Hierarchy of Roadmap Items: Prioritization Strategy Development in Aircraft MRO Industry to Enhance Profit and Sustainability

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Abstract: Aviation's global aftermarket is expected to grow 22% in 2023, topping $94 billion, and will reach $125 billion by 2033 with a 2.9% compound annual growth rate. Besides that, the aircraft maintenance industry operates in a highly dynamic and competitive environment where ceaseless development is a requirement to ensure continuity, profitability, and sustainability. Hence, and based on the actual technological level and so striving for higher level advancement and introduction of new technologies and processes in this area, a significant number of research and development projects are under way or in the pipeline. With so many new ideas and innovations, it is hard for the upper management to make informed decisions and be sure that those decisions are what the company needs. Usually, these decisions are mainly made from one or a set of managers' points of view. However, the decision might not be suitable from a scientific point of view due to the numerous factors, data, and concerns that are very hard to spot without a numerical perspective. Hence, it is important to create a scientific strategy to prioritize these new ideas or items based on accurate factors and indications to give a vision of what is the most needed idea to adopt by the company. This is what the present paper is focused on. A case study investigation was made herein, where after collecting all the proposed ideas and development areas from the assigned managers and decision-makers, a prioritization was made. The ideas were ranked based on a novel hierarchy model which was developed to govern the development process of the maintenance repair and overhaul activity in the optimum and effective way to reach the set expectations. It means that the companies can have a scientific tool to point at the development direction that they should follow, and their focus will be shed on the most essential activities at hand and aim to get the most value towards the fulfilment of the upper management goals and stakeholders' vision. The proposed framework has assessed three different groups of aircraft maintenance development concepts based on a set of picked criteria and concludes which out of the three should be pursued next for more development. The results taken from the created framework showed that the "Development and Digitalization of the Operational Process for MRO Applications" topic is the most interesting one with 34 scores, which is higher than the second one by 21%. The proposed solution not *only showed the reliability of this framework to give good decision support but also showed that it could build a suitable, unified structure and procedure to follow while determining the company's future development direction.*

Keywords: Aircraft maintenance repair and overhaul; Management strategy; Roadmap Item Prioritization; Decision Making

1 Introduction

The aviation industry in the shape it is now is the outcome of years of human engineering and development, with aircraft serving as the lifeline of modern transportation and connectivity. Maintaining and assuring the safety and dependability of these aircraft with their complex components and systems is a constant challenge. This is where aircraft Maintenance, Repair, and Overhaul (MRO) comes in, playing a huge and critical role in ensuring that aircraft stay in optimum condition throughout their operating lifespan [1]. However, in the ever-changing aviation market and aircraft technology [2], MRO companies need to be flexible enough to adapt to new ideas and methodologies to keep services of high quality, efficiency, and accuracy.

MRO in the context of aviation refers to all activities and actions taken to keep aircraft airworthiness, such as inspections, repairs, component changes, and system updates [3]. It is the backbone of aviation safety and efficiency, ensuring that aircraft function consistently while meeting severe regulatory requirements from both the manufacturers and authorities [4]. Achieving one single flight requires many man-hours of maintenance labour, which often goes unseen to passengers but is extremely indispensable.

Aircraft design and manufacturing science have developed quite a lot in the past few decades, the proof of that is the countless research articles in different fields, which include many developments in electrification [5], [6], sustainability [7] [8] [9], noise reduction [10], the propulsion system [11] and its components [12] for example.

Based on [13] MRO demand expanded 18% in 2022. The compound annual growth of global maintenance, repair, and overhaul services is expected to grow 22% in 2023, topping $ 94 billion, which is a mere 2% below its 2019 peak. It will reach $ 125 billion by 2033 expectedly at a compound annual growth rate of 2.9%.

The developments of the aeronautical sciences and technologies together with the increasing need/business for the MRO services, force the concerned companies to reach for cutting-edge technologies and innovations. And since maintenance goes hand in hand with aircraft design, it needs to keep pace with the aircraft evolution. It is no longer enough to use basic and standardized approaches and procedures, MRO is growing into a highly complex sector that employs modern data analytics [14], predictive maintenance [15], robotics [16], digitalization [17], and automation [18] to enhance efficiency and reduce downtime.

However, in a sea full of new ideas, picking the correct development direction or idea is not as easy as it looks. The management needs to be up to date with the actual situation in the scientific and industrial world at once, plus, they need to be aware of all the pros and cons that one idea could have. This is why, it is important to pick the highest-ranking idea and correctly manage the allocation of human and financial resources that will bring additional profit and success to the company rather than wasting those resources on a direction that the work environment is not ready for. Hence, upper management must make well-established decisions regarding which concepts or projects to invest in.

This paper focuses on concept evaluation, highlighting the importance of prioritization in the aircraft MRO field, and it sheds light on a specific case study conducted in a modern MRO enterprise. The goal of this study is to create a framework on which companies can rely while picking a direction that is most aligned and suitable for their own internal development that will lead to further international strength and presence in global MRO markets.

The next chapter of this study will begin by introducing how will a company gather ideas relying on the industry's future innovation, then it will establish the vision, explaining in detail the concept generation and how items are selected for the roadmap. Afterward, the criteria, on which the items or concepts will be ranked off are defined, finally, the framework for the ranking is created, and the result of the assessment is announced. The created framework although used on a specific MRO study case and MRO enterprise can be a promising tool that can be developed further to be used as a universal decision-support tool for upper management and innovation teams.

2 MRO Roadmap

When aviation first began, the maintenance culture was quite limited, if not "non-existent," because there were few sensors aboard the aircraft and therefore a minimal amount of data and information available. Maintenance was ignored as efforts were focused primarily on aircraft development. As time and electrification/digitalization progressed, more sensors were placed on the aircraft structure and airframe, resulting in a greater amount of data that may be used to create Knowledge-Based Maintenance (KBM) [19].

Due to the need for cleaner and more ecologically friendly for the next decade, innovations are shifting to low-emission and hybrid-powered aircraft. The maintenance costs will be reduced when conventional and electric-powered propulsion systems are integrated since the operational time over a given period will be reduced, and therefore the intervals between inspections may be extended. MRO-related culture is predicted to receive more attention [20].

Since the MRO technology needs to follow the aircraft technology, it is crucial to keep in mind that all concepts and idea proposals should align with the MRO roadmap.

Figure 1 depicts the technology roadmap for MRO activities in the aeronautical sector. This roadmap essentially specifies the elements of the direction, from which numerous projects may be initiated. The roadmap contains various groups and product items, which can be updated based on the actual economic situation from time to time in one hand, and then year by year, and according to business values, items are picked from this roadmap to be evaluated and ranked, and only when the Business Cases are available and Return on Invest (ROI) is sufficiently high to be approved, can these items be started to be developed.

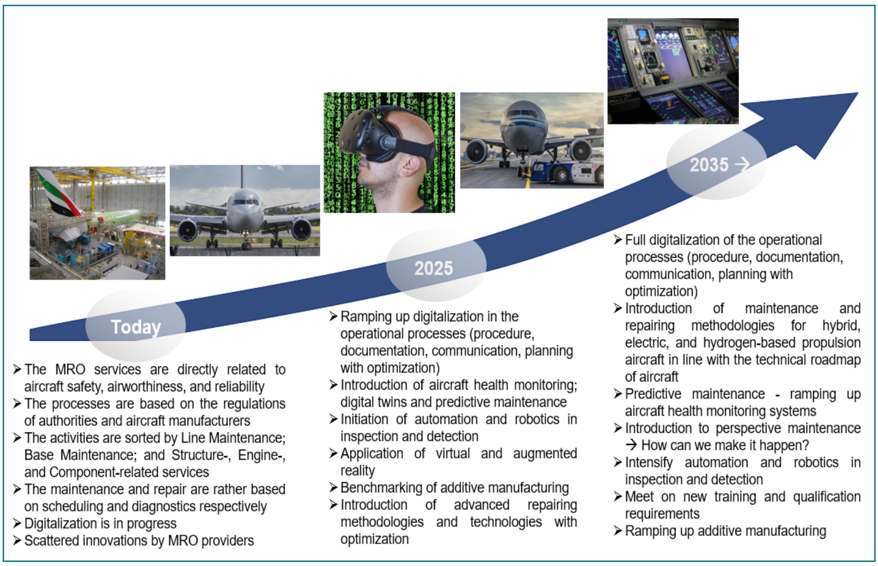

Figure 1
Technical roadmap of MRO activities in the aeronautical sector [20]

3 Prioritization Strategy

Concept or project evaluation means the critical examination of collected and proposed maintenance ideas and strategies. Although innovative ideas are generated long before any design or engineering work is done, they can come from either the management or the engineers and technicians, companies need to take into consideration many aspects to make the best decision about what projects will be started. These aspects are the outputs of the market study, the customer experiences and specifications, the product features, the product-market fit, the cost, ROI, the profit, the sustainability, among many others, which are needed to support the decision about the concepts to be initiated, and this is why developing a prioritization strategy becomes essential [21].

Prioritization has existed in our daily life routine since we started having more responsibility. Effective prioritizing is essential for development since one can only discover what works and what doesn't, what is worth doing and what is not, by putting things to the test in real life after detailed examination. Similarly, organizations and bigger enterprises perform some sort of prioritization process [22].

Additionally, there are many improvements, developments, new products, and services available in the market, so it can be a bit overwhelming to pick and choose from the numerous ideas. Therefore, there is an emphasis on the importance of finding a system to create this hierarchy of importance. Finding this kind of system, will not only maximize the profit and the sustainability, but it makes the job easier and will also increase transparency so that every employee understands what the plan is to follow, and what types of ideas should be supported and sought after in the first place.

In this case study, Aeroplex of Central Europe (ACE) [23] was approached in cooperation with the Budapest University of Technology and Economics (BME) [24] in order to find the most important project to develop under the framework of a Ph.D. research.

3.1 Generation of Concept from an Industrial Point of View

The five-step process was used as a reference when building the prioritization framework as indicated in Figure 2.

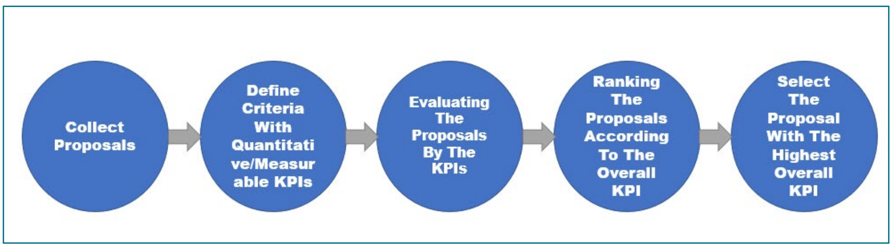

Figure 2
The five-step process prioritization framework

The first step to generate a selective concept system for prioritization is to complete deep literature research in order to collect all available innovations in the field of MRO including the vision of aircraft manufacturers. The ideas ranged from implementing new technology for maintenance to improve current procedures or implementing cost-cutting efforts, to create totally new maintenance methodologies by integrating robotics.

It was challenging trying to prioritize every proposal as it was a wide spectrum of ideas and solutions, which is why it was necessary to do a grouping for the ideas under three main categories as indicated in Figure 3.

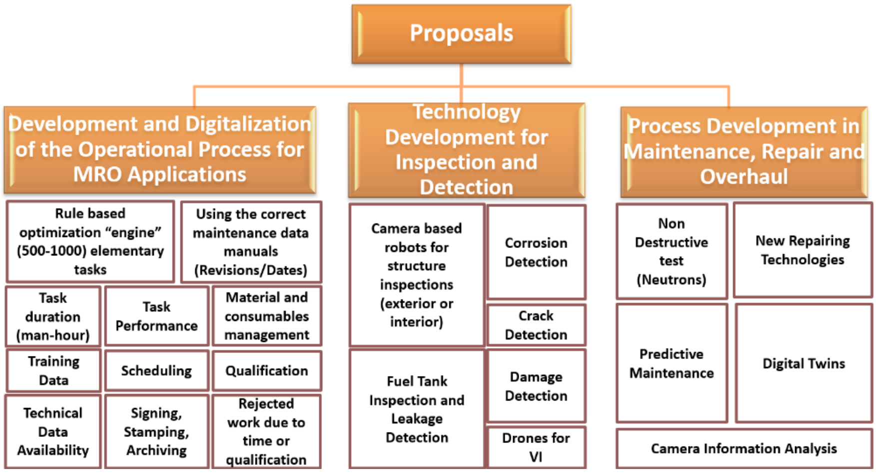

Figure 3

Grouping of MRO innovation project proposals as an output of the scientific literature research

Therefore, the topics of the research work have been categorized into the following three main groups, and these concepts will be evaluated instead of each individual idea:

- Development and Digitalization of the Operational Process for MRO Applications
- Technology Development for Inspection and Detection,
- Technical Developments in Maintenance, Repair, and Overhaul.

To make sure that these ideas were relevant in the scientific world and aligned with the MRO roadmap, a cross-check was made from the scientific literature studies and investigations. And indeed, every study that was found fits perfectly under one of these three groups. There are several studies that investigate planning [25] and scheduling problems [26] that can be included in topic 1 Development and Digitalization of the Operational Process for MRO Applications. Even research that concerns digitalization [24], Augmented Reality (AR) new maintenance manuals

[28], Virtual Reality (VR) new training material [29], speech recognition to aid technicians [30], and even applications [31] and software development [32]. As for the second concept, the literature is full of novel ideas that help with the detection and inspection of the aircraft structure. Some researchers proposed using robots for visual inspections [33] [34] [35], or to perform fuel tank inspections instead of humans due to the health hazards [36], and other studies that incorporated drones for structure inspections [37] and many more. The third concept includes various repair innovations such as using machine learning for predictive maintenance [38], new ways to do aircraft structural health monitoring [39], digital twins [40], intelligent troubleshooting [41], integrating new eddy current sensors into the repair patches [42], and many more studies like these.

So, it seems like these three concepts apply even to the studies found in the literature, and based on that it will be enough if the evaluation would only focus on them.

Each concept must be rigorously evaluated, considering criteria definitions that match the company's set goals and future vision such as practicality, cost-effectiveness, safety concerns, and the potential to improve the maintenance process's reliability and dependability for example.

3.2 Criteria Definition

The project prioritization is a complex problem. There are three main methods for the project prioritization in the scientific literature as 1. Scoring Model, 2. Project Prioritization Matrix and the 3. Payback Period [43]. A technique for project prioritization based on the opinions of subject matter experts is the scoring model. All that is involved in the scoring process is assessing various project components and then giving each one a numerical value scale. This model is the most general, it considers all aspects needed for decision making with special care for the R&D sector. The mentioned list of criteria in [43] is limited. Hence, an MRO industry-related specification list is developed in the framework of the present research.

The ideal strategy to define the prioritizing criteria is to begin by identifying the company's key development drivers and determining with them which concept out of the three to focus on.

Having a straightforward and structured set of criteria for ranking the project and research proposal allows one to make more consistent and better selections than merely depending on perceptions and individual opinions. Hence, the criteria were chosen that describe the greatest ability to have impact for the future of the enterprises, as shown in Figure 4.

The next step was to create an evaluate spectrum or scale for the 13 criteria, this enabled to have enough variation between the results. An example of the evaluation spectrum can be identified in Figure 5.

- 1. Project expenditure
- 2. Product cost estimation
- 3. Potential in revenue
- 4. Ability to achieve company's future goals
- 5. Degree of risk for failing to meet objectives
- 6. Level of technical complexity
- 7. Circumstances with patents
- 8. Meeting the criteria of the project
- 9. Technology level of the product (state of the art)
- 10. Avialibility of the needed technologies at the company
- 11. Level of safety compliance
- 12. Reliability of the product
- 13. Level of accuracy and efficiency increase

Figure 4
Prioritization criteria for the concepts

Project Assessment and Prioritization

Specifications and Their Descriptions	Score and explanation of the assessment			
	0	1	2	3
1. Project expenditure				
- Required investment - Yearly project cost - Needed FTEs (Full Time Equivalent)	- >100 t€ - >40 t€ - 3 or more man years are required	- 50-100 t€ - 20-30 t€ - 2 man years are required	- 10-50 t€ - 10-20 t€ - 1 man year is required	- 1-10 t€ - <10 t€ - less than 1 man year is required
2. Product cost estimation				
- Between minimum and maximum value based on products/similar solutions are available in the market.	- Highest product costs	- Medium-high product costs	- Medium-low product costs	- Lowest product costs
3. Potential in revenue				
- Based on the customer requirements, price/value ratio and market research (described in the Business Case).	- Lowest estimated product revenue	- Medium-low revenue	- Medium-high revenue	- Highest possible revenue
4. Ability to achieve company's future goals				
- Scale is defined according to the strategy and the relevances of the technical/operational roadmap items and based on MoSCoW method: M - Must have, S - Should have, C - Could have, W - Won't have.	- The outcomes won't have ability to achieve company's future goals.	- The outcomes could have ability to achieve company's future goals.	- The outcomes should have ability to achieve company's future goals.	- The outcomes must have ability to achieve company's future goals.

Figure 5
Evaluation spectrum

4 Assessment of the Results

The evaluation itself is the next step of the priority process. The votes were made by all partners involved in the project. Following the ratings and summarising the results, the prioritization is made. The ranking of the concepts is done based on their strategic value and expected impact. Concepts that, besides the others, promise the most advantages, whether in terms of increased safety, operational reliability, profit, sustainability, or cost savings, were prioritized. It is worth mentioning that given the frequently restricted resources available, not every concept could be pursued concurrently, so the accepted budget determines the number of projects to be started.

Based on the detailed assessment using the mentioned criteria, the results are found in Figure 6.

As a summary of the assessment, concept one, entitled "Development and Digitalization of the Operational Process for MRO Applications" has received the highest mark 34 and so the priority level amongst the others (see Figure 7), so it has been selected to be the most important from the industry point of view today. Thus, it has been nominated to be the topic of the development project to work out.

Criteria	Concept 1	Concept 2	Concept 3
1. Project expenditure	3	2	1
2. Product cost estimation	3	2	1
3. Potential in revenue	3	2	2
4. Ability to achieve company's future goals	3	3	3
5. Degree of risk for failing to meet objectives	2	2	1
6. Level of technical complexity	3	2	1
7. Circumstances with patents	2	1	1
8. Meeting the criteria of the project	3	2	2
9. Technology level of the product (state of the art)	3	3	2
10. Avialibility of the needed technologies at the company	1	2	2
11. Level of safety compliance	3	2	2
12. Reliability of the product	2	3	3
13. Level of accuracy and efficiency increase	3	2	2

Figure 6

Concepts assessment results

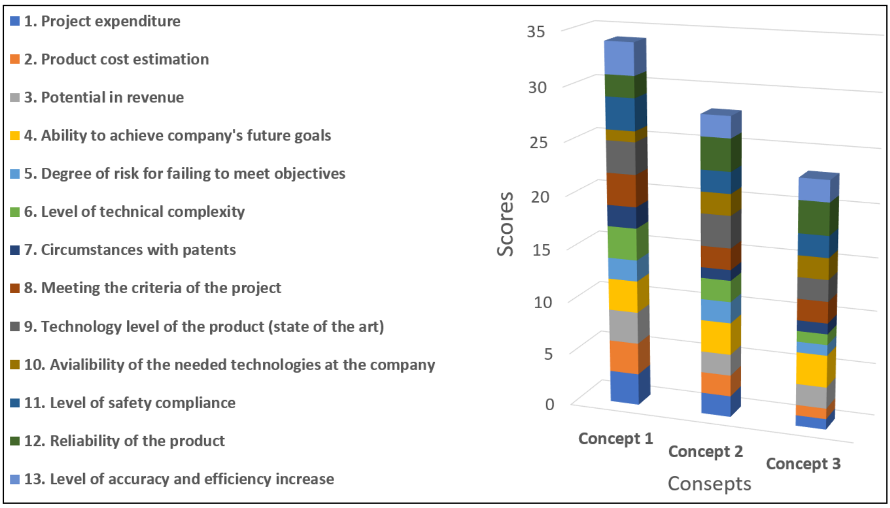

Figure 7

Assessment result chart

The expected benefit from selecting this concept and so to promote sustainable development are saving cost, time, and capacity due to the paperless documentation/administration based on

- reduction in the material and energy consumption,
- decrease in human error,
- less employees required to manage and deliver work packages,
- smaller size of the space for storing documents,
- better project/task/cost transparency,
- improved communication, and
- higher flexibility of the workplaces (e.g.: open office, home office).

Additionally, the capacity, the cost, the investment, the inventory, the tools, the workplace, the asset use, and the incoming task planning can be optimized more quickly, accurately, and frequently.

Whereas concept "Technology Development for Inspection and Detection" was in the middle with 28, and concept number three "Technology Developments in Maintenance, Repair, and Overhaul" ranked the lowest with 23 points, meaning these two concepts didn't bring the highest value from the company's perspective.

After the assessment procedure comes to the realization of the concept and execution of the project in the most efficient way in accordance with the company's set goals and visions. Following that is the plausibility check, verification, and validation of the outcomes and the realisation of the above-mentioned benefits are going to be compared with the actual situation using the baseline version of the process.

As these results are unique, company-dependent, and are under a confidentiality agreement in most of the cases, there are no similar topics published in the scientific literature according to the best knowledge of the authors.

Conclusions

The need for services in the field of aircraft maintenance, repair, and overhaul is increasing continuously. Although there is quite a development in the MRO industry today, there is still a potential for more technological and procedural advancement. Also, there is a gap in utilizing the latest innovations as much as it would be. This can also be proven by the fact that processes are rather based on human intervention instead of digital solutions.

Aircraft MRO is a vital and active part of the aviation sector. It guarantees that aircraft are safe, airworthy, and reliable throughout their operating lifespan. However, as aviation technology advances, the necessity for effective concept appraisal and prioritizing becomes even more critical. Stakeholders may strategically manage resources by carefully reviewing and prioritizing maintenance ideas, keeping aircraft at the forefront of safety and performance while navigating the ever-changing skies of the aviation business.

Based on the detailed literature research in the field of MRO innovation, and on the higher number of the project proposals, grouping was made for the given developments and concept ideas. Three groups have been identified as follows: “Development and Digitalization of the Operational Process for MRO Applications”, “Technology Development for Inspection and Detection”, and “Technical Developments in Maintenance, Repair, and Overhaul” for distinguishing the innovations. Then, it was important to identify specifications that can be used to prioritize these roadmap items. The specifications were made based on the identified criteria items which were picked to be in accordance with the goals and vision of the upper management. As a practical implication, the present work offers a direction also for managers of the MRO sector in structuring and applying this hierarchy for prioritizing processes aimed at organizational efficiency.

It was concluded that the concept titled “Development and Digitalization of the Operational Process for MRO Applications” ranked noticeably the highest compared to the other two. It means for the time being the improvements of the operational processes are the direction to be realised while considering the company’s future steps. Hence, for future developments, the company needs to establish a project plan, which includes a project description with clear goals, members and roles of the steering committee, achievable outcomes, and a timeline with milestones according to the official process description.

According to the prioritization framework and the criteria that it was based on and taking into consideration the high score of 34 points that the “Development and Digitalization of the Operational Process for MRO Applications” concept reached, it is safe to say that if the company follows that road, a major decrease in cost, time, and capacity will be realized. Hence, following the detailed investigation and analyses of the recent process, a new digital framework is going to be developed in the future in the form of a development project and Ph.D. research to improve the operational characteristics that are aligned with the results achieved.

Digitalization in this context means not only data transferring, handling, and storing but using them to find the best solutions for planning using the theories of the Internet of things, big data, machine learning, business analytics, blockchain, data processing, and artificial intelligence for example. The outcomes of this project development are expected to be in line with the regulation of quality insurance, which includes the expectations of aviation authorities and manufacturers. And of course, the provided solutions are going to be verified and validated based on different examples and test scenarios.

The benefit of the developed digital solution must be proven with the recently used, rather manual-based process management and planning activities by using KPIs (Key Performance Indexes).

References

[1] E. Karakilic, E. Gunaltili, S. Ekici, A. Dalkiran, O. Balli, and T. H. Karakoc, "A comparative study between paper and paperless aircraft maintenance: A case study," *Sustainability*, Vol. 15, No. 20, p. 15150, 2023

[2] F. Ekici, G. Orhan, Ö. Gümüş, and A. B. Bahce, "A policy on the externality problem and solution suggestions in air transportation: The environment and sustainability," *Energy*, Vol. 258, p. 124827, 2022

[3] EASA, "Study on the need of a common worksheet/work card system." EASA, Dec. 10, 2007, Accessed: Dec. 17, 2023 [Online] Available: https://www.easa.europa.eu/sites/default/files/dfu/Study%20for%20task%20145-020%20-%20work%20card%20system.pdf

[4] M. Quinlan, I. Hampson, and S. Gregson, "Outsourcing and offshoring aircraft maintenance in the US: Implications for safety," *Safety science*, Vol. 57, pp. 283-292, 2013

[5] D. Sziroczak, I. Jankovics, I. Gal, and D. Rohacs, "Conceptual design of small aircraft with hybrid-electric propulsion systems," *Energy*, Vol. 204, p. 117937, 2020, doi: https://doi.org/10.1016/j.energy.2020.117937

[6] J. Rohacs and D. Rohacs, "Energy coefficients for comparison of aircraft supported by different propulsion systems," *Energy*, Vol. 191, p. 116391, 2020, doi: https://doi.org/10.1016/j.energy.2019.116391

[7] S. Ekici, A. Dalkiran, and T. H. Karakoc, "A short review on sustainable aviation and public promises on future prospects," in *Research Developments in Sustainable Aviation: Proceedings of International Symposium on Sustainable Aviation 2021*, Springer Nature, 2023, p. 1

[8] M. S. Abdalla, O. Balli, O. H. Adali, P. Korba, and U. Kale, "Thermodynamic, sustainability, environmental and damage cost analyses of jet fuel starter gas turbine engine," *Energy*, Vol. 267, p. 126487, 2023

[9] P. Korba, O. Balli, H. Caliskan, S. Al-Rabeei, and U. Kale, "Energy, exergy, economic, environmental, and sustainability assessments of the CFM56-3 series turbofan engine used in the aviation sector," *Energy*, Vol. 269, p. 126765, 2023

[10] J. Bera and L. Pokorádi, "Monte-Carlo simulation of helicopter noise," *Acta Polytechnica Hungarica*, Vol. 12, No. 2, pp. 21-32, 2015

[11] K. Beneda, "Investigation of novel thrust parameters to variable geometry turbojet engines," in *2021 IEEE 19th World Symposium on Applied Machine Intelligence and Informatics (SAMI)*, IEEE, 2021, pp. 000339-000342

[12] M. Spodniak, L. Főző, R. Andoga, K. Semrád, and K. Beneda, "Methodology for the water injection system design based on numerical models," *Acta Polytechnica Hungarica*, Vol. 18, No. 4, 2021

[13] OliverWyman, "Global fleet and MRO market forecast 2023-2033." Accessed: Dec. 21, 2023 [Online] Available: https://www.oliverwyman.com/our-expertise/insights/2023/feb/global-fleet-and-mro-market-forecast-2023-2033.html

[14] M. Pelt, K. Stamoulis, and A. Apostolidis, "Data analytics case studies in the maintenance, repair and overhaul (MRO) industry," *MATEC Web Conf.*, Vol. 304, p. 04005, 2019, doi: 10.1051/matecconf/201930404005

[15] T. Tyncherov and L. Rozkova, "Predictive maintenance model of refined aircraft tires replacement," in *International Conference on Reliability and Statistics in Transportation and Communication*, Springer, 2020, pp. 164-173

[16] G. Niu, J. Wang, and K. Xu, "Model analysis for a continuum aircraft fuel tank inspection robot based on the Rzeppa universal joint," *Advances in Mechanical Engineering*, Vol. 10, No. 5, p. 1687814018778229, 2018

[17] J. Ordieres-Meré, T. Prieto Remon, and J. Rubio, "Digitalization: An opportunity for contributing to sustainability from knowledge creation," *Sustainability*, Vol. 12, No. 4, p. 1460, 2020

[18] S. Bouarfa, A. Doğru, R. Arizar, R. Aydoğan, and J. Serafico, "Towards automated aircraft maintenance inspection. A use case of detecting aircraft dents using Mask R-CNN," in *AIAA Scitech 2020 forum*, 2020, p. 0389

[19] F. Ansari, R. Glawar, and W. Sihn, "Prescriptive maintenance of CPPS by integrating multimodal data with dynamic bayesian networks," in *Machine Learning for Cyber Physical Systems*, Springer, 2020, pp. 1-8

[20] S. Ichou and Á. Veress, "Technology roadmap for aircraft maintenance, repair and overhaul," *Aeronautical Science Bulletins*, Vol. 34, No. 3, pp. 19-30, 2022

[21] K. Hayat, M. I. Ali, F. Karaaslan, B.-Y. Cao, and M. H. Shah, "Design concept evaluation using soft sets based on acceptable and satisfactory levels: an integrated TOPSIS and Shannon entropy," *Soft Computing*, Vol. 24, pp. 2229-2263, 2020

[22] J. R. Marques, "Project process improvement and other points – How to do it and apply it?," Portal. Accessed: Sep. 20, 2023 [Online] Available: https://www.ibccoaching.com.br/portal/rh-gestao-pessoas/projeto-melhoria-processos-outros-pontos-como-fazer-aplicar/

[23] Aeroplex of Central Europe Aircraft Technology Center, "Company Profile." Accessed: Sep. 20, 2023 [Online] Available: https://www.aeroplex.com/content/company-profile.html

[24] Budapest University of Technology and Economics, "Budapest University of Technology and Economics," Budapest University of Technology and

Economics. Accessed: Sep. 20, 2023 [Online] Available: https://www.bme.hu/?language=en

[25] D. Dinis, A. Barbosa-Póvoa, and Â. P. Teixeira, "A supporting framework for maintenance capacity planning and scheduling: Development and application in the aircraft MRO industry," *International Journal of Production Economics*, Vol. 218, pp. 1-15, 2019

[26] S. Albakkoush, E. Pagone, and K. Salonitis, "An approach to airline MRO operators planning and scheduling during aircraft line maintenance checks using discrete event simulation," *Procedia Manufacturing*, Vol. 54, pp. 160-165, 2021

[27] M. Esposito, M. Lazoi, A. Margarito, and L. Quarta, "Innovating the maintenance repair and overhaul phase through digitalization," *Aerospace*, Vol. 6, No. 5, p. 53, 2019

[28] S. Hongli, W. Qingmiao, Y. Weixuan, L. Yuan, C. Yihui, and W. Hongchao, "Application of AR technology in aircraft maintenance manual," in *Journal of Physics: Conference Series*, IOP Publishing, 2021, p. 012133

[29] A. Siyaev and G.-S. Jo, "Towards aircraft maintenance metaverse using speech interactions with virtual objects in mixed reality," *Sensors*, Vol. 21, No. 6, p. 2066, 2021

[30] A. Siyaev and G.-S. Jo, "Neuro-Symbolic speech understanding in aircraft maintenance metaverse," *IEEE Access*, Vol. 9, pp. 154484-154499, 2021

[31] H. M. Shakir and B. Iqbal, "Application of Lean principles and software solutions for maintenance records in continuing airworthiness management organisations," *The Aeronautical Journal*, Vol. 122, No. 1254, pp. 1263-1274, 2018

[32] C.-C. Yuan, C.-H. Li, and C.-C. Peng, "Development of mobile interactive courses based on an artificial intelligence chatbot on the communication software LINE," *Interactive Learning Environments*, Vol. 31, No. 6, pp. 3562-3576, 2023

[33] Y. Sun, L. Zhang, and O. Ma, "Robotics-assisted 3D scanning of aircraft," in *AIAA AVIATION 2020 FORUM*, 2020, p. 3224

[34] A. Doğru, S. Bouarfa, R. Arizar, and R. Aydoğan, "Using convolutional neural networks to automate aircraft maintenance visual inspection," *Aerospace*, Vol. 7, No. 12, p. 171, 2020

[35] B. Ramalingam *et al.*, "Visual inspection of the aircraft surface using a teleoperated reconfigurable climbing robot and enhanced deep learning technique," *International Journal of Aerospace Engineering*, Vol. 2019, 2019

[36] F. Heilemann, A. Dadashi, and K. Wicke, “Eeloscope—Towards a novel endoscopic system enabling digital aircraft fuel tank maintenance,” *Aerospace*, Vol. 8, No. 5, p. 136, 2021

[37] M. Hrúz, M. Bugaj, A. Novák, B. Kandera, and B. Badánik, “The use of UAV with infrared camera and RFID for airframe condition monitoring,” *Applied Sciences*, Vol. 11, No. 9, p. 3737, 2021

[38] Z. M. Çınar, A. Abdussalam Nuhu, Q. Zeeshan, O. Korhan, M. Asmael, and B. Safaei, “Machine learning in predictive maintenance towards sustainable smart manufacturing in industry 4.0,” *Sustainability*, Vol. 12, No. 19, p. 8211, 2020

[39] C. Boller, “Ways and options for aircraft structural health management,” *Smart materials and structures*, Vol. 10, No. 3, p. 432, 2001

[40] T. Tyncherov and L. Rozkova, “Aircraft lifecycle digital twin for defects prediction accuracy improvement,” in *International Conference on Reliability and Statistics in Transportation and Communication*, Springer, 2019, pp. 54-63

[41] A. Y. Yurin, Y. V. Kotlov, and V. M. Popov, “The conception of an intelligent system for troubleshooting an aircraft,” 2021

[42] S. Schmid, U. Martens, W. K. Schomburg, and K.-U. Schröder, “Integration of eddy current sensors into repair patches for fatigue reinforcement at rivet holes,” *Strain*, Vol. 57, No. 5, p. e12387, 2021

[43] D. Wakeman, “Project prioritization: How to prioritize projects & strategy,” ProjectManager. Accessed: Dec. 21, 2023 [Online] Available: https://www.projectmanager.com/blog/how-to-prioritize-projects-and-strategy