers, it will allow them to do it on their own PED as soon as possible and while waiting for the security control. Next, it will send/download the Briefing PDF avoiding the need to print the document and the eventual delays due to eventual printer problems or delays.

Antenna **2** will detect and register the exact time the crew member PED approaches the exit to get the bus (air-side) and the moment it leaves the area. Furthermore, it will send a trigger to the bus terminal informing that a crew is waiting for a bus in order for *Groundforce Portugal* to verify if there is a bus available at the pick up point. If not available, immediately send a bus to pick up the crew.

4.2. Case Study Two - Pre-flight Procedures at the A/C

For this case study a solution was proposed based on the implementation of a RFID technology.

Firstly, the RFID technology will remove the need for the cabin crew (PNC) to verify some items of the checklist manually, by doing it automatically with an RFID reader. This will save time and avoid human error. Secondly, the RFID technology will provide updated information regarding the items to the Aircraft Maintenance and Engineering Operating System (AMOS).

This technology is not able to automatically verify all the requirements that shall be checked in the safety checklist. In this sense, it shall be noted that each piece of equipment, fixed or portable, has its specific verification characteristics. In a preliminary evaluation, it has been concluded that the most manageable types of equipment to check with an RFID technology are those whose checks are: existence, quantity, the existence of seals, and expiry date. An in loco evaluation took place in order to confirm which items could be entirely verified with RFID.

The setup of the RFID technology will vary from item to item. As a starter the RFID will verify the existence of the items. It will also enable to keep updated information in the AMOS which will, in its turn, also update the maintenance department updated regarding the state (validity, condition, quantity,and existence) of those items on each A/C. Lastly, regarding items that should be sealed, the tag will be placed in a way that it will be disabled whenever the item is used.

4.3. Case Study Three - Maintenance

In this case study, several challenges have been found regarding logistics and inventory of the maintenance department. In special, it is important to control the entry and exit of tools from the warehouse, such as drills, and torches, among others, and do it in a way that is efficient.

In order to optimize the management of the inventory and automate procedures, the proposed solution is the implementation of a Quuppa technology. Quuppa is a Bluetooth-based technology, which protocol allows for a more precise location. It is an active RFID technology because it sends its identification through radio communication (Radio Frequency IDentification).

A tag will be attached to each tool. This tag identifies the tool and periodically communicates its identification to a system in which it is stored with the serial number of the respective tool to enable integration with existing software. When a tag is in the warehouse, the anchors will locate it within this space, informing the system that the respective tool is in storage. Tags that are located outside of the warehouse are not being detected. Thus, those are considered to be outside of the warehouse. The tool inventory can be checked in real time, and the inputs and outputs of the different tools can be known. In this way, it will be possible to know which assets have been taken away during a shift, whether they have already been returned, the last time they were in the warehouse, and the Aircraft Maintenance Technician (TMA) who took the tool.

5. Analysis of the solutions

The feasibility of each case study solution is analysed hereunder, forecasting their operational and financial impact. It briefly discusses the proposed solutions, costs and benefits.

5.1. Case Study One - Pre-flight Procedures at the TTA

The delays caused by the late arrival of crew members to the aircraft (codes 63 and 66) was predicted in order to estimate the NPV of the solution.

It begun by establishing which flights would benefit from this solution. In this sense, the sample was limited, creating a population of flights with PGA delays longer than 15 min, which corresponds to 9.29% of the total flights to be studied - this parameter comes from the data in Figure 1, the value in yellow, which corresponds to the percentage of flights with delays longer than 15 minutes with partial or total responsibility of the PGA (by responsibility, it means having one or more PGA delays codes). In this regard, the actual number of flights is calculated.

The Table 3 displays the parameters obtained for the calculus of the savings of the solution. The second column lists the percentage of delays, for each month that will not belong to PGA, when correctly attributed. Column three displays the total number of flights foretasted for each month. Finally, columns 4 give the saved time, in minutes, estimated for the delays 63 and 66.

Table 3: Detailed information required to estimate the time saved.

Month	Non_PGA	#Flights	Time Saved [min] 66&63
Jan	30%	1068	87.72
Feb	20%	920	43.49
Mar	20%	1175	60.66
Apr	50%	1233	152.16
May	70%	1263	228.39
Jun	80%	1268	261.93
Jul	85%	1349	296.04
Aug	90%	1224	284.42
Sep	85%	1129	247.78
Oct	70%	1098	198.47
Nov	50%	1109	143.26
Dec	50%	1156	149.21

The parameter Non_PGA represents the percentage of delays for each month, which, when correctly attributed, is determined as caused by external entities. The remaining delays still concerns PGA. Over the winter season, especially the first months of the year, the airline schedule is not that intense. Thus, there is more operational availability from the handling company at Lisbon airport, which leads to fewer failures on their part. PGA resources are constant throughout the year. When the number of flights increase during the summer season, the number of crew members remains the same and the handling operation is more demanding. This happens, for example, in the case of the transportation between TTA and the A/C, because the number of buses is constant throughout the year. It leads to the conclusion that in the months with less busy flights, the probability of delays being effectively PGA's fault is higher, then the Non_PGA parameter is lower.

According to the most recent data, from July 2022, in 2021, the average cost of aircraft block (taxi plus airborne) time for U.S. passenger airlines was 80.52 U.S. dollars per minute [6]. the value of 80.52 U.S. dollars per minute was considered for this work. This value includes the direct aircraft operating costs per block minute considering:

- 28.14 U.S. dollars per minute - flight crew;
- 22.50 U.S. dollars per minute - fuel;
- 14.84 U.S. dollars per minute - Maintenance;
- 12.06 U.S. dollars per minute - Aircraft Ownership;

- 2.99 U.S. dollars per minute - Other.

Considering the exchange rate published in *Banco de Portugal* [7], updated on 19th October 2022 - 0.9778 U.S. dollars per 1 EUR - the following value was considered for the costs per minute: $Cost\_min = 82.07\ EUR$. The previous value allow the measurement of the expected savings obtained with the implementation of this solution. Using the values from Table 3.

Finally, the estimated value obtained for the annual profit by implementing this solution was around **178 000 EUR/year**.

The proposed quotation from the company to implement this solution is in the order of tens of thousands of euros plus an annual cost of one order of magnitude lower. The additional cost includes technical services and an extended warranty period for all proposed equipment for the entire duration of the contract. It is important to note that this amount is purely indicative. Some of the services in the proposal can be discarded as the company can provide them without having to pay.

To be more conservative, the budgeted amount was multiplied by a safety factor of 1.5. Not only does this value consider inflation, but it also takes into account the cost of potential training and development of the solution by Portugália Airlines.

It quickly became evident that if this solution is implemented, the break even will be reached during the first semester of the first year. Hence, it presents few financial risks for the airline. Nonetheless, an analysis was made of the NPV of this solution up to year 10 in Figure 5. To commercially protect the companies that collaborated with this project, a fictitious value is used for the budget, which does not change the conclusions of the analysis. This value also includes the safety factor described earlier.

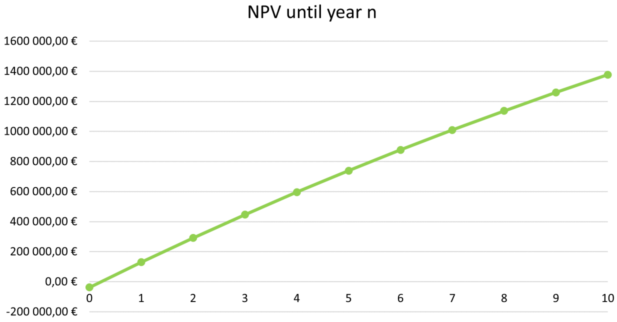


Figure 5: NPV until year n=10 - case study 1.

The results show that the acquisition price of this solution is negligible, when compared to its annual savings. The break even happens in the middle of the first half of the first year.

The adoption of this solution is not only translated into saved money. The graph in Figure 6 is an extrapolation from the direct impact on the number of flights affected by delays 63, and delays 66 in the analysis versus the total number of flights departing form Lisbon.

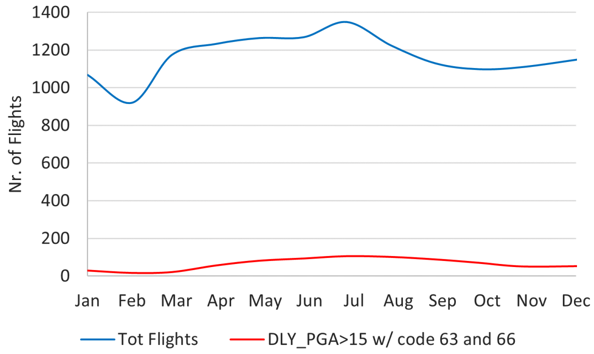
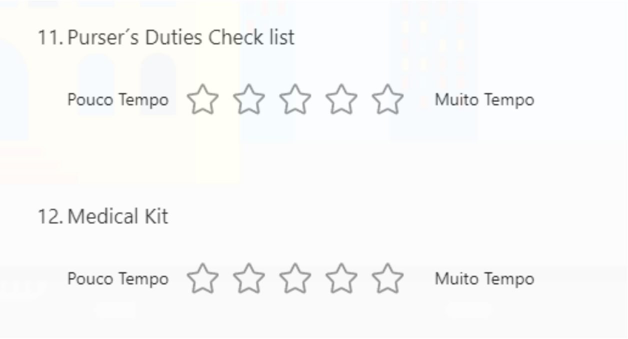


Figure 6: Extrapolation of the total number flights and number of delayed flights by code 63 or 66.

The implementation of this solution will provide an in-depth understanding of this process. Later it will serve as a tool to understand what is happening. With that information, it will be possible to conclude what is happening at each part of the process and possibly the true origin of the delays. This knowledge will ease the creation of a solution that dissipates these two delays. This way, ideally, the red curve in Figure 6 will have a more asymptotic behavior, trending towards zero.

5.2. Case Study Two - Checklists

Three forms were created, listing all the items on the checklist of safety emergency equipment, one for each position - Purser (PU), E2, and E3. These forms start by requesting the average time a crew member usually takes to complete this checklist at the corresponding position. Next, all the items were listed in sequential questions in order to be rated by the surveyor. As shown in Figure 9, each question has to be rated from 1 to 5. A score of 1 star means that it is an item that takes minimal amount of time to check. On the other hand, a score of 5 stars means that it takes a more significant time interval.



11. Purser´s Duties Check list

Pouco Tempo ☆ ☆ ☆ ☆ ☆ Muito Tempo

12. Medical Kit

Pouco Tempo ☆ ☆ ☆ ☆ ☆ Muito Tempo

Figure 7: Sample of two questions of the PNC form.

The methodology chosen to analyse those surveys was by organizing the answers of the forms as in matrix $\mathbf{A}_{N\times M} = (a_{ij})_{N\times M}$ and vector $\mathbf{t} = t_i$.

$$\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1M} \\ a_{21} & a_{22} & \cdots & a_{2M} \\ \vdots & \vdots & \ddots & \vdots \\ a_{N1} & a_{N2} & \cdots & a_{NM} \end{bmatrix} \quad (1)$$

$$\mathbf{t}^T = \begin{pmatrix} t_1 & t_2 & \dots & t_N \end{pmatrix} \in \Re^{(1 \times N)} \tag{2}$$

The matrix **A** contains all the scores/points given to each item per form. In its turn, the vector **t** contains the time indicated in the first question of each form.

In the matrix presented in equation (1) each line - index i - identifies a set of answers ($i \in \mathbb{N} \wedge i = [1, N]$), and each column - index j - identifies the question ($j \in \mathbb{N} \wedge j = [1, M]$). The arguments ($a_{ij}$) represent the score attributed to each question.

In the vector presented in equation (2) each argument (t_i) stores the average time answered in each form - index i.

The arguments in matrix **A** were transform into minutes was made by matrix calculations,

Table 4 shows the conclusions drawn from the analysis of the answers to the forms. Each row refers to one work post. For each workstation, the table shows three parameters. The second column shows the value obtained for the parameter *av_total_time*. Additionally, the third column displays the amount of time that the solution may save for each cabin crew member. The amount of time saved corresponds to the sum of the time spent with the items for which the (RFID) tags are supposed to be placed. Finally, in the last column of Table 4, is the value of the optimization that this solution would make in the process.

Table 4: Summary of the analysis of the data from the responses to the surveys.

	av_tot_time	Expec. Time	Optim.
PU	7 min 02 sec	5 min 53 sec	16%
E2	7 min 08 sec	4 min 51 sec	32%
E3	7 min 27 sec	5 min 17 sec	29%

The values are most satisfactory, though there is a significant deviation from E2 and E3 for the PU. Higher process optimization is verified for the positions of E2 and E3 when compared to PU. If one reviews the items that were more time-consuming in this analysis, it is possible to conclude that the only item that does not belong to the group of item that can be checked using an RFID system is from the PU's position. Notwithstanding, it is also possible to conclude why this solution has a smaller impact for the PU position, as seen above - Table 4. However, the solution still grants an optimization of more than 10%, which is also great.

The solution for this case is not a turn-key solution. Besides setting up the system and executing the annual ordinary maintenance, it will be necessary to keep a regular check on the existing tags. It shall be noted that each selected item must be tagged and that such tag has not an unlimited duration. Tags may broke, in which case they shall be replaced. Also, some items may need to be tagged more than once.

The hardware cost comprises the RFID readers and the tags. Each RFID reader costs thousands of EUR and each tag costs 10 cents. There are many software options on the market ranging from tens of thousands of EUR to hundreds of thousands of EUR.

Table 5: Tags per item and full tagging price per aircraft .

Equipment	Nr. Tags	
Crew life vests	0	
Medical Kit	1	
FAK	2	
Precautions kit	2	
Spare life vests case:		
Adult	2	
Infant		
Seat belt case:		
Extensions	24	
Infant loop Belts		
PNC box	1	
Intubation kit	1	
PAX life vests	0	Price/A/C
		3,30 EUR

While visiting one of the aircraft, it was possible to verify that the life jackets are already incorporated with RFID tags. The cost and process of tagging this item is, therefore, avoided. The equipment with the shortest validity is the life vest (three months). Considering the low number of occurrences with the safety emergency equipment, inspections with tag renewals were considered every three months. Considering that the TMA already visits the aircraft on a daily basis this trimestrial review would not cause major changes to their schedule.

The estimated cost of the implementation of this solution may surpass hundreds of thousands of EUR. This value includes software plus hardware. However, the maintenance cost is very low - around **274 EUR** per year. The reduction of workload can be used to improve the company's customer service. According to cabin crew management, this will help avoid any uncompleted tasks caused by lack of time. Among which are the cleaning check and the catering check. Currently, the only check that the PNC shall complete is a safety check to confirm that there are no suspicious objects inside the trolleys. Nevertheless, the verification of existing meals is not done. Business class, by norm, comes with a meal.

The company responsible for catering on TAP flights departing from Lisbon - delivers the sealed trolley in the aircraft. However, it does not guarantee that the meals, drinks, utensils, and extra meals for sale on board comply with the characteristics of the respective flight. Sometimes, halfway through the flight, it is realized that business class meals are insufficient or that those passengers' food restrictions have not been taken into account by the catering company. These inefficiencies leads to poorer costumer services and affects the reputation of TAP as an airline.

5.3. Case Study Three - Maintenance

The material for the analysis in this section was taken from the AMOS database. This database is where the requisition for each tool is recorded, storing the following information: Date, Booking, Part nr., Serial nr., Description, Quantity, Tool-user, Station, Store, A/C.

The data referring to Lisbon - station = LIS - was analyzed. It began by considering the number of daily tool requests - Booking = Handed Out or Handed Over - in the main warehouse - store = MAIN - for which the data from Table 6 were obtained. This table gives the monthly average of checkouts per day. For these values, the utmost recent data from 2022 was used.

The third column of Table 6 considers the fleet growth, it assumes that the company does not use external services for the maintenance of its aircraft.

Table 6: Average tool checkout per month.

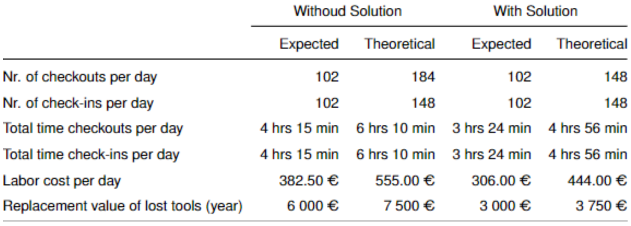
Month	Av. Checkout per day	Forecast Checkout per day
Jan	131	191
Feb	121	177
Mar	134	196
Apr	125	183
May	143	209
Jun	137	199
Jul	132	194
Aug	142	207
Sep	148	217
Average	135	197

According to an analysis conducted by the operator, the current system spends around 2.5 minutes requesting and delivering a tool. The same study also predicted that implementing an automatic request system would save around 30 seconds per interaction.

The following data was considered for this analysis:

- Labor cost [EUR/hour] - 45;
- Workdays per year - 365;
- Average time to request 1 tool [min] - 2.5;
- Average time to return 1 tool [min] - 2;
- Average time to request 1 tool w/ RFID [min] - 2;
- Average time to return 1 tool w/ RFID [min] - 2.

Considering, now the data obtained by the analysis of the AMOS database can be found in Figure 8.



	Withoud Solution		With Solution	
	Expected	Theoretical	Expected	Theoretical
Nr. of checkouts per day	102	184	102	148
Nr. of check-ins per day	102	148	102	148
Total time checkouts per day	4 hrs 15 min	6 hrs 10 min	3 hrs 24 min	4 hrs 56 min
Total time check-ins per day	4 hrs 15 min	6 hrs 10 min	3 hrs 24 min	4 hrs 56 min
Labor cost per day	382.50 €	555.00 €	306.00 €	444.00 €
Replacement value of lost tools (year)	6 000 €	7 500 €	3 000 €	3 750 €

Figure 8: Data for the financial analysis of case study three.

This study considers that the expense of replacing lost tools is 6 000 EUR in the current situation. For the theoretical scenario, without RFID will be approximately 7 500 EUR. Since the system ensures better control of the tools, a conservative assumption is made that this solution optimizes 50% of the current situation.

Finally, the cash flow for each year is calculated based on the previous assumptions is presented in Table 7.

Table 7: Cash Flows (Year).

	Expected	Theoretical
Labor per year	+ 27 922.50 €	+ 40 515.00 €
Replacement of lost tools	+ 3 000 €	+ 3 750 €
TOTAL	30 922.50 €	44 265.00 €

As in the quotation of the first case study, to be more conservative, the budgeted amount for this solution (in the order of tens of thousands of EUR plus an annual cost of one order of magnitude lower) was multiplied by a safety factor of 1.5. Not only does this value consider inflation, but it also takes into account the cost of potential training and development of the solution by Portugália. A load factor of 1.2 is also added to the value of the annual expense, to compensate for the replacement of lost tags, which are not insured by the company, and for inflation.

An analysis was made of the NPVs of this solution up to year 10. For confidentiality obligations towards the companies that collaborated with this project, a fictitious amount is used for the budget, which does not change the conclusions of the analysis. This value also includes the safety factor described.

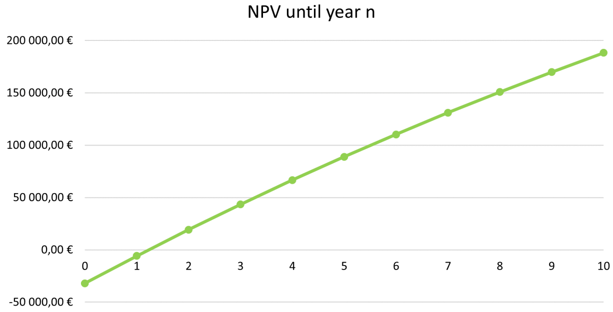


Figure 9: NPV until year n=10 - case study 3.

The valuable feature of the solution is to automate the migration of the tool's information to AMOS without the need to update it manually. There is also a second, less significant advantage: When a tool checks out and does not return with a check-in, the implemented technology can do this update.

An additional remark in behalf of this solution: although it was concluded that it says it saves 30 seconds on each tool checkin and checkout interaction, the truth is that these 0.5 minutes are, in fact, 1 minute. This is due to the fact that, in order to obtain a conservative perspective, only the time saved by the TMA responsible for the warehouse was considered. However, there is a TMA that during that time is standing still, waiting for the tool. This time is not considered for the calculations. It is not possible to come up with enough mathematical representativeness to be considered.

In light of the above, it is possible to conclude that this is a solution that guarantees more efficient and automated inventory management. It automatically verifies that all tools have been returned (or which) at the end of each shift. In the event that an object is missing, it provides detailed information about the instant it was moved making it easier to retrieve it. Finally, it promises a payback midway through the second year of its implementation.

6. Conclusions

Although the name of this paper refers the use of an iBeacon technology, it soon was concluded that this was not the best solution for any of the case studies. Other technologies were analysed and it has been concluded that, in some cases, it is advantageous to implement more than one technology.

The solution of the first case study - implementation of a Quuppa technology for the TTA pre-flight procedures - will be capable of clearly identifying the cause of some flight delays. Therefore, this information will provide the operator with relevant data which can be analysed to reduce or avoid such delays, in the future. In addition, this solution optimizes the procedure and resources of crew check-in by providing updated information of the status of the crew check-in, not only to the operator but also to the handling company. Also, it will improve the company's sustainability since all the process will be completed digitally, saving human and material (printers, toners, paper and computers, *etc.*) resources.

In relation to the second case study, the suggested solution - implementation of a RFID technology on the A/C pre-flight procedures - enables an optimization of the pre-flight checking procedures at the A/C. The current procedure consists of a manual check of the status of several items, by the PNC, within a short period of time. The solution will automate this process for some selected items and, therefore, will reduce the number of checks that the PNC shall complete, giving them more time to complete the rest of the pre-flight procedures at the A/C. Currently, the pre-flight checking procedure is made by three PNC members. Overall, this solution will save around five minutes, within forty five minutes for the pre-flight checks.

Lastly, in case study three it is proposed to implement an active RFID technology, proposed by Quuppa, using Bluetooth-based technology in order to optimize the maintenance inventory and logistic procedures at the warehouse. This technology will work by automatically controlling the check-in and check-out of maintenance tools, automatically storing the information regarding the TMA who requested the tool, and keeping updated information regarding the inventory of the warehouse. This optimization will turn the current manual control procedure automatic, which has obvious benefits, such as avoiding human mistake, saving the TMA's time and better controlling the existing inventory inside the warehouse.The investment for the implementation of this solution will reach the break even point within two years.

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