Extended Abstract

Technological solution for the location of vehicles at Lisbon Airport

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Abstract

The Single European Sky concept, promoted changes at various levels in the European Union's airport system. On a technological level, it was identified the need to improve the *situational awareness*, for all airport system stakeholders, of the positioning of aircraft and all operations involved in its trajectory, especially ground-handling operations (operational area OFA 01.02.02 Enhanced Situational Awareness). Considering the need to adapt Lisbon Airport to SESARs' recommendations, improve the performance of ground-handling operations and improve airport safety, a set of technological options was defined that could allow knowing the positioning of people, vehicles and equipment to support ground-handling operations. The main goal of the dissertation was to evaluate a set of defined technological solutions in order to make a recommendation on the best option. Through a multi-criteria analysis on the options, using the decision support system M-MACBETH, was formed a hierarchy of technological options: 1st GPS + RFID, 2nd GPS + Video, 3rd GPS+Bluetooth and 4th GPS + WiFi, with very close global scores. Therefore, it was concluded that the recommended alternative to apply at Lisbon Airport would be the combination of GPS system with RFID. Despite the robustness of the results obtained, it is clear that it is very difficult to evaluate technological options, verifying the very close overall scores for each option. Therefore, all options would be equally interesting, considering that complementary analysis should be done.

Keywords: Situational Awareness, Positioning, MACBETH, Multi-criteria analysis, Airport.

1 Introduction

The increasing air traffic in Europe has contributed to the development of the concept of Single European Sky (SES), which proposes a centralized management of airspace. The main objective of SES is to transform the European airspace on different levels: airports, human factors, technology, security and performance. The technological pillar of SES, the SESAR (Single European Sky – Air Traffic Management Research Project) proposes operational changes to be implemented in the European air traffic network [1]. From this project and directly related to airports were developed the Work Packages (WP): WP6-Airport Operations and WP12-Airport Systems [2], which focused on topics related to operations, infrastructure and management projects [3]. The ATM Master Plan defined the plan for operational and technological changes, proposing alterations on communications, navigation and security [1].

The operational changes were proposed for different areas of the airport system, en-route operations, TMA (Manoevering areas) and airport system, considering ICAO's concept of operations on the improvement of safety on the runway [B0-75 Improved Runway Safety (A-SMGCS Level 1-2 and Cockpit Moving Map] and improving safety and efficiency in operations on airport surface [B1-75 Enhanced Safety and Efficiency of Surface Operations (ATSA-SURF)] [1]. Regarding these concepts, one of the operational changes proposed was improving *Situational Awareness*, by knowing the positioning of the aircraft and all operations involved in its trajectory [4].

Considering the need to adapt Lisbon Airport to SESARs' recommendations, improve the performance of ground-handling operations and improve airport safety, a set of technological options was defined that could allow knowing the positioning of people, vehicles and equipment to support ground-handling operations. The main objective of this dissertation is to evaluate a set of technological solutions in order to make a recommendation on the best option to implement in Lisbon Airport.

The methodology followed was a literature review considering the study of the airport system, specifically the process of ground-handling of an aircraft (*turnaround)*. In parallel, it was carried out a review and characterization of positioning technologies. Considering Lisbon Airport's needs and the characteristics of the technologies, were identified decision factors that would determine the choice of a suitable technological solution. Through a series of interviews, it was possible to define a set of possible technological options to apply to Lisbon Airport, as well as define the evaluation criteria of technologies best suited to the case study. Applying a multi-criteria evaluation method, through the M-MACBETH decision support system, it was possible to make an evaluation of technological options.

In Chapter 1 was defined the framework for the dissertation, the objectives and the methodology applied. In Chapter 2 were identified the agents of the airport system, the activities involved, the areas of an airport and its needs. In Chapter 3 were defined positioning technologies possible to apply to Lisbon Airport. In Chapter 4 were defined decision support methodologies and the reasons for the choice of M-MACBETH software. In Chapter 5 the Lisbon Airport was characterized. In Chapter 6 was developed a multi-criteria analysis, using M-MACBETH, in order to evaluate the technological options. In Chapter 7 were defined the conclusions and were proposed future developments.

2 The Airport System

An airport is an air transport infrastructure serving the aircraft, passengers and cargo vehicles and is divided into two main areas: the airside and landside. In each of these areas a variety of agents is responsible for different functions and operations. There are four major agents in air transport: airlines, air traffic controllers, airport operators and ground handling operators. The latter consists of a variety of agents that perform different functions on the aerodrome, supporting the *turnaround* process of an aircraft. Therefore, there are a large number of people, vehicles and equipment that have interference in this process. As identified in SES, there is a need to improve knowledge of the positioning of these stakeholders, through the operational area with the designation *OFA 01.02.02 Enhanced Situational Awareness*. This enhancement could contribute to increase operations efficiency, reducing time lost and therefore reducing costs.

3 Positioning Technologies

The development of positioning systems arose from the utility of locating people and equipment, evolving to innumerous applications.

In order to estimate the position, there is a wide variety of methods of measurement: triangulation methods, proximity, fingerprinting and vision analysis.

Technological advances have enabled the development of different positioning systems such as GPS (*Global Positioning System*), positioning by video, wireless systems and communication systems such as TETRA.

Regarding airports, aircraft positioning systems have also evolved, starting in the 40s the *Instrument Landing System* (ILS) and later in the 90s the *Microwave Landing System* (MLS). With the development of the satellite tracking system, ILS and MLS systems were replaced by GPS. Today, the identification of aircrafts on airports is made by Radar.

4 Decision Support

The decision analysis is a process of analysis that allows the decision maker, when facing a series of alternatives, to reach a decision. Therefore, considering the complexity of problems and the variety of alternatives of choice, sometimes it is necessary to develop a multi-criteria analysis. This analysis allows stakeholders to share different opinions, sometimes contradictory objectives and evaluating several criteria. Multi-criteria analysis requires the definition of alternatives and evaluation criteria, weighting of evaluation criteria and assessment of the impact of alternatives on each criteria, and finally the aggregation of judgments and ranking of alternatives.

There are many multi-criteria analysis methods, among them the methods of prevalence (ELECTRE and PROMETHEE) and compensatory methods, such as the multi-attribute utility and value theories (MAUT, UTA, AHP or MACBETH).

The evaluation of technologies implied the choice of a multi-criteria analysis method to use. Therefore, the choice of MACBETH method was due to its ability to evaluate a set of alternatives through differences of value, in order to quantify the relative attractiveness between options, through qualitative judgments. The goal of MACBETH method is to help decision-makers to have a better understanding of the problem [5]. MACBETH is a humanistic, interactive and user-friendly, and constructive approach [6]. Additionally MACBETH facilitates verification of the consistency of judgments of decision makers, but also suggests improvements on these judgments if inconsistent [7]. The MACBETH approach has the ability to generate numerical scales through qualitative judgments [5], which may be more intuitive and less time-consuming than quantitative judgments. However, it has some limitations, firstly because it is a personal interpretation of differences of attractiveness, which may cause ambiguity of responses [5]. Secondly, lack of information about the criteria or options can lead to less robust conclusions.

5 Lisbon Airport

The Lisbon Airport is located 7 km from the city center of Lisbon, and consists of two civil terminals and a military terminal. Air traffic increasing at this airport imposes the application of the technological improvements proposed by SESAR, in order to improve efficiency of operations on the aerodrome.

At Lisbon Airport were identified the agents involved in the process of *turnaround* operations: people, vehicles and equipment. Simultaneously, were identified existing technologies (TETRA and Wi-Fi) and the needs of the airport, in order to improve *Situational Awareness* at the aerodrome.

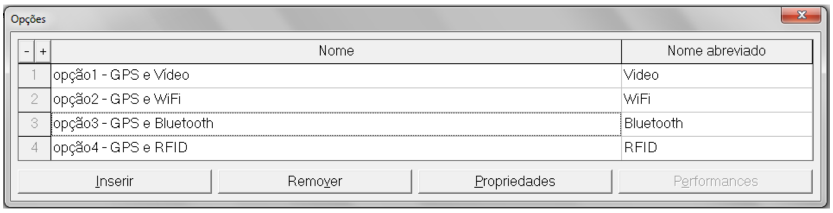
6 Technological options evaluation

6.1 Structuring

Through the decision support software M-MACBETH [8], it was possible to evaluate a set of technological options (combinations of technologies).

According to the needs identified on Lisbon Airport, concerning the positioning of vehicles, equipment and people on the aerodrome, and analyzed the existing positioning technologies, it was possible to define a set of technologies that, according to its characteristics, could be adapted to Lisbon Airport.

It was considered that GPS system could be used in the aerodrome, in areas with line of sight to satellites. The goal was to introduce GPS tracking system in TETRA equipment, in order to facilitate the positioning of operations personnel at the aerodrome. However, the use of GPS could lead to low reliability of the system in “covered” areas or areas with obstacles to the transmission of the GPS signal. Therefore, there was the need of combining GPS with systems that could allow knowing the positioning even in case of low "line of sight" with satellites or in exterior/interior transition areas on the aerodrome. It was also considered the possibility of using video cameras, with fixed positions, in order to compare the position of *objects* with the position on a calibration grid. Through a set of *frames*, it could be possible to detect and follow the presence of equipment, people or vehicles. The limitations of using fixed video cameras (unseen areas), could be compensated by using GPS system in combination. Considering the existence of a Wi-Fi system in the aerodrome at Lisbon Airport, introduced the possibility of using this system in combination with GPS, to know the positioning in areas with low coverage of GPS system. Therefore, it was proposed using this system for detecting equipment and people in the interior areas, by detecting the antennas signal already on the aerodrome. Another possibility was to combine GPS with Bluetooth, which would work similarly to Wi-Fi, based on mobile networks and transmitted signals between antennas and devices. Finally, it was considered using RFID, or radio-frequency identification, in combination with GPS. The positioning could be done through a system of *tags*, which would be attached to vehicles, knowing its position in real-time. The combination of these technologies allowed to define four technological options (Figure 1), considered the alternatives of decision on the multi-criteria analysis developed in *software* M-MACBETH: GPS and video, GPS and Wi-Fi, GPS and Bluetooth, GPS and RFID.



	Nome	Nome abreviado
1	opção1 - GPS e Video	Video
2	opção2 - GPS e WiFi	WiFi
3	opção3 - GPS e Bluetooth	Bluetooth
4	opção4 - GPS e RFID	RFID

Figure 1 – Technological Options.

The definition of technological options evaluation criteria took into consideration the opinion of experts, in order to be a credible decision basis. Through the *software* M-MACBETH, was build a decision tree with the criteria (Figure 2).

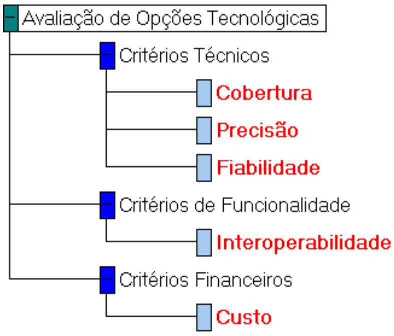
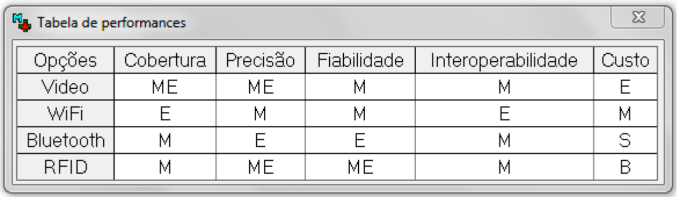


Figure 2 – Evaluation criterion.

For the assessment of technological options, it was used an indirect comparison basis, through the attribution (by a specialist) of qualitative levels of performance for each criterion, in order to assess the attractiveness of options on criterion indirectly (Figure 3). In order to operationalize the criteria, it was associated to each of them a performance descriptor, an ordered set of qualitative levels of performance per criterion, in order to evaluate their performance: "Very high" (ME), "High" (E), "Medium" (M), "Satisfactory" (S) and "Low" (B).

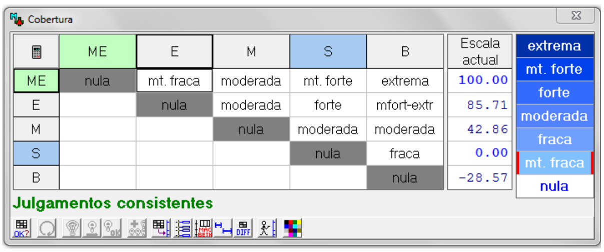


Opções	Cobertura	Precisão	Fiabilidade	Interoperabilidade	Custo
Video	ME	ME	M	M	E
WiFi	E	M	M	E	M
Bluetooth	M	E	E	M	S
RFID	M	ME	ME	M	B

Figure 3 – Qualitative levels of performance.

6.2 Evaluation

For each criterion, were defined differences of attractiveness between levels of performance (Figure 4), through the qualitative M-MACBETH judgments: "Extreme", "Very Strong", "Strong", "Moderate", "Low", "Very Weak" and "Neutral".



	ME	E	M	S	B	Escala actual
ME	nula	mt. fraca	moderada	mt. forte	extrema	100.00
E		nula	moderada	forte	mfort-extr	85.71
M			nula	moderada	moderada	42.86
S				nula	fraca	0.00
B					nula	-28.57

Figure 4 – M-MACBETH qualitative judgments.

For each criterion were defined reference levels (upper and lower references) (Figure 5) in order to define the intrinsic value of each option evaluated, and to convert qualitative levels of performance into a value functions.

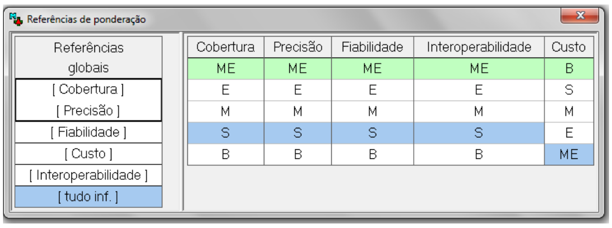


Figure 5 – Reference levels for the criterion.

Finally, through the qualitative M-MACBETH judgments, was made an evaluation of the difference of the overall attractiveness for the defined criterion (Figure 6).

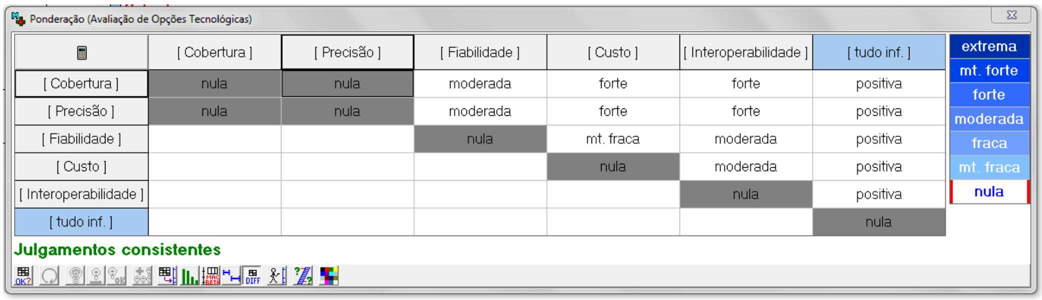


Figure 6 – Qualitative M-MACBETH judgments.

The constructed model led to the weighting of criteria "Coverage" and "Accuracy" with an equal value of 32%. Then it was observed that the criterion "Reliability" had a value of 18% and the criterion "Cost" a value of 14%. Finally, the criterion "Interoperability" represented only 4% of the weighting of the overall assessment of the options (Figure 7).

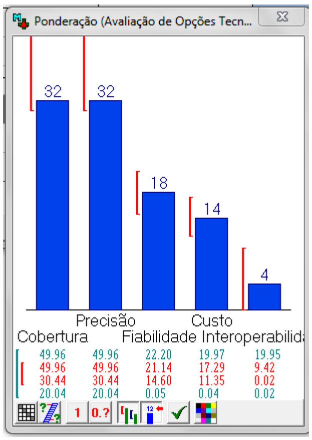


Figure 7 – Weighting of the overall assessment of options.

6.3 Results and Recommendation

The multi-criteria evaluation model developed through the *software* M-MACBETH, led to a hierarchy of technological options, considering the weighting of criterion (Table 1).

Table 1 – Hierarchy of technological options.

Options	Order	Global Score (%)	Coverage	Accuracy	Reliability	Cost	Interoperability
GPS+RFID	1st	79,05	42,86	100,00	100,00	100,00	33,33
GPS+Vídeo	2nd	78,00	100,00	100,00	44,44	33,33	33,33
GPS+Bluetooth	3rd	72,48	42,86	85,71	88,89	100,00	33,33
GPS+WiFi	4th	66,38	85,71	57,14	44,44	66,67	83,33
Weights (%)			32	32	18	14	4

Considering the results obtained, it was verified the contribution of the score of an option on a criterion, to the overall score. It was observed that the high overall score for option GPS + RFID (1st place) was due to high scores in Accuracy and Reliability criterion. For option GPS + Video (2nd place), the high overall score was due to high scores in Coverage and Accuracy criterion, being the most unfavorable option in the Cost criterion. The option GPS + Bluetooth (3rd place) presented low score in Coverage criterion. Finally, the option GPS + WiFi (4th place) presented the lowest overall score due to low score in Accuracy and Reliability criterion.

Analyzing the differences of overall score among the options considered, it was observed that they were very low: 1% between RFID and Video options, 5.5% between Video and Bluetooth options, 6% between Bluetooth and WiFi options. This result led to the need to understand the differences in the scores assigned to each criterion, for each option, and to assess the sensitivity of the model built.

Through sensitivity analysis to the weights of the criteria it was observed that the model was very sensitive to the variation of the weight of Coverage and Accuracy criterion, considering that a slight variation of 0.4% above the initial weighting (32%) could change the hierarchy of technological options, appearing the option GPS + Video in 1st place and the option GPS + RFID in 2nd place. The same change in hierarchical order occurred when the Reliability criterion was weighted 1.1% below the initial (18%) or the Cost criterion was weighted 1.6% below the initial weighting (14%), showing the high sensitivity of the model to these criteria. However, the model was not sensitive to variations in the weight of the Interoperability criterion.

The robustness analysis confirmed the technological options' hierarchy obtained.

Considering the hierarchy defined and the sensitivity of the model, it would be advisable to opt for the combination of GPS and RFID. However, the combined solution of GPS and Video could be an option to adopt. The small overall score difference between options observed in the hierarchy of technological options, show that all options could be equally interesting, which is something expected, considering the pre-analysis performed initially to reach these four options.

7 Conclusions

Through SESAR's recommendations, operational measures were proposed to be applied in European airports, in order to improve the efficiency of processes of ground-handling and safety in the aerodrome. These goals could be achieved by improving *Situational Awareness*, knowing all the activities involved in ground handling operations, including the resources and information, in real time. Considering that Lisbon Airport is at an early stage of adaptation to the technological recommendations of SESAR and the concept of *Situational Awareness*, it was identified the need to predict last-minute changes in the turnaround on the aerodrome, to improve the efficiency of ground-handling process, through knowledge of the availability of vehicles and people on the aerodrome, and improve the safety of operations. In order to address these needs, would be necessary to monitor the ground handling activities and resources available, finding the resources (vehicles and equipment) and humans (operators) in the aerodrome. In order to know the positioning of these resources (vehicles, equipment and people) on the aerodrome of Lisbon Airport, it was necessary implementing technological systems, considering the local constraints. Therefore, considering the characteristics of the existing positioning technologies and the opinion of experts, it was identified a set of technological options (combination of technologies) possible to implement at Lisbon Airport: GPS and video option, option GPS and Wi-Fi, GPS and Bluetooth option, GPS and RFID option. The main objective of the dissertation was to evaluate this set of technological solutions in order to make a recommendation on the option to apply at Lisbon Airport.

Through multi-criteria analysis, with the support of the *software* M-MACBETH, it was developed an evaluation of options, considering the criterion: Coverage, Accuracy, Reliability, Cost and Interoperability. The definition of evaluation criteria proved to be a difficult process, but decisive in the evaluation of technological options, because it allowed understanding the views of stakeholders in the decision-making process, allowing to adapt the technological options to the case study.

Table 2 – Hierarchy of technological options.

Options	Order	Overall Score (%)
GPS + RFID	1st	79.05
GPS + Video	2nd	78.00
GPS + Bluetooth	3rd	72.48
GPS + WiFi	4th	66.38

Building the model of multi-criteria analysis, according to the judgments, it was possible to set scores for the evaluation criteria and reach a hierarchy of technological options (Table 2). The results obtained allow recommending the technological option of combination of GPS system with RFID as the best solution to be implemented at Lisbon Airport. However, the option that combines the GPS system and the video could also be recommended. It would also be possible to apply the options GPS and Bluetooth and the option GPS and WiFi, due to the very close overall score for each option. Therefore, all options would be equally interesting.

The results were very sensitive to all criterion, except for the Interoperability criterion, confirming being acceptable to use any technological option.

The model of evaluation of options presented some limitations, such as the inherent subjectivity to judging the difference in attractiveness between the criteria and levels of performance of the alternatives. Therefore, the results depended on personal interpretations, both in the selection of evaluation criteria and in the definition of decision alternatives. Additionally, the judgments provided could have been *a priori* subject to “errors” due to wrong information regarding technologies that were analyzed in general, not specifically taking into account their technical performance. The evaluation of a technological option (combination of technologies) is not so strict as the individual evaluation of each technology. The use of qualitative performance levels to construct value functions can be less rigorous, considering the preferences of the decision maker.

The implementation of positioning systems at Lisbon Airport could bring benefits to the airport, particularly improving the efficiency of ground-handling process, enabling to locate the physical and human resources available on the aerodrome, check their availability, and make allocation changes of vehicles and equipment to the aircraft in real time. On the other hand, it could increase safety of aircraft (and people) at an airport, locating equipment or persons in safe zones. Increasing information flow and knowledge between all agents can bring significant improvements to the airport. The main challenge is the application of technological systems according to the requirements of SESAR, within the time frame defined by SESAR, considering the budget constraints and facing the need to improve the system, due to increased traffic in Lisbon Airport.

It is considered that through more interviews and the participation of a larger number of actors in the process of multi-criteria analysis could lead to more robust results.

The technological options assessment could be improved through more rigorous analysis to local coverage areas, in order to know the necessary infrastructures (number of items, equipment and *software*) to cover the necessary areas, combine technologies and know the real costs of the systems. In addition to the acquisition cost of each option, could be calculated the costs of maintenance, operation and overall installation of each option in order to undertake a cost-benefit analysis of each option. However, despite more rigorous, this method would involve a much more time-consuming process of evaluating the alternatives compared to the method used.

Considering the high investments required for implementation of positioning systems in an airport, it is also considered that the solutions could be tested in reality (small scale), in order to understand their suitability to Lisbon Airport.

It would be interesting to extend the study of positioning of equipment and people to the landside of Lisbon Airport, in order to know the location of airport operators, the location of passengers, luggage and location of "baggage cars" at the airport.

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