

A ranking method for maintenance strategy selection of airport mechanical equipment using an analytic hierarchy process

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ABSTRACT

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Despite the growing consciousness that the appropriate blends of maintenance strategies aid substantial reduction in plant downtimes, the extant literature fails to adequately explain how the critical maintenance criteria of mechanical equipment in airports could be ranked to impact the maintenance program positively. This paper offers the analytical hierarchical process (AHP) to explain how the significant maintenance criteria from a technical perspective (i.e., adaptability and maintainability) and in relationship with customer viewpoints (i.e., funds availability and customer trust) impact rank determination. Expandability and maintainability were equally ranked first with a criterion weight of 0.36 each. Customer trust was ranked second (criterion weight of 0.17) and the least important criterion of funds availability was ranked third (criterion weight of 0.10). Thus, the AHP proposes the choice of either adaptability or maintainability to yield satisfying results as inputs into maintenance program development. Consequently, the AHP provides explanations on how the choice of maintenance criteria for an airport's mechanical equipment helps to solve the maintenance program development dilemma for maintenance engineers and managers.

Keywords: maintenance program; risk; maintenance strategies; airport; mechanical equipment

1. INTRODUCTION

In the present decade, making sound maintenance decisions has been heralded as a principal requirement for an organization to retain a world-class position or strive towards becoming one (Liu et al., 2019). Contemporary decision-making in maintenance involves analysis and decisions on the environmental influence of maintenance, downsizing and restructuring, hiring and firing of maintenance employees, new product development, plant expansion, and disposal (Schmidt et al., 2017).

Despite the growing consciousness that the appropriate blends of maintenance strategies aid substantial reduction in plant downtimes, the extant literature fails to adequately explain how the critical maintenance criteria of mechanical equipment in airports could be ranked to impact maintenance programs positively (Mishra et al., 2015). The types of equipment of concern are travelators, elevators, escalators, baggage equipment, and air-conditioners. So the problem entails prioritizing maintenance criteria of expandability, maintainability, funds availability, and customer trust. The application of the celebrated tool of AHP is made

since it is a proven and dependable method of multicriteria analysis as well as suited to prioritise airport maintenance criteria. The application of AHP has been extensively documented as very successful in the maintenance engineering applications (Bertolini & Bevilacqua, 2006). The use of AHP for practice is commenced by drawing up a hierarchical structure, consisting of three phases, notably the goal, which is the maintenance program development for mechanical equipment. The criteria definition and the specification of the alternatives are the second and third phases, respectively. For the maintenance situation, literature is sought and the unique criteria definition by Triantaphyllou and Mann (1995), from the perspective of hardware expandability, hardware maintainability, finance availability, and user-friendly attributes are adapted for use in the current study. For a suitable adaptability of Triantaphyllou and Mann's (1995) idea in the maintenance program development environment of an airport's mechanical equipment, the respective criteria are defined as equipment (interchange) expandability, maintainability, funds accessibility, and customer trust. Table A1 in the appendix shows a summarized literature review on the subject of this work.

Furthermore, a critical appraisal of the extant literature on airport management, maintenance planning, and maintenance decision-making discloses that numerous articles have been written on airport maintenance and the majority focus of articles are towards estimating the maintenance cost of aviation equipment, while prototypes and numerical systems were used for illustrations. Moreover, a literature review on ranking and criteria classification methods highlights that limited quantitative studies have been reported on this subject, especially in airport maintenance ground service performance improvement (Durán, 2011; Dozic et al., 2018). Only a very few studies have considered the ranks of parameters with emphasis on ground support equipment. Exploring alternative methods to quantifying the qualitative descriptions of maintenance outcomes, such as "poor power output of equipment", by intuition and experience of the maintenance manager and the support team requires comprehensive analysis. Further research is essential to understand how the qualitative outcomes of maintenance decision-making are made possible through multicriteria analysis. While existing studies have identified some key issues in strategic asset management, such as maintainability, funds availability, expandability and customer trust, there is significant untapped potential in studying how the qualitative description for these descriptors could be transformed into quantitative outcomes, in ranks and weight descriptions. There is a need for more studies on multicriteria analysis and its applications to airport maintenance. The use of the analytic hierarchy process offers great potential to solve this problem.

The objective of this paper is to apply the analytical hierarchical process (AHP) to airport maintenance criteria from a technical perspective (i.e. adaptability and maintainability) and relationship viewpoint (i.e., funds availability and customer trust) and determine ranks and maintenance criterion weights, respectively.

2. MATERIALS AND METHODS

The AHP structure adopted resembles a pyramid possessing a unit of analysis at the top, known as the goal, which reflects the determination of an effective maintenance program for the airport's mechanical equipment. More units of analysis, represented by boxes, evolve as we proceed from the top of the pyramid's base. Thus, in summary, the maintenance program development is represented by three phases: goal definition (phase 1), the criteria for judgement (phase 2), and the specification of alternatives (phase 3). In a complex hierarchical structure involving multiple goals, the rule is to relate only one criterion to a goal. This goal is the same for all the considered criteria. In this case, each alternative unit is given a value related to it.

In a situation presented, a decision matrix comprising four attributes and five alternatives is presented. Each option has its value of attribute related to it. To implement the AHP framework, the first step is as follows:

Step 1: Establish a structure for the hierarchy.

The structure is in several levels. The first level is for selecting the superior maintenance policy for the airport. The second level relates to the decision criteria. In this aspect, four decision criteria are considered: expandability in the first criterion, which relates to the ability of the maintenance manager to easily scale, modify or upgrade the maintenance infrastructure in the airport, such that expansion in activities relating to new technologies or future air traffic increase could be accommodated. The second criterion is maintainability, which focuses on the cost-effectiveness, speed, and ease with which equipment, as well as facilities, can be regulated and kept working for the intended service. The third criterion is the customer fund, and it is equally tied to a positive passenger experience, which is achieved through the safety and reliability of the aircraft and equipment securing the customer while in the airport. The fourth criterion is fund availability. This criterion is associated with financial resources, capital required, as well as the budget needed to start and control maintenance policy in the plants.

Step 2: Establish the comparative significance of the diverse criteria with the maintenance program development goal.

This step is described as the creation of a relative matrix in pairs. This matrix reveals the comparative importance of the maintenance system attributes in association with the maintenance program development goal. Consider the first cell on the first row, the question may be how significant is expandability to a maintenance manager when the manager is deciding to install an effective maintenance program. A second question concerning the next horizontal cell when considering the first row relates to what the significance of maintainability is when the maintenance manager is planning for the maintenance program. For the next two cells, the related questions could be what is the importance of funds availability in the attempt by the maintenance manager to install an effective maintenance program for the mechanical equipment. What is the significance of customer trust in the effort to create an effective maintenance program for the airport's

mechanical equipment? The pairwise matrix of comparison is often developed by relying on Saaty's definition of the degree of comparative importance, which assigns numbers from 0 to 9 as follows (Table 1).

The span of the pair-wise matrix equates to the number of attributes employed in the maintenance program development process. In this situation, a 4 x 4 matrix emerges from four attributes. These are dependability, maintainability, funds availability, and customer trust (Table 2).

Table 1. Saaty's comparative importance dimension

Value representation	Description
1	Identical magnitude
3	Reasonable magnitude
5	Robust magnitude
7	Extreme robust magnitude
9	Tremendous magnitude

Table 2. Pairwise comparison matrix for the airport's mechanical equipment

Attribute →	Expandability	Maintainability	Funds availability	Customer trust
Expandability	1	1	7	1
Maintainability	1	1	3	3
Funds availability	1/7	1/3	1	1
Customer trust	1	1/3	1	1

Step 3: Evaluate the consistency.

The third step is to evaluate consistency, which implies checking the correctness of the calculated values. In explaining this, the same pairwise comparison matrix elements have been used.

For the current problem, the consistency index. (CI.) is calculated as in Equation 1:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (1)$$

In this case, n refers to the number of elements compared. Since n is 4, there are four criteria. Next, the consistency ratio is obtained, the division of the CI with the random index (RI). The RI is the CI of a randomly generated pair-wise matrix.

3. RESULTS AND DISCUSSION

In this section, the results are shown and discussed based on the prioritization of maintenance needs in the airport. The results could also be discussed from the perspectives of allocating resources and selecting strategies to be used in the airport's judgment. In particular, issues concerning maintenance criteria weight, which show important ranking as well as consistency checks, are discussed.

The data in Table 2 was sourced from experts with mechanical and industrial engineering backgrounds. One of the authors is senior engineering personnel in an airport in a developing country. The senior engineer proposes the interrelationships between parameters and the second author reviews the submission for acceptance, rejection or modifications. The criteria used are based on an extensive literature review and primarily could be obtained specifically as follows: Balo et al. (2024) mentioned trust as a critical element of a service system. Therefore, customer trust is adopted from the suggestion of Balo et al. (2024) in the present work. In addition, maintainability was mentioned during the analysis of the building maintenance problem using an AHP. Since mechanical equipment maintenance is a service with many common issues with the maintenance of buildings the factor named maintainability is adopted from Das et al. (2010) and used

in the present study as a factor to analyze the AHP. Moreover, the factors of expandability and funds availability were considered by the present authors as relevant based on the practical experience of one of the authors. These factors were then considered for use in Table 2.

Furthermore, the value obtained in the pairwise matrix depends on the decision maker. Consider determining the cell value representing the intersection of expandability on the row and maintainability on the column. Here the decision maker asks the question of how important is expandability to maintainability when considering mechanical equipment maintenance in airports. Based on the experience of the expert, expandability is of a reasonable magnitude to maintainability. It means that if maintainability is given a value, expandability will be allocated thrice to this value. This is observed from Table 1, where a value of 3 is given for reasonable magnitude. Therefore, for the cell of interest, a value of 3 is placed in the cell. It is interesting to note that in the matrix, there are reciprocals of cells. For example, on the row of maintainability, there is an interaction with expandability along the column. The reciprocal of an earlier value is placed here. In addition, all values along the diagonals are given 1. Thus, by interpreting the analysis in this way, Table 2 is completed.

The value allocated in the pairwise matrix depends on the experience and judgment of the decision maker relative to the problem being solved as he/she will judge the preference of an item to the other. This may be information obtained from maintenance managers who are experienced in the area of mechanical equipment whose programs are to be developed. To explain, let us consider the second cell in the first row. This is the cell that relates expandability with maintainability. A possible question to ask is how significant is expandability to maintainability? Is it of identical magnitude with maintainability? If maintainability is given a value of η then expandability will be given the same value η . It could be seen from Saaty's comparative importance dimension that for identical magnitude, a value of 1 is obtained. To calculate the value in the cell, the row element is divided by the column element and the value of the second cell in the first row is 1. Likewise, the value's reciprocal is assigned to the first empty cell of row two. For the third empty cell in the first row, to obtain a value therein, the

question is, how important is funds availability compared with expandability? In the same manner, expandability is of extremely robust magnitude with funds availability. If expandability is given a value η , then funds availability is given 7η . It could be seen from Saaty's comparative importance dimension that for extremely robust magnitude, a value of 7 is assigned. To calculate the value in the cell, the row element is divided by the column element and the value assigned to the third empty cell of the first row is 7. Following this procedure, all the cells apart from the common cells where the same item in the

vertical column intersects at the horizontal row. These are called diagonal elements and are assigned the value of 1 since each item on the horizontal row in aligning with itself on the vertical column is of equal importance. The next stage is to sum up the values along the columns. For the first column, the sum is obtained from 1, 1, 0.14, and 1 as 3.14. Similarly, other sums of 2.66, 12, and 6 are obtained horizontally along the pairwise comparison matrix. The next stage is to obtain the normalized pairwise matrix from Table 3 as in Table 4.

Table 3. AHP pairwise comparison matrix (Improper fractions to decimals; Summed up in cells)

Attribute →	Expandability	Maintainability	Funds availability	Customer trust
Expandability	1	1	7	1
Maintainability	1	1	3	3
Funds availability	0.14	0.33	1	1
Customer trust	1	0.33	1	1
Sum	3.14	2.66	12	6

Table 4. Normalized pairwise comparison matrix

Attribute →	Expandability	Maintainability	Funds availability	Customer trust	Criteria weight
Expandability	0.32	0.38	0.58	0.17	0.36
Maintainability	0.32	0.38	0.25	0.5	0.36
Funds availability	0.04	0.12	0.08	0.17	0.10
Customer trust	0.32	0.12	0.08	0.17	0.17
Sum	3.14	2.66	12	6	

Table 4 is obtained by dividing each value in the original cell of Table 3 by the sum of the columns. For example, to obtain the first empty cell of Table 4 in the first row, the original value in the corresponding cell of Table 3 is 1, and it is divided by the sum and a new value of 0.32 is fixed in the corresponding cell in Table 4. This is calculated for all the cells and to complete Table 4. The last column of Table 4 evaluates the criteria weights by summing up elements along the row and finding the average of the same. For the cell under criteria weight in Table 4, the averages of 0.32, 0.38, 0.58, and 0.17 are obtained as 0.36 for row one. For rows two to four, the values of 0.36, 0.10, and 0.17 are obtained as the criteria weight. Table 5 shows details of consistency tests.

Data collection and expert input issues while using the analytical hierarchy process in airport maintenance are important. They involve a structured, judgment-oriented method where the data collected displays elements of technical documentation and subjective expert evaluations.

The experts comprehensively review the data on the four critical parameters of interest, namely customer trust, maintainability, funds availability and expandability. This data review is such that the experts provide a pairwise comparison on how important these four parameters are to one another. Instead of the absolute ratings, the experts weigh parameters in pairs. (e.g. expandability vs funds availability) using Saaty's 9-point scale. This scale contains verbal expressions which handle ambiguity. The exercise results in numerical values obtained from the conversion efforts. While it is known that the quality of the AHP outcomes is a function of the experience and knowledge of the experts who provide inputs to the analysis, within the limitations of this study, a senior engineer who has worked for several years in the airport is the most experienced expert who engaged in this project. This engineer's effort was coupled with that of another expert with over two decades of continuous experience in maintenance and selective experience in airport maintenance.

Table 5. AHP comparison table with tests for consistency

Criteria weights	0.36 Expandability	0.36 Maintainability	0.10 Funds availability	0.17 Customer trust	Weighted sum value (WSV)	Criteria weights (CW)	WSV/CW
Expandability	$1 \times 0.36 = 0.36$	$1 \times 0.36 = 0.36$	$7 \times 0.10 = 0.70$	$1 \times 0.17 = 0.17$	1.59	0.36	4.42
Maintainability	$1 \times 0.36 = 0.36$	$1 \times 0.36 = 0.36$	$3 \times 0.10 = 0.30$	$3 \times 0.17 = 0.51$	1.53	0.36	4.25
Funds availability	$0.14 \times 0.36 = 0.05$	$0.33 \times 0.36 = 0.12$	$1 \times 0.10 = 0.10$	$1 \times 0.17 = 0.17$	0.44	0.10	4.40
Customer trust	$1 \times 0.36 = 0.36$	$0.33 \times 0.36 = 0.12$	$1 \times 0.10 = 0.10$	$1 \times 0.17 = 0.17$	0.75	0.17	4.41

To obtain Table 5, the original value in the pairwise comparison table that is not normalized is used. Each value in the cell is multiplied by the criterion value. For the first cell in the first row, from Table 3, the cell has a value of 1, which is multiplied by 0.36 (i.e., 1×0.36) and summed with the rest as $(1 \times 0.36) + (1 \times 0.36) + (7 \times 0.10) + (1 \times 0.17)$, which gives 1.59. The value 1.59 on the first row is the weighted sum value, obtained from adding up all the values of the attributes along a row. Similarly, the weighted sum values of 1.53, 0.44, and 0.75 were obtained for the second to the fourth rows. The weighted sum value divided by the criteria weight is calculated for each row, obtained as 4.425, 4.25, 4.400, and 4.41 from the first to the last row, respectively. Now $\lambda_{\max}$ is obtained from the average of these values as $\lambda_{\max} = 4.37$. The next step is to calculate the CI as in Equation 1 in the section on

methodology. By using the randomly generated pair-wise matrix, the following table is adopted (Table 6).

In this numerical example, $n = 4$ and the consistency ratio (CR) = $0.12/0.90$, which gives 0.13. Since the value of consistency ratio $CR = 0.13 > 0.10$, for the proportion of inconsistency to be more than 0.10, which is the standard, we cannot assume that our matrix is reasonably consistent. However, using AHP, the pairwise comparison matrix was recomputed for the airport's mechanical equipment by modifying the entries to obtain Table 7.

Afterwards, the procedure follows through Tables 3 to 6 by the AHP pairwise comparison matrix development, normalization of the pairwise comparison matrix, development of the AHP comparison table with tests for consistency, and the consideration of the random index. Based on the adjustment, Table 8 is now obtained.

Table 6. Random index

<i>N</i>	1	2	3	4	5	6	7	8	9	10
<i>RI</i>	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 7. Pairwise comparison matrix for the airport's mechanical equipment

Attribute →	Expandability	Maintainability	Funds availability	Customer trust
Expandability	1	3	7	5
Maintainability	1/3	1	3	6
Funds availability	1/7	1/3	1	3
Customer trust	1/5	1/6	1/3	1

Table 8. AHP comparison table with tests for consistency

Criteria weights	0.554	0.271	0.112	0.063	Weighted sum value (WSV)	Criteria weights (CW)	WSV/CW
	Expandability	Maintainability	Funds availability	Customer trust			
Expandability	$1 \times 0.554 = 0.554$	$3 \times 0.271 = 0.813$	$7 \times 0.112 = 0.784$	$5 \times 0.063 = 0.315$	2.466	0.554	4.451
Maintainability	$0.333 \times 0.554 = 0.184$	$1 \times 0.271 = 0.271$	$3 \times 0.112 = 0.336$	$6 \times 0.063 = 0.378$	1.169	0.271	4.314
Funds availability	$0.143 \times 0.554 = 0.079$	$0.333 \times 0.271 = 0.090$	$1 \times 0.112 = 0.112$	$3 \times 0.063 = 0.189$	0.470	0.112	4.196
Customer trust	$0.200 \times 0.554 = 0.111$	$0.167 \times 0.271 = 0.045$	$0.333 \times 0.112 = 0.037$	$1 \times 0.063 = 0.063$	0.256	0.063	4.063

Finally, based on Equation 1, the new CI is calculated as 0.085. In this situation, $n = 4$ and the $CR = 0.085/0.90$, which gives 0.094. Since the value of $CR = 0.094 < 0.10$, we can assume that our matrix is reasonably consistent. Based on the requirement of the maintenance manager, we may use the criteria weight specified in Table 5, so expandability is 55.4%, maintainability is 27.1% weightage, funds availability is 11.2% weightage and customer trust is 6.3% weightage.

From the results of Table 8, which indicate the criteria weight, the results that show the parameters exhibiting the greatest influence on maintenance decision are expandability (0.554), maintainability (0.271), fund availability (0.112) and customer trust (0.063). The expandability is the highest weight, having a value of more than 55% for expandability; the AHP model largely favours the maintenance project. This may be at the expense of some other objects, which could be urgent but require a lower cost of repair. It could be a neglect of an effort to improve passenger experience in the airport, which comes under the customer trust parameters. This is assigned the lowest weight obtained from expert judgement, which could be subjective

and could be personal biases of the expert, instead of the objective operational data.

In comparing the results with the literature, the study by Alharasees and Kale (2023) may be mentioned. The work applied AHP to supplier selection in aviation. Although the contribution is useful within the aviation industry, it does not fill the gap that the present study attempts to bridge. The focus of the present study differs in the primary objective, principal decision criteria and the nature of alternatives, thereby strongly suggesting a deep investigation into the present focus if the knowledge gap should be bridged with urgency.

Moreover, on comparing the present study with the literature, the paper by Jamali et al. (2021) is considered. While the present study prioritises expandability and maintainability with a heavy focus on physical infrastructure, Jamali et al. (2021) emphasised customer-centric policies, competition and finances. Jamali et al. (2021) prioritised financial viability while considering funds availability as a secondary issue. Moreover, the present study favours operational capacity over market-driven metrics. Furthermore, the comparison of the present work with

Wafa and Sunitiyoso (2025) focuses on supply chain and procurement management for aircraft maintenance. Comparison is made with respect to four key issues: objective, key driver, financial orientation, and end-user influence. The objective of the present paper is to prioritise infrastructure/ system maintenance as well as improvement. However, the focus on materials/parts while selecting the best supplies is the main concern of the comparison paper. The key driver of the present paper is expandability, while quality and cost drive the comparison paper. From a financial perspective, funds availability is the secondary filter while direct cost, including price and payment agreement, is the topmost criterion of the comparison paper. Concerning end-user influence, customer trust attracts a low weight in the present study. However, customer satisfaction and quality compliance are emphasized to ensure the airworthiness of aircraft after maintenance.

Adding value to organizations as a whole or a subsection thereof (such as a maintenance system), through the adoption of an AHP framework, is an open problem that challenges both researchers and practitioners. Though significant advancements have been made in the adoption of AHP on the operational aspects of airports and airlines, the influence of AHP on maintenance decision-making is blurred and largely restricted (Yoo & Choi, 2006; Chen et al., 2009; Zietsman & Vanderschuren, 2014; Karaman & Akman, 2018; Kilic & Ucler, 2019). Furthermore, studies displaying how multi-criteria theories could be utilized to improve insight into maintenance criteria choice on maintenance planning and implementation performance for airport mechanical equipment are almost absent in the literature (Lee et al., 2018). With such a perspective, this research proposes structural support to maintenance units to express the route to efficient maintenance program development through the analytical hierarchy process. By adding facts from the review of literature on maintenance planning and related issues with the outcomes of a numerical example, a structure for AHP implementation to determine the criteria of the maintenance system for the airport's mechanical equipment has been put forward to guide maintenance engineers and managers to take advantage of the values obtained when analytical hierarchy process is executed.

Contributions of the study. This contribution expands the intellectual capacity of maintenance managers and the maintenance unit as it tries to make the development of maintenance programs for airports more effective. It offers an understanding of how data on criteria determination for mechanical equipment in airports could be extracted, with the final objective of improving the decision-making process of the maintenance unit within the technical airport organization. Another contribution of this work is the extension of Triantaphyllou and Mann's (1995) suggestion on the choice of criteria for analysis for the example problem discussed in the work. The initial scale comprising four criteria, demonstrated in Triantaphyllou and Mann's (1995) is customized to the airport scenario, a new dimension to validate the authors' suggestion.

4. CONCLUSION

In this paper, the application of the analytic hierarchy process method was made to the airport maintenance decision-making process. The obtained results revealed the quantified, collective priorities of the airport experts,

which accounted for a structured trade-off among maintenance cost, its efficiency and safety practices. Based on the findings of this study, the following conclusions are made. Firstly, there is a need for a highly strategic, proactive maintenance method. The expandability parameter, which had the highest criterion weight of 0.554 (55.4%), shows that the studied airport is at a development-focused stage. The maintenance decisions in the airport are driven by infrastructural expansion, such as the rehabilitation of runways to allow large aircraft participation in service to customers. Moreover, the high value, 55.4%, of expandability, portrays the existing maintenance strategy as one which not only accommodates current operations to run but also incorporates long-term capacity expansion of the airport.

Secondly, the fact that expandability exceeds funds availability in the criterion value indicates the willingness of stakeholders of the airport to accept a higher initial outlay on the condition that the maintenance solutions concur with long-term expansion. Thirdly, the results reveal that alternative solutions aimed at improving adaptability for future activities in maintenance are prioritized despite requiring higher operational expenditures than the traditional approach to maintenance in the airport. Fourthly, risk is accepted in the maintenance operations as the focus is on expandability, which brings in higher tolerance for operational disruptions at the expansion stage. This makes prioritizing future over instantaneous customer convenience feasible. Next, the results reveal the need to balance decision-making as expandability takes more than 50% importance. This makes the final decision sensitive to expandability. Besides the discussion above, three additional strategic implications of the results of the study need to be noted. The obtained criterion value of 0.271 indicates the need for a long-term reliability aim. Moreover, the value of 0.112 for fund availability shows the preference for growth over cost for the system. Furthermore, customer trust, having a value of 0.063 as the criterion value, indicates a preference for infrastructure over experience.

In this work, no sensitivity analysis on the weights of the criteria was conducted. However, changing the weights, for instance, increasing the value of customer trust from 0.063 to 0.200, could influence the ranking of the alternative. Therefore, sensitivity analysis should be conducted to understand the behaviour of the criteria more deeply.

AUTHOR CONTRIBUTIONS

S.A.O. and O.T.S. were involved in planning and supervision of the work, O.S.O. collected and analyzed the field data and drafted the manuscript. S.A.O. aided in interpreting the results and worked on the manuscript. All authors discussed the results and commented on the manuscript.

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APPENDIX

Table A1. Summary of literature concerning AHP research

S/N	Authors	Work done	Findings	Theme	Gaps
1	Lai et al. (2015)	Use of AHP to incorporate the influence of input and output variables on data envelopment analysis as well as assurances region DEA(DEA_AR).	Judgment owing to the AHP method offers a novel understanding of airport efficiency.	Using AHP with some evaluation models to determine performance in the airport environment.	Development of alternative machinery of input and output variables to give a more comprehensive insight into certain aspects of airport management.
2	Goossens and Basten (2015)	Investigation of maintenance policy selection via AHP usage.	AHP is appropriate for maintenance strategy choice in novel settings.	Application of AHP for maintenance selection in the maritime sector.	The use of other MCDM methods with the analytic network process for maintenance policy selection.
3	Mahtani and Garg (2018)	Use of fuzzy AHP approach to identify and order vital issues of airline companies' financial distress in India.	Financial factors are largely essential and grouped as the chief inspiration for the commercial steadiness of airlines.	Using fuzzy AHP to ascertain factors affecting airline operation performance.	Application of fuzzy AHP and other MCDM methods to understand airlines' performance factors in different aviation sectors.
4	Durán (2011)	The use of fuzzy AHP approach for comparative evaluation of some computer-aided maintenance management systems (CMMS) alternatives.	The projected software substitutes the conservative AHP scheme and other fuzzy-oriented schemes in its ease of integrating biased parameters.	Use of fuzzy AHP to capture uncertainty and prioritize maintenance issues.	Maintenance program development factors have not been considered.
5	Karaman and Akman (2018)	Application of AHP in Turkish airline business to assess and weigh corporate social accountability (CSA) program attributes among multiple options.	CSA concept in the airline business is seen contained by the totality of systematic efforts bringing in societal and environmental magnitude instead of toward complex matters.	AHP as a tool for ranking CSA programs of airline companies.	Use of AHP for ranking of CSA programs of airline business with emphasis on customer one station and other stakeholders.
6	Carfora et al. (2016)	Investigation on the largely competent design of the maintenance part to substitute the diverse cassettes in an isolated usage viewpoint using AHP.	Application of AHP approach for enhanced and focused selection.	Application of AHP approach for selection of maintenance process.	The need to enhance comparative accurateness of construct options by tallying results from qualitative analysis.
7	Wang et al. (2007)	Evaluation of diverse maintenance policies for varied equipment using fuzzy AHP.	The revised fuzzy AHP method applies to maintenance strategies and other similar MCDM problems.	Analysis of maintenance strategies using fuzzy AHP.	Need to establish the maturity time to contemplate on fuzzy judgement opinion matrix as being incompatible and undesirable, and ought to be accustomed.

Table A1. Summary of literature concerning AHP research (continued)

S/N	Authors	Work done	Findings	Theme	Gaps
8	Arunraj and Maiti (2010)	Choice of maintenance rooted in equipment failure risk appraisal and maintenance cost employing AHP and goal programming.	Condition-oriented maintenance (COM) is a favorite strategy compared with time-oriented maintenance (TOM). COM exhibits superior risk decline potential than TOM. With cost, corrective maintenance (CM) is favored. Nonetheless, AHP and goal programming results with risk and cost as criteria, COM is the favored equipment and CM for depleted risk facilities.	Choice of maintenance strategy employing AHP and goal programming.	A study to consider the reduction of failure consequences, the effect of poor maintenance on equipment failure, and the ratio of breakdown that can be lessened by assuming appropriate maintenance.
9	Hadidi and Khater (2015)	Development and application of rank for turnaround maintenance contractors' selection.	Contractors are ranked based on predicted safety altitudes before the real grant of contract and also enhance safety altitude before the project execution.	Using the AHP model to rank contractors involved in turnaround maintenance.	There is a need to incorporate logistics and transportation in evaluation method during turnaround maintenance shutdowns.
10	Azadeh et al. (2017)	Development of an AHP tool to appraise resilience engineering in maintenance systems.	There is a close linkage between resilience engineering as well as human-related accomplishment issues, indicating the potential to reduce human error and improve safety.	Application of the AHP model to the analysis of human error and safety in maintenance organizations.	Link for maintenance program development is essential.
11	Bertolini and Bevilacqua (2006)	Uses of joint AHP-GP scheme to choose the superior maintenance strategies for centrifugal pumps of oil refilling plants.	Permits introduction of precise check-up plan for vital breakdowns to reduce catastrophic failures.	Vitalization of AHP and goal programming for selection strategies.	Association with maintenance program development is necessary.
12	Yu et al. (2018)	Risk appraisal for aground pipeline maintenance scheme subjected to uncertainty by AHP and expert knowledge.	Interval examination can successfully domesticate, signify, evaluate, and broadcast the uncertainty in the risk appraisal scheme.	Virtualizing AHP to evaluate risk in oil and gas pipeline maintenance schemes.	Linkage of risk to maintenance program development is necessary.
13	Dozic et al. (2018)	Use of fuzzy AHP to indicate aircraft kind(s) for market and airlines' requirement.	The improved logarithmic fuzzy preference programming scheme proposes regional turbo-prop aircraft ATR 72-600 as largely appropriate.	Aircraft type selection using fuzzy AHP approach.	Use of group decision-making to include variety in thoughts inclined to position in airline and through instructive setting.
14	Chou (2008)	Development of AHP based on the previous understanding of experts and establishing the significant weight of criteria.	The case-based reasoning model used was understood as being largely competent in considering the experience-oriented weight of criteria weighed against the circumstance that the attributes are considered similarly significant.	Analysis of paramount maintenance cost using the AHP approach.	Design and execution of a web-oriented scheme embedded with the put-forward case-oriented way of thinking to treat the similarity of computerization and recovery.

Table A1. Summary of literature concerning AHP research (continued)

S/N	Authors	Work done	Findings	Theme	Gaps
15	Sennaroglu and Celebi (2018)	Use of AHP joint PROMETHEE and VIKOR method to choose the largely suitable airport for military personnel.	AHP-PROMETHEE and VIKOR can be adopted for both location selection problems and multi-criteria decision problem.	AHP and alternative manifold-attribute zdecision schemes are used to resolve the choice problem.	Use of fuzzy MCDM method in linguistic terms to evaluate the significance of attributes and evaluate options compared with attributes.
16	Ozcan et al. (2017)	Use of goal programming and combined AHP-TOPSIS methodology to select maintenance strategies in hydroelectric power plants.	The application of the maintenance strategies resulted in a significant reduction in power plant downtimes.	Selection of maintenance strategies using manifold-attribute decision schemes.	Need to study the method and integrate it with the maintenance program.
17	Ierace and Cavalieri (2009)	Vitalization of AHP-oriented schemes to choose decision groups in the maintenance area.	Relationship between structural and infrastructural decision categories.	Choice of decision groups in maintenance setting via AHP approach.	The need to improve the AHP model to have an understanding of the main element that influences decision.
18	Zhou et al. (2013)	Use of breakdown-tally oriented maintenance influence appraisal scheme for preventive maintenance of a fleet of buses.	Higher spending yields, better maintenance effects.	Evaluating the body of maintenance strategies through several operating data.	Investigation of maintenance influence appraisal approach rooted in breakdown severity.
19	Gopalakrishnan et al. (2015)	Analysis of the current state of work on maintenance reveals the gap from present practice to strategic maintenance planning for increased productivity.	Active decision support is required for competent maintenance and attained using the application of crucial grouping to plan maintenance.	Maintenance activities planning in manufacturing industries.	Maintenance activity planning needs to incorporate multi-criteria decision-making for more effectiveness.
20	Sabaei et al. (2015)	Evaluation of manifold-attribute decision formulation approach for the management of maintenance.	The analysis helps decision makers to choose an approach for their decision formulation in the management of maintenance devoid of rate of uncertainty and problem complication.	Analysis of several manifold-attribute decision formulation approaches to augment maintenance strategies.	Evaluating decisions for maintenance management under outsourcing condition.
21	Amrina et al. (2019)	Use of fuzzy manifold-attribute approach to appraise sustainable maintenance for rubber production.	The model assists in understanding existing performance levels in sustainable maintenance and to augment their sustainable maintenance accomplishment.	Sustainable maintenance planning in industries using fuzzy MCDM approach.	Development of sustainable maintenance appraisal tools for rubber production.
22	Baidya and Ghosh (2015)	Selection of effective maintenance technology using predictive maintenance pointer value based on AHP.	The scheme tackles the features of maintenance procedure choice for competence oriented on a strategic need.	Using the AHP approach to enhance the productivity of companies by selecting an effective maintenance technique.	Expansion of the methodology to address the strategic intent of other organizations involved in maintenance selection.