AIRCRAFT MAINTENANCE PLANNING
AND
SCHEDULING PLATFORM

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A Capstone Project Submitted to Embry-Riddle Aeronautical University in Partial Fulfillment of the Requirements for the Aviation Management Certificate Program

Embry-Riddle Aeronautical University
Sao Paulo, Brazil
October 2023

Abstract

Aircraft maintenance areas pose a major challenge to air transportation. This paper addresses the challenges of line maintenance planning encountered during scheduled operations. The lack of a technological tool for line maintenance management is a contributing factor to outdated and ineffective planning. Maintenance management software or available systems on the market are not suitable for these tasks and are focused on maintenance activities performed in hangars, such as heavy checks. The tasks executed during line maintenance carry significant importance, and the dynamic nature inherent in this activity cannot fully mitigate the repercussions of planning and scheduling service failures. Consequently, any deviation in this process directly affects the operational readiness of aircraft. The outcome of this endeavor is the creation of a management and planning tool for line maintenance, producing greater efficiency in maintenance schedules through resource optimization and reduced aircraft unavailability time. This, in turn, contributes to a decline in operating costs and to an increase in safety.

Keywords: maintenance, planning, management tool, innovation, technology, safety, efficiency.

Introduction

Technological progress in the aviation industry has been evident over the past decades, with the introduction of new aircraft and aeronautical systems. However, this progress has not always been accompanied by efficient processes utilized by airlines for operational control and activities that govern the aviation sector. This research project aims to address a deficiency identified in the planning and scheduling of aircraft line maintenance services for a commercial airline.

This project proposes to solve a deficiency found in the process of planning and scheduling aircraft line maintenance services of a commercial airline. The objective is to use and exploit technology and automation to the fullest, to provide greater quality and efficiency for this process. There is a vast opportunity for the application of technological means, for the construction of scenarios, and for the development of barriers that protect against possible human failures, specifically in the process of scheduling aircraft maintenance services. Therefore, this project proposes the construction of a robust platform to monitor line maintenance items, encompassing preventive, corrective, and predictive maintenance. The platform will aid in decision-making, providing planning analysts with quick access to consolidated information and a tool to prevent possible failures in the process.

We classify the future application of this platform as an exceptional result, with a later window for the application of artificial intelligence, in the creation of proposals for programming services in an autonomous way, where analysts could only validate or not the proposal carried out automatically by using it in a set of the platform with an engine managed by artificial intelligence. The parties interested in this project are the areas of Aircraft Maintenance Planning, Maintenance Teams, Operational Control Center, Maintenance Control Center, and Supplies, among others. The findings of this study are important as they could help reduce the downtime of aircraft due to maintenance procedures. This, in turn, could improve the overall availability of the aircraft, resulting in lower operating costs and better service for passengers and the network.

Problem Statement

Computerized systems used to control aircraft maintenance activities do not have a dedicated module to assist in the planning and scheduling process of these services. The proposed project aims to develop a computerized platform focused on assisting in the planning and scheduling of line maintenance activities. To build this technological platform, a computerized tool called Skywise (Airbus & Palantir Technologies) will be used, which will provide the necessary technological resources to overcome the difficulties currently encountered in the mentioned process.

Line maintenance activities are planned during operational windows, usually during overnight when aircraft are out of operation. These services must be scheduled considering the capacities of each maintenance base (airports). Additionally, the availability of resources such as materials, tools, trained manpower, airport infrastructure, and ground equipment should be considered.

The challenge lies in efficiently managing tasks across varied aircraft or bases, which share scarce resources, to mitigate competitive demands. Moreover, addressing tasks disrupted by interferences like technical limitations or system conflicts during testing, inspection, or repair poses a significant planning dilemma. This scenario naturally leads to falling productivity and inefficiencies.

It is also essential to highlight the impact that errors in maintenance planning can have on aircraft operations. The ground time available for maintenance services is one of the resources that must be respected in this process. If the planned services require more time for the unavailability of the aircraft than the actual time made available by the Operational Control Center, delays in the release of aircraft will be frequent.

The proposed technological platform will gather all necessary information regarding maintenance activities, assumptions, and restrictions to consider while planning. It will also provide alerts if any of these assumptions need to be complied with. This data centralization will make the planning and execution of maintenance activities more efficient.

The project aims to address maintenance planning issues by combining technology and professional expertise. The solution will involve analyzing historical data and indicators to better align with common problems encountered during aircraft maintenance planning and scheduling. The goal is to improve the overall maintenance process and enhance aircraft safety.

Project Goals and Scope

This project involves the development of a platform to assist, through the use of technology, the process of planning and scheduling line maintenance services on aircraft. The objective is to create, based on the maintenance premises and its rules, a technological tool that makes the process of planning and scheduling services more effective and agile, in addition to creating automated barriers to possible failures or deviations. In addition, we intend to generate integration between the various areas involved in this process, opening a window of possibilities for the use of artificial intelligence to automate the process.

Some indicators of programming effectiveness and maintenance team productivity will be used to measure the effectiveness of this process and the application of the platform that will be developed. Currently, the fulfillment of these assumptions and the respect of the limitations related to the planning of maintenance activities are guaranteed mainly by the performance of the planning analysts, who are subject to human errors that can directly affect the availability of aircraft for operation, resulting in a potential reduction of revenue and a loss of credibility with customers and the market in which the company operates.

Expected Contributions

The importance of this topic is based on reducing the time of aircraft in maintenance activities and reducing maintenance interventions in AOG conditions, thereby increasing the availability of aircraft for operation, and consequently reducing costs for airlines. It is understood that this platform may have a positive and potential impact on increasing the company's revenue with the additional availability of aircraft for passenger or cargo transportation operations, using resources assertively, and reducing losses.

Definition of Terms

Line Maintenance: Atividades de Manutenção realizadas regularmente para garantir a operacionalidade segura e confiável das aeronaves entre os voos. Envolve inspeções visuais rápidas, testes operacionais, lubrificação e reparos menores que são realizados no local, muitas vezes durante as escalas entre voos.

Heavy Maintenance: Atividades de Manutenção pesada que ocorrem nos hangares e demandam por capacitação técnica e grande infraestrutura, trata-se de um tipo mais abrangente e extenso de manutenção. Demandam por um hangar e indisponibilizam a aeronave a operação por grande período.

envolve a desmontagem, inspeção detalhada, reparo, substituição de componentes e sistemas importantes da aeronave

Operational Control Center (OCC): Departamento responsável por supervisionar e coordenar todas as atividades relacionadas à operação das aeronaves de uma companhia aérea. Isso inclui monitorar os voos em tempo real, garantir o cumprimento dos horários, lidar com emergências, otimizar o uso de recursos, como tripulação e combustível, e manter a comunicação constante com a tripulação em voo.

Maintenance Control Center (MCC): Responsável por prover suporte técnico para a operação das aeronaves, além de monitorar possíveis falhas das aeronaves durante a operação, atuando junto ao time de manutenção para prover meios para que as aeronaves em pane, retornem a operação no menor tempo possível.

Ground Time (GT): Tempo de solo das aeronaves direcionados para execução de serviços de manutenção programada.

List of Acronyms

ANAC- Agência Nacional de Aviação Civil

EASA- European Aviation Safety Agency

FAA- Federal Aviation Administration

RBAC- Regulamento Brasileiro de Aviação Civil

ACFT – Aircraft

AOG – Aircraft On Ground

MCC – Maintenance Control Centre

OCC – Operations Control Centre

Categories of Research - Exploratory Investigations

The primary objective of exploratory research is to provide a characterization of the issue, aiming at the viability of a particular program or technique. It involves the collection of data about a phenomenon of interest without extensive theorization. Thereby, this inspires thoughts or indicates alternative explanatory hypotheses.

In this scenario, prior to the application of the planning platform software, was found inconsistency in scheduling available resources. When it came to available manpower, services were planned beyond the installed capacity. We observed more than 2% of scheduled items were cancelled due to lack of manpower. Delivery of materials was another problem noted, with delays and lack of materials causing a 4% failure in scheduling.

Research Approaches - Bibliographic Exploration

Bibliographic exploration encompasses all existing publications on a given subject, across various forms of dissemination. This approach enables researchers to engage directly with the body of published work. Thus, allowing simultaneity in analysis of research and knowledge treatment, leading to improved comprehension and innovative conclusions. Moreover, extensive research led to concepts on decision-making, maintenance activities, costs, and human factors. Those concepts were used to justify the creation of the line maintenance planning and scheduling software.

Document Exploration

It entails gathering types of documents (historical, institutional, associational, official) that have not undergone systematic scientific or analytical treatment. This literature review technique serves specific objectives. This procedure involves consultation of distinct types of archives and employs materials like files, presentations, and forms.

The foundation of the planning and scheduling software was gathered from Brazilian airlines' line maintenance data. Another approach to gathering information is the interviewing process. With that, the information needed to plan maintenance services was dispersed and confusing. Given to the volume of daily scheduled tasks, checking for incompatibilities or lack of resources was an unfeasible activity. That could lead to many failures once done manually.

Through the consolidation and automation of the collected data, it was proved the feasibility of the software. This would lead to greater reliability in the maintenance planning process. Automation brings agility and becomes an effective support for decision-making during scheduling maintenance services. Intuitive and user-friendly dashboards provide information on the volume of scheduled activities. The man-hours and technical capacity of each maintenance base is visible making the analyst's work much more effective.

Techniques for Data Collection

Data collection techniques encompass a set of processes within the domain of science that pertain to the practical aspects of data gathering (LAKATOS; MARCONI, 2001). Properly conducted data collection ensures valid, reliable, and useful information for achieving its intended purpose. That has shown to be fundamental to research It involves gathering and recording information for analysis and decision-making.

Primary Source of Documentation – Field Research

Bastos and Keller (1999) elucidate that in field research, data collection occurs in the very settings where phenomena naturally unfold. These intend to minimize researcher intervention. It stands distinct from experimental research and does not seek to fabricate or reproduce the studied phenomena. As defined by Fachin (2001) field research involves observing a social fact within its contextual framework and scrutinizing it. Subsequently, dedicated methods and techniques are used to elucidate the problem.

Analysing the data on rework rescheduled services, around 9% of scheduled activities were not carried out maintenance. The main cause of this is a failure in the planning process or the lack of specific resources. This represented an average of 2,300 tasks monthly, causing rescheduling and unavailability to the operation. Another impact is the process of re-planning cancelled tasks. It cascades to the logistics areas and service orders for maintenance.

Techniques for Data Analysis - Qualitative Analysis

According to Vieira (1996), qualitative research relies on qualitative analysis. It´s essentially eschewing the utilization of statistical tools in data interpretation.

This approach emphasizes understanding the phenomena studied through methods such as interviews, participant observation and content analysis. Qualitative analysis values subjectivity and contextualization, allowing a holistic view of the phenomena. On the other hand, the quantitative approach quantifies and generalizes the results. Qualitative research is a tool for exploring complexities and nuances in areas where statistics would not be appropriate.

This technique includes evaluating documents, texts or interview transcripts to identify patterns, themes and underlying meanings. Another method would be to participate in an environment or social group. It also allow to observe and understand the interactions and behaviors of the participants.

Analysing historical documents, policies, or other written sources could be a method for conducting a qualitative analysis. Other methods like case analysis, triangulation, thematic analysis could be applied to carry out qualitative analysis.

These qualitative techniques are flexible and adaptable. Researchers are able to explore in depth and gain a richer contextualized understanding of the phenomena studied.

Data Analysis Plan

The data used in this business research was gathered from Azul Linhas Aereas, from September to December 2022. It contains information about the number of scheduled line maintenance tasks, tasks effectively performed and cancelled tasks due to lack of resources or failure in the schedule. It is sourced from the Azul Linhas Aereas maintenance control system, TRAX, ensuring authenticity and reliability. Automated data extraction methods are used to minimize human error. Access control and encryption protocols are used to secure the data. Data is interpreted using standardized fields and normalized for consistency. The insights derived from the data are presented in charts and tables. Data validity is ensured through direct extraction, consistency, and security measures.

The method for testing the data consists in using the Microsoft Excel spread sheets as follows:

Data Preparation: to organize the data in an Excel spreadsheet. Ensure it is well-structured with clear headers and relevant labels.

Data Entry Validation: to set rules for data entry. This can prevent users from entering invalid or incorrect data, by selecting the cells where validation will be applied.

Data Cleaning: to review the data for inconsistencies, missing values, and errors.

Data Sorting and Filtering: to arrange data in a logical order and isolate specific subsets for analysis; This can help identify patterns or anomalies in the data.

Data Formulas and Functions: to apply formulas and functions to perform calculations, manipulate data, and check for consistency.

Data Visualization: to create charts, graphs, and pivot tables to visualize data trends and patterns.

Data Analysis Tools: to utilize Excel's built-in data analysis tools like Goal Seek, Scenario Manager, and Solver. The idea is to perform advanced data analysis and solve complex problems.

Data Validation Testing: to perform thorough testing by entering different types of data to ensure that the functions as expected.

Documentation: to document the testing process, including any validation rules, formulas, and assumptions. This can be helpful for future reference and collaboration.

Quality Assurance: Another person reviewing and validating the workbook to catch any issues during testing.

A phenomenon that has not been considered is the canceled maintenance activities due to weather conditions. When severe weather events occur, airlines often cancel flights to ensure the safety of passengers and crew. Furthermore, bad weather also plays a significant role in flight diversions. It can create hazardous flying conditions that compromise the safety and efficiency of air travel. When pilots encounter these weather-related challenges, they may choose to divert to alternative airports to mitigate risks. Bad weather can lead to airport closures or reduced visibility. It makes impossible to land or take off safely. As a result, aircraft cannot reach the maintenance base where the activities were scheduled to happen. However, the weather is a variable that cannot be controlled by human actions. It drove the group to not consider it in the data analysis.

Table 1 – Line maintenance activities data from 2022 last four months

Months	Programmed	Accomplished	Cancelled	% Accomplished	% Cancelled
Sep/2022	22804	20981	1823	92%	8%
Oct/2022	23753	21927	1826	92%	8%
Nov-22	23663	21859	1804	92%	8%
Dec/2022	24405	22180	2225	91%	9%

Figure 1 - Evolution of the Failure Rate

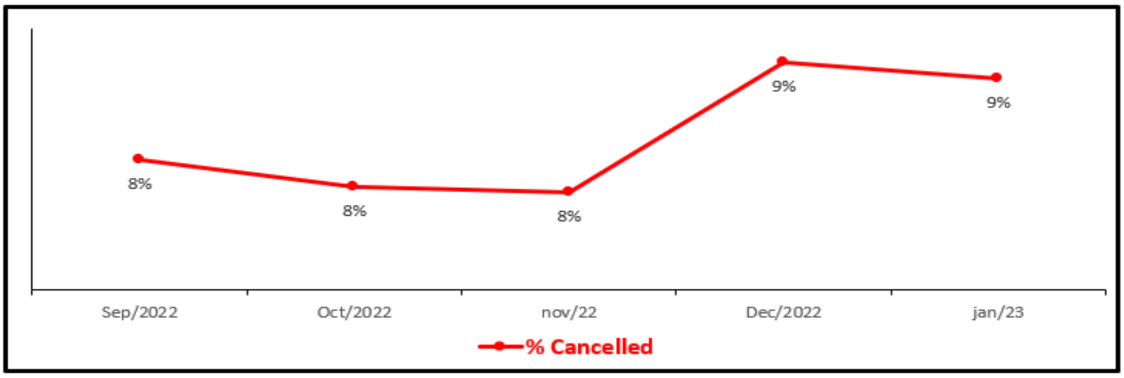
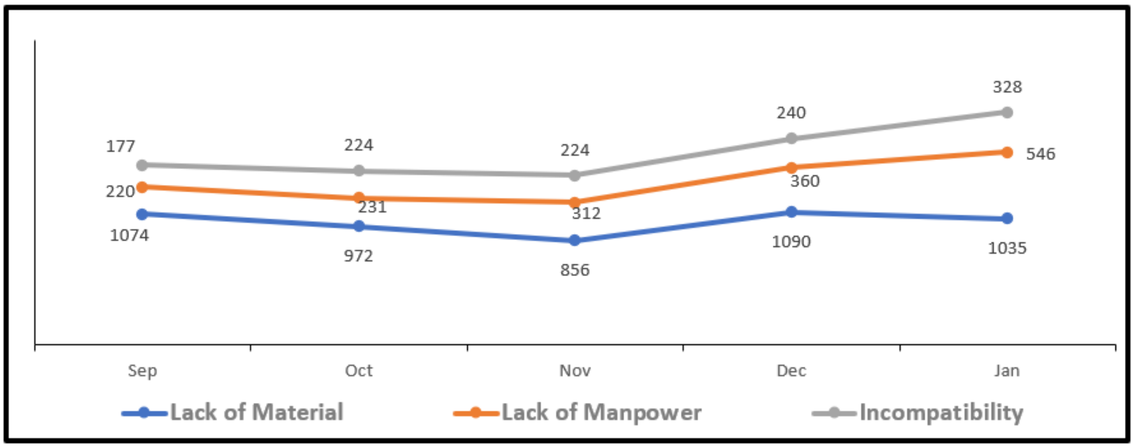


Table 2 – Reasons for line maintenance activities cancelations

Reason for Cancellations	Sep	Oct	Nov	Dec	Jan
Lack of Material	1074	972	856	1090	1035
Lack of Manpower	220	231	312	360	546
Incompatibility	177	224	224	240	328

Figure 2 - Evolution of reasons for cancelation



Project Outcomes

Based on the data collected and the objective we set out to achieve with the implementation of the Aircraft Maintenance Planning Platform, we understand that the main results we are looking for is an improvement in the effectiveness indicators. This is related to the reduction in items canceled during execution, due to lack of any necessary resources. Therefore, the data we are going to present, because of implementing the tool under study, is directly linked to the results observed after January 2023, when the Maintenance Planning team was trained, and the tool was implemented into the team's routines. To present the impacts measured after using the Programming Platform, we will use the same format presented in the Data Analysis section, so that there is a clear visualization of the variations in results after implementation.

Table 3 – Line maintenance activities data after Platform implementation (Jan/2023)

Months	Programmed	Accomplished	Cancelled	% Accomplished	% Cancelled
Sep/2022	22804	20981	1823	92%	8%
Oct/2022	23753	21927	1826	92%	8%
Nov-22	23663	21859	1804	92%	8%
Dec/2022	24405	22180	2225	91%	9%
Jan/2023	**26190**	**23851**	**2339**	**91%**	**9%**
Feb/2023	22349	20947	1402	94%	6%
Mar/2023	22417	21258	1159	95%	5%
Apr/2023	22185	21034	1151	95%	5%
May/2023	23246	22106	1140	95%	5%
Jun/2022	22520	21452	1068	95%	5%
Jul/2023	22094	21101	993	96%	4%
Aug/2022	22317	21414	903	96%	4%

Figure 3 - Evolution of the Failure Rate after Platform implementation (Jan/2023)

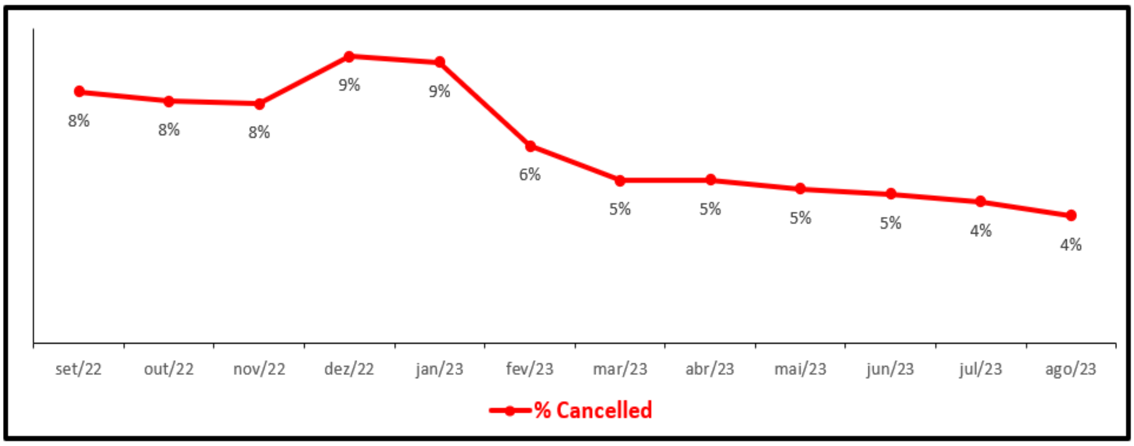
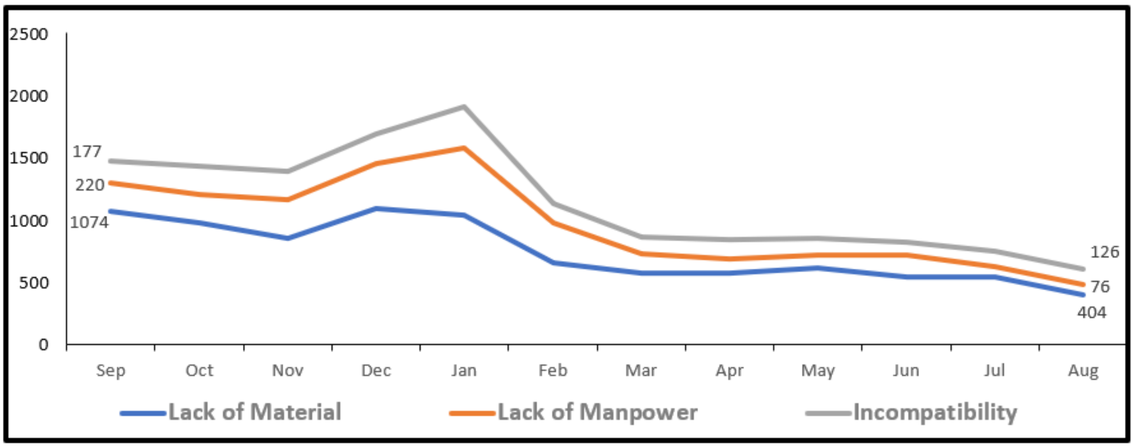


Table 4 – Reasons for line maintenance activities cancelations after Platform implementation

	Before implementation					After implementation						
Reason for Cancellations	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Lack of Material	1074	972	856	1090	1035	656	573	574	618	538	538	404
Lack of Manpower	220	231	312	360	546	318	155	115	103	178	84	76
Incompatibility	177	224	224	240	328	163	140	149	128	110	123	126

Figure 4 - Evolution of reasons for cancelation after Platform implementation



The average effectiveness measured, in the four months prior to the implementation of the tool, was around 92%, i.e., only 92% of the activities were performed. After January, when the programming platform was applied, this average increased to 95% and the number of items canceled due to lack of resources fell by 48%, since before the implementation around 2003 items were canceled each month and this number fell to an average of 1036 per month.

Conclusions

In summary, the proposed project to create a platform dedicated to the planning and scheduling of aircraft maintenance activities represents a significant innovation in response to the challenges that permeate the aviation sector. By combining advanced technology and professional expertise, this platform aims to optimize efficiency, safety, and productivity in the aviation industry.

This mission is extremely important, as it aims to reduce aircraft downtime and minimize unscheduled maintenance interventions, resulting in greater aircraft availability. This not only improves airline operations, but also has the potential to increase revenues and contain costs, generating substantial economic benefits.

In addition, the integration of different areas and the incorporation of artificial intelligence to automate the process have the potential to radically transform the way maintenance is planned and executed. This project not only meets the demands of the sector, but also promises to improve the customer experience and strengthen the competitiveness of airlines in the market. In short, the development of this platform represents a significant milestone towards more efficient, safe, and profitable aviation, with tangible benefits not only for airlines, but also for passengers and the industry as a whole.

Recommendations

The recommendations we can apply to this project can be divided into the various phases, from construction to implementation and consolidation as a process. Therefore, our recommendations are based on actions that could be followed by any area or company that chooses to implement this platform in their company.

Here are the topics we consider most important:

1. Extensive Testing: Carry out rigorous testing of the proposed platform to ensure that it works according to expectations and can deal with a variety of real-life scenarios and situations.

2. Training: Provide adequate training for users of the platform, ensuring that they are familiar with all the functionalities and can use it effectively.

3. Ongoing Evaluation: Implement an ongoing evaluation process to monitor the platform's performance and adjust as necessary to optimize efficiency and effectiveness.

4. Data Security: Ensure the security of the data collected and processed by the platform, following the best cybersecurity practices.

5. Collaboration: Establish solid collaboration between maintenance teams, IT and other stakeholders to ensure the integration and effective implementation of the platform.

6. Technological Update: Keeping up to date with the latest technologies and trends in the field of aviation and information technology, ensuring that the platform complies with the latest standards.

7. Data Collection: Implement an effective data collection and recording system to feed the platform with accurate and up-to-date information.

8. Results Evaluation: Regularly evaluate results and performance indicators to measure the platform's impact on operational efficiency and savings.

9. Stakeholder Engagement: Maintain a constant dialog with all stakeholders, including airlines, suppliers, and regulatory bodies, to ensure that the platform meets their needs and regulations.

10. Cost-Benefit Analysis: Carry out a periodic cost-benefit analysis to ensure that investments in the platform are aligned with the benefits obtained.

These recommendations aim to ensure the continued success of the project and the maximization of the expected benefits for the aviation industry.

References

Bastos, C., & Keller, V. (1999). *Aprendendo a aprender: introdução à metodologia científica.* Atlas.

Dinis, D., Barbosa-Póvoa, A. P., & Teixeira, A. (2019). A supporting framework for maintenance capacity planning and scheduling: Development and application in the aircraft MRO industry. *International Journal of Production Economics*, *218*, 1–15. https://doi.org/10.1016/j.ijpe.2019.04.029

Fachin, O. (2001). *Fundamentos de metodologia*. Ed. Saraiva.

Hobbs, A. (2008). *ATSB Transport Safety Report Aviation Research and Analysis An Overview of Human Factors in Aviation Maintenance.* https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=30dc0e83a2d59488f4319 f7d63291ed30c57f80f

Lakatos, E. M., & Marconi, M. A. (2001). *Fundamentos: metodologia científica.* (4th ed.). Atlas.

Papakostas, N., Papachatzakis, P., Xanthakis, V., Mourtzis, D., & Chryssolouris, G. (2010). An approach to operational aircraft maintenance planning. *Decision Support Systems*, *48*(4), 604–612. https://doi.org/10.1016/j.dss.2009.11.010

Петрова, E., & Ștefănescu, R. (2022). Decision making, some individual decision-making styles and software for decision making. *PrzegląD Nauk O ObronnośCi*, *15*, 1–12. https://doi.org/10.37055/pno/156919

Knotts, R. M. H. (2006). Civil aircraft maintenance and support. *Journal of Quality in Maintenance Engineering 12 (7)*, 239–251.

Scott, S. G., & Bruce, R. A. (1995). Decision-Making style: the development and assessment of a new measure. *Educational and Psychological Measurement*, *55*(5), 818–831. https://doi.org/10.1177/0013164495055005017

Van Kessel, P. J., Freeman, F. C., & Santos, B. F. (2023). Airline maintenance task rescheduling in a disruptive environment. *European Journal of Operational Research*, *308*(2), 605–621. https://doi.org/10.1016/j.ejor.2022.11.017

Vieira, M. M. F. (1996). *A comparative study on quality management in the brazilian and the Scottish prison service.* [PhD Dissertation on Business Studies]. University of Edinburg.