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A Suggested Approach for Maintenance Performance Framework: An Aircraft Maintenance Organization as a case study

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Abstract

This study developed a Maintenance Performance Measurement (MPM) framework aligned with a company's vision and maintenance strategy across management levels. SMART analysis was utilized as it ensures that monitoring and evaluation activities are focused, and progress towards goals and objectives can be tracked and evaluated. Eight key Maintenance Performance Indicators (MPIs) were selected based on literature and criteria set by a committee of eight managers. These indicators included outsourcing costs, accident/incident rates, customer quality complaints, rework order percentage, returning customer rate, employee satisfaction, maintenance plan compliance, and new customer addition rate. The framework aids maintenance managers in assessing and aligning maintenance strategies with corporate objectives and vision.

Keywords: organizations, measurement, framework, Performance Indicator, SMART analysis.

1. Introduction

Although research in this field concentrated on the improvement and assessing the types of maintenance [1-10], the main difficulties challenging organizations are still of a great importance in designing an efficient and effective plan to improve the operational abilities constantly, reduce maintenance costs and to achieve competitiveness in the business referred to. Subsequently, formulating maintenance guidelines and strategies for asset maintenance is crucial to assessing their efficiency and effectiveness. The Maintenance Performance Measurement (MPM) system permits organizations to recognize the value created by maintenance, to reassess and modify their maintenance programs and techniques, to validate investment in new patterns and techniques, to change resource distributions, and to recognize the impact of maintenance on the stakeholders, as well as on health and safety, etc. [11].

Significant issues related to this field are what to measure and how to evaluate in feasible and financially savvy way [11].

Maintenance measurements have frequently been confused and are regularly erroneously utilized by organizations. Performance Measurements (PM) should not be utilized to indicate that workers are not taking care of their responsibilities. They should highlight chances for improvement [12]. Improper usage of measurement system frequently led to insufficient outcomes. This is due to the inability of the organization to dispose of metrics that do not reflect its needs and inappropriate measurement techniques [13].

Measurement provides management with variables that enable the company to compare its status with targeted or standard values .It also helps in selecting remedial and preventive actions. This is extremely difficult without having suitable information to build supporting decision-making models [14]. The aspects of PM incorporate relevance, interpretability, correctness, reliability, and validity [15]. An operational PM framework acts as an early-warning system.

The Jordanian Aircraft Maintenance Corporation is an approved maintenance organization (AMO) that focuses on aircraft maintenance, repair, and overhaul. It is approved by the Jordanian Civil Aviation Regulatory Authority (JCARC), the European Aviation Safety Agency (EASA), and the US Federal Aviation Administration (FAA).

The Jordanian Aircraft Maintenance Corporation has built a sound path record as a leading independent commercial aircraft maintenance corporation that serves a wide range of customers in the Middle East, Europe, South Asia, Africa and the Commonwealth of Independent States (CIS) countries, offering services that cover several aircraft models, for example: Airbus (A300-600, A310, A320 Family, A320-neo, A330, A340), Boeing (B737-Classic, B737-NG, B737 MAX, B787-8/-9, B777-200/ -300), and Embraer fleets (ERJ 170, ERJ 190) (JORAMCO, 2020)

MPIs and key performance indicators (KPIs) are used to judge the effectiveness and quality of the maintenance, to justify the investment in maintenance and to help in

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determining the future actions that should be taken to improve the process depending on historical data [16].

Most MPM existing models, methodologies, and frameworks are generic, and they do not consider the business specific environment of the company, where these tools should be applied. Therefore, the link between the corporate strategy and the used MPM and corresponding MPI was absent.

This research will focus on developing a MPM framework for aircraft Maintenance that links the corporate strategy to the MPM and corresponding MPIs, which will finally justify the investment in aircraft maintenance.

2. Literature Review

In this section, the review of literature will emphasize the importance of maintenance, MPM, and management (MPIs), and Maintenance Performance Measurement frameworks. Maintenance incorporates the engineering decisions and related actions that are needed for the optimization of specified equipment function[17]. Plant maintenance is part of the strategic business processes of the companies that forms an integral part of the business practices which adds value to the industry[18 and 19]. Maintenance also affects the morale and motivation of the employees, safety of the processes, operations costs, sustainable high product quality and time of delivery of products to the market [20].Plant maintenance is considered as an investment that adds value.

Due to the huge turnover of the operation and massive capital investment of the assets, maintenance is considered as one of the business policies of the company in this highly competitive business environment. Successful implementation of the maintenance activities contributes to the profitability of the company [20]. Horenbeek and Pintelon, [21] discussed the principles of the maintenance function to support the production process with satisfactory levels of availability, reliability, and safety. In their work, they indicated that there are five significant maintenance criteria, while others considered safety, management of workers and spare parts inventory objectives in literature. Most of the significant maintenance principles are referenced in literature although not each of them was utilized in maintenance management models.

The main maintenance goal is to improve equipment ability to perform within a range of performance levels that may contribute to capacity, cost, quality, safety, and responsiveness [20].

2.1. Maintenance Performance Measurement and Management

MPM received a huge attention by researchers and practitioners. Accordingly, different researchers have created frameworks that focus on non-financial metrics to accomplish competitive advantages, [22]. Performance is considered as a component of “ability and motivation”, the essential concept of performance, and exertion and opportunity [14],while Horenbeek and Pintelon [23]recognized performance measurement as the comparison of status to targeted or standard values.

Performance Indicators (PIs) are extensively grouped as leading or lagging indicators. The leading indicator is a performance driver, which acts as an early warning signal. For example, the prominent number of stops or down-time at the operational level indicates less availability of equipment, which, in turn prompts less capacity utilization at the top level. On the other hand, the leading indicator is one of the non-financial types that fairly and dependably predicts ahead of time the outcome of the process. Moreover, leading indicator functions as a performance driver to discover the status in correlation with the reference ones. Indicators, such as noise, vibration, thermograph, and particles in oil are very good examples of leading indicators [16].

Lagging indicators are the outcome metrics that form the basis for considering the deviations after the fulfillment of the activities. The cost of maintenance and time between breakdowns can be recognized as lagging indicators. These indicators help in understanding the current performance status and maintenance action required for the corporation such as maintenance overhaul or any replacements needed to meet the agreed goals. Assessment of rectification costs may lead to repair or replacement. For example, the lagging indicator maintenance cost per ton at operational level 3 can be used for monitoring maintenance cost and budget at tactical level 2 and controlling future delivery of investment in plant maintenance.

Leading indicators are used to monitor whether the tasks being performed will lead to the expected output while lagging indicators monitor the outputs that have been achieved and can be used at the strategic level [16].

Various researchers were working to create a balanced performance measurement framework, which can incorporate both financial and non-financial perspectives. Kaplan and Norton’s balanced scorecard cards is the most popular approach. It comprises four perspectives: financial, customers, innovation, and learning [24]. It investigates both sides of any business process which are tangible and intangible aspects. Maintenance effectiveness and quality are to be evaluated to justify the investment in maintenance [25] while measurement of maintenance performance is essential for continuous improvement. Different researchers have suggested different criteria for evaluating maintenance performance. For example: maintenance process and maintenance task [26].

2.2. Maintenance performance indicators (MPIs)

To assess the equipment maintenance activity accomplishment, an indicator estimating the maintenance performance can be chosen. The terms effectiveness and efficiency are used punctually in this context. Effectiveness refers to the extent to which customer requirements are met, while efficiency is a measure of how economically the firm’s resources are utilized [27].

Parida [27] considered MPIs as “the means to measure efficiency and effectiveness of maintenance and related performance.” While Liyanage and Kumar [29] recognized MPIs as “a measurement equipped with baselines and realistic targets to encourage prognostic, and diagnostics measures to justify related decision and resulting actions at suitable levels in the organization. MPIs could be utilized

for financial reports to evaluate the performance of employees, the health, safety and environmental (HSE) rating, customer satisfaction, overall equipment effectiveness (OEE), and many other applications. Moreover, MPIs need to be customized for different industries. The process of selecting the variables or factors to create different performance criteria, such as productivity, effectiveness, efficiency etc., are decisive step in developing process of a comprehensive performance measurement system in any organization [1].

2.3. MPM frameworks

Much research on the MPM models and frameworks was conducted in different fields. The MPM framework forms a crucial and integrated aspect of the PM system of the organization. The MPM framework should provide decision-makers with a solution for performance measurements by connecting them straightforwardly with the organizational hierarchy comprising of financial and non-financial indicators. However, there is little literature available that covers the development of a systematic approach to PM in maintenance [17].

Kumar, Soni and Agnihotri [17] explained that the framework backings the holistic process by illustrating boundaries and specifying dimensions. Kaplan and Norton [24] developed a balanced scorecard performance measurement framework that focused on financial aspects, customers, internal processes, learning and growth, which allowed them to make observations from both financial and non-financial perspectives. To fulfill shareholder's requirements, they developed a framework of performance prisms from five perspectives.

Sari et al. [30] provided a comprehensive list of MPIs and ratios. They identified 21 indices under the four categories of machine/facility maintenance efficiency, task efficiency, organizational efficiency, and profit/cost efficiency. The MPIs refer to different hierarchies but failed to identify the specific hierarchy. These MPIs do not have obvious connections to the long-term goals of the company.

Parida and Chattopadhyay [11] proposed a multi-criterion hierarchical MPM framework based on link-and-effect structure to accomplish the total maintenance effectiveness and efficiency. It took into consideration the overall objective of the organization and its business units.

Parida [27]generated MPM schemes for the strategic management of maintenance that incorporate the two important effects (internal and external). He introduced a multi-criteria hierarchical framework that arranges MPIs into numerous classifications, such as finance and maintenance tasks. However, the majority of the MPM frameworks, so far, focused on schematizing MPIs or gathering them, although there is a limit to quantitatively evaluating the maintenance performance.

3. Research Methodology

To accomplish this study, a six stage-approach and several techniques are applied. The process of creating a suggested MPM framework for aircraft maintenance organizations started with reviewing the company's vision and mission and the derived long-term goals, secondly, all the MPIs available in the literature were reviewed, then in order to understand the work process of the company, a two-week survey was conducted, after that SMART (Specific, Measurable, Achievable, Realistic, and Timely) analysis was applied to evaluate the quality of MPIs in the current MPM system available in company, and the MPIs were retrieved from literature.

The MPIs that met the criteria were selected to be in the suggested MPM framework and each selected MPI had an assigned target value, some of the target values were found in the literature (global targets) and others were agreed on by the committee. Finally, all the MPIs have been grouped into one framework that is directly linked to the company's vision and maintenance strategy that will support maintenance managers with the decision-making process. Followed steps of the methodology are:

1. Analysis of the status of the company (Reviewing JORAMCO vision, mission and goals and translating them into targets and goals at the operational level)
2. Reviewing all the MPIs in the literature
3. Analysis of JORAMCO present MPM system and evaluation of the currently used MPM system
4. Comparison of the quality of the performance metrics from both literature and the current company system by conducting the SMART approach
5. Formulation and selection of the MPIs that reflect JORAMCO strategy by distributing and analyzing a questionnaire.
6. Development of a suggested MPM framework that will support the decision-making process in the maintenance management of the company.

3.1. The Jordanian Aircraft Maintenance Corporation vision, mission, and goals.

JORAMCO Vision, mission and values can be summarized as shown in Table 1 below.

Table 1. Jordanian Aircraft Maintenance Corporation Vision, Mission, and Values

The Jordanian Aircraft Maintenance Corporation	
Vision	Global independence world-class MRO and technical aviation service partner of choice.
Mission	To supply our customers with safe, efficient, flexible, and quality services, we will invest in our people to develop a distinguished, passionate, dedicated and highly competent team.
Core values	Integrity, Excellence, Society and Environment, People, Customer.

3.2. MPIs in literature.

MPIs offered in former literatures vary from one researcher to another, but can be gathered into several categories. Parida [28] comprised seven criterions for system performance evaluation like cost, customer satisfaction, equipment, training, maintenance task, health and safety, and employee satisfaction. On the other hand, Rana and Koroitamana. [29] emphasized several perspectives on performance metrics. They suggested six kinds of performance procedures such as financial, customer satisfaction, employee satisfaction, public

responsibility, product and service quality, and operational measures. But Campbell and Jardine [31] split MPIs into key functional areas: productivity, organization, efficiency, cost and quality. Table 2 lists the MPIs of the groups surveyed in the existing literature. Since MRO organizations are providing maintenance services to aircraft operators and owners, overall equipment performance, reliability, and maintainability will be excluded from this study as they are monitored by the operator/ owner. However, this study is limited to the maintenance work efficiency indicators, maintenance cost, training, customer satisfaction, health and safety environment and employee satisfaction which are derived from company vision and directly linked to its long and short-term goals. MRO organizations do not follow many of the maintenance indicators related to equipment as these indicators are the responsibility of the aircraft owners or operators. MRO are concerned with measuring the performance of internal maintenance process and any other indicators that directly affect performance effectiveness and efficiency.

3.3. Analysis of the current Maintenance process in the Jordanian Aircraft Maintenance Corporation.

Process mapping is the most important step to understanding the existing flow of work process in the corporation. The maintenance process and existing work practices in aircraft MRO is to be followed. For this corporation, the process mapping was figured out by thoroughly studying the existing process and interviews with experienced people.

3.4. Maintenance Process in the Jordanian Aircraft Maintenance Corporation.

The aircraft maintenance process in the Jordanian Aircraft Maintenance Corporation was studied in detail to understand the production processes, their layouts, design, capacity and drawbacks. The bottlenecks were studied for any likely drawback of the maintenance process.

The commercial department is the first point of contact with assigned customers and potential customers and is the trigger for starting any project in the organization. The Planning and Engineering department is responsible for planning and issuing the related Work orders (WOs) which are called later Work Package (WP). The production department takes an active role in executing the daily cleaning and maintenance checks and issuing failure reports. The Quality and Safety department will make sure the maintenance process is following the authority procedures and applicable Aircraft Maintenance Publications (AMP) keeping utmost safety practices. Simultaneously, the process engineer and the quality engineer also share their responsibilities to maintain the system working state to achieve the desired maintenance level.

The maintenance activity consists of replacing, repairing, adjusting, inspecting, preventive maintenance such as lubrication, and modification. The maintenance planning is made to undertake the maintenance work promptly. Accordingly, the work orders are prepared by determining the required man power, material, tools, and external assistance. Then the scheduled maintenance plan is fully implemented, and the inspection/checks are carried out to ascertain the correctness of functional efficiency of the components or the sub-system. All these actions are attested in the operational/maintenance software system.

Table 2. Maintenance Performance Indicators in literature

Item	MPIs	Reference
Equipment performance	Overall equipment effectiveness, equipment-availability, and equipment efficiency	• [16]
Reliability and maintainability	Number of failures, failure time, breakdown frequency rate, breakdown durability rate, MTBF, MTTR, and number of instantaneous stops.	• [12]
Maintenance work efficiency	Work order coverage, Number of customer quality complaints, maintenance plan compliance, percentage of planned maintenance, participation rate in production PM, percentage of preventive maintenance, percentage of breakdown maintenance, maintenance work productivity, number of improved maintenance events, and autonomous maintenance support rate, percentage of WO assigned for rework.	• [32] • [21]
Maintenance cost	Cost of failure, Breakdown maintenance cost, total maintenance cost, maintenance cost per unit output, payment maintenance cost, outsourcing service ratio, maintenance cost per ERV, spare parts cost per ERV, and cost of spare parts inventory	• [11]
Education and training	Training cost per person, training cost per salary, percentage of employees with technical training, number of self-educated employees, and existing number of qualifications	• [30]
Health and safety environment	Number of accidents and incidents	• [13]
Customer satisfaction	Percentage of returned customers, percentage of positive responses.	
Employee satisfaction	Percentage of employee satisfaction	• [14] • [25]

3.5. Interviews with experienced people

To understand the existing maintenance process, 17 people were selected based on their positions and work assignments. All departments at the shop floor and managerial levels of the Jordanian Aircraft Maintenance Corporation were covered. Interviews were conducted to shed light on:

1. The types and classification of maintenance and analysis of maintenance tasks (process).
2. The maintenance working process, work order, job card, maintenance planning, inspection system, maintenance task reporting, and describe the failure system of maintenance process.
3. The implementation of maintenance tasks and how they are carried out,
4. Maintenance data analysis.
5. The possibility of maintenance scheduled time tasks modifications.
6. The documentation of each task is according to international civil aviation standards.

3.6. The Jordanian Aircraft Maintenance Corporation current MPM system

The scope of maintenance was moved from a just defined manufacturing or operational viewpoint to the corporate key point of view. Accordingly, the role of maintenance managers became essential and called on to integrate and coordinate the maintenance efforts to meet organizational strategic targets efficiently and effectively [31].

The Jordanian Aircraft Maintenance Corporation lacks an agreed-upon methodological approach to select or derive business-specific MPIs. Accordingly, maintenance managers are left to choose important MPI for their business circumstance.

The MPIs in the Jordanian Aircraft Maintenance Corporation were created individually by departments and there were no criteria for the selection. To make the idea very clear, the company's KPIs were classified according to their output into five branches: Maintenance cost, Maintenance work efficiency, Learning and Growth, HSE and customer satisfaction. Also, it was very clear that the company doesn't have an agreed-upon target value for each MPI so they can't find the gap between the actual status and the required status. In other words, no gap analysis is carried out on a periodic basis to find the deviation of the actual status from the planned (targets) status. The results of analysis of the key performance indicators of the Jordanian Aircraft Maintenance Corporation can be summarized through items that can be measured. These items are:

1. *Maintenance cost*: total maintenance cost, cost of modifications (service bulletins), cost of materials ratio, and cost of outsourcing maintenance.
2. *Maintenance work efficiency*: Work order coverage, percentage of work improvement for each project, and percentage of quality findings.
3. *Learning and Growth*: Percentage of achieved training courses.
4. *HSE*: Number of accidents / incidents
5. *Customer satisfaction*: Number of quality complaints

3.7. Current MPIs in the Jordanian Aircraft Maintenance Corporation

Current MPIs used by the Jordanian Aircraft Maintenance Corporation maintenance management team was evaluated by a committee composed of eight managers: commercial manager, maintenance manager, safety and quality manager, engineering and planning manager, financial manager, quality supervisor, safety supervisor and aircrafts project manager.

SMART analysis was conducted to evaluate the established MPIs that reflect the characteristics of the Jordanian Aircraft Maintenance Corporation. Therefore, a SMART incorporates all these criteria to help focus on efforts and increase the chances of achieving your goal.

Each criterion was given a score of 5 points. In the evaluation items, the Specific is how well defined, clear, and unambiguous the goal is. The second criteria aim to evaluate the Measurability of goals with consideration of the company progress towards the accomplishment of the goal. Realistic is an assessment of whether the goals are within reach, realistic, and relevant to company purpose. And Timely goal is how clearly defined timeline, including a starting date and a target date. The purpose is to create urgency.

The evaluation was carried out using Google forms for a safer and fast way to collect data. Google forms lets users collect information from people via personalized surveys and automatically record the answers. This makes Google Forms probably the most straightforward approaches to save data immediately into a spreadsheet. The evaluation was sent to the management level of the Jordanian Aircraft Maintenance Corporation to be filled online. Management levels include commercial manager, maintenance manager, safety and quality manager, engineering and planning manager, financial manager, quality supervisor, safety supervisor and aircrafts project manager. The research project and the MPIs were explained to evaluators in separate meetings. With reference to the result shown in Table 6 the evaluation committee has agreed to choose the MPIs that has the value of 20 or higher, as they see that these MPIs are the actual ones that represent the company performance from deferent criteria and this score can be changed based on scientific research to be conducted by the management department on a regular basis. A score of 20 or higher is also conducted to select the most appropriate MPIs currently used by the company. Table 3 demonstrates that there are 3 indicators (cost of outsourcing services, number of accidents and incidents and number of customer quality complaints) had the score of 20 (company vision) and higher which fulfill the criteria was assigned by committee and they will be used in the suggested MPM framework. Cost of outsourcing services indicator will be included to the maintenance cost division; number of accidents and incidents will be added to health and safety environment division and number of customer quality complaints will be classified as maintenance efficiency indicator.

3.8. Deficiencies of the status of the corporation

A significant concern in evaluating maintenance performance is the determination of MPIs that reveal a

company's strategy and give the maintenance management team a quantitative information about the actual results of the maintenance strategy compared to the planned ones [33].

As it is obvious from that most of the MPIs are not directly related to the company vision, are difficult to measure, ambiguous, and incapable to adapt rapidly and successfully to the new conditions.

Another shortcoming of the current structure is that it didn't consist of an early warning tool (leading indicators) to act as performance drivers that can guide the decision-makers about any out-of-track process.

Three MPIs have an average value above 20 in the evaluation results, Cost of outsourcing services, number of customer quality complaints and number of accidents and incidents which means that these indicators are representing the company long term goals that were derived from company vision.

The current MPIsdo not cover all the criteria that were recommended by most literature and were not aggregated as strong structure like scorecard or a framework. Most of the MPIs don't have an assigned target and timeline, so the company can't make gap analysis to figure out the shortcomings in the maintenance performance.

4. Results and Discussions

To improve the current MPM structure in the Jordanian Aircraft Maintenance Corporation; a new MPIs should be selected based on the methodological approach that is built on scientific research. The new MPIs need to be directly linked to the company vision and maintenance strategy, also these MPIs should have a world-class target value or an agreed-upon committee value that should be reached to achieve that goal. This can be done by: Evaluating the MPIs in the literature using SMART analysis technique by the same committee that evaluated the present MPIs of the Jordanian Aircraft Maintenance Corporation, then selecting the new MPIs that meet the criteria assigned by the committee, then a target will be assigned for each MPI, after that a suggested framework will be presented to the company.

4.1. Evaluation of literature MPIs

SMART analysis was conducted to evaluate the MPIs surveyed from literature (Table 3) to select the MPIs that reflect the characteristics of JORAMCO. The same criteria will be used and each of them has a score of 5 points.

Table 4shows the results of the evaluation of the 27 goals and their average evaluation score. (MPIs with a score of 20 and higher have been highlighted to be distinguished easily).

4.2. Selection of new core MPIs

Based on the average score and referring to Table 4, the highest score is 22.7 points, and the lowest one is 16 points. The purpose of this study is to determine the Jordanian Aircraft Maintenance Corporation suitable MPIs to construct a framework. Therefore, MPIs with score of 20 points or above (as stated by experts) were selected to be a part of the framework. As a result, five new MPIshave been selected and added to the current MPIs that havea score of 20 or above. The selected MPIs are shown in Table 5.

Table 3. Evaluation of the Jordanian Aircraft Maintenance Corporation Current MPIs

MPI	Evaluator 1	Evaluator 2	Evaluator 3	Evaluator 4	Evaluator 5	Evaluator 6	Evaluator 7	Evaluator 8	Average Score
1. Total maintenance cost.	17	17	17	19	15	19	21	15	17.5
2. Cost of modifications (service bulletins).	17	19	17	17	19	15	19	21	18
3. Cost of material ratio	19	21	19	19	21	17	21	19	19.5
4. Cost of outsourcing services.	25	23	21	23	19	23	21	25	22.5
5. Work order coverage.	17	17	15	19	19	19	17	23	18.25
6. Percentage of work improvement.	17	19	19	21	21	17	15	19	18.5
7. Percentage of quality findings	17	19	17	19	19	17	19	21	18.5
8. Percentage of achieved training courses.	17	19	19	19	17	19	17	19	18.25
9. Number of accidents and incidents.	23	23	25	23	25	23	25	23	23.75
10. Number of customer quality complaints.	23	25	21	19	25	23	21	21	22.25

Table 4. The evaluation of the eight evaluators

MPI	Evaluator 1	Evaluator 2	Evaluator 3	Evaluator 4	Evaluator 5	Evaluator 6	Evaluator 7	Evaluator 8	Average Score
1. Work order coverage.	17	19	17	19	15	21	19	17	18
2. Percentage of WO assigned for rework.	21	23	23	21	21	25	23	21	22.2
3. Cost of failure loss.	17	17	15	17	19	15	17	17	16.7
4. Training cost per person.	17	19	17	19	15	21	19	17	18
5. Number of self-educated employees	17	17	17	19	15	19	17	15	17
6. The percentage of new added customers.	25	23	23	21	19	25	23	21	22.5
7. Percentage of employee satisfaction	23	19	23	25	23	25	23	21	22.7
8. Autonomous maintenance support rate.	19	15	15	17	19	15	15	17	16.5
9. Number of improved maintenance events.	17	19	17	19	15	21	19	17	18
10. Maintenance work productivity.	19	15	17	21	15	19	15	15	17
11. Percentage of breakdown maintenance.	17	19	15	17	19	15	19	17	17.2
12. Percentage of preventive maintenance.	17	19	19	19	15	15	17	17	17.2
13. Participation rate in production PM.	17	15	15	19	15	15	17	15	16
14. Percentage of planned maintenance.	15	17	15	17	19	15	15	19	16.5
15. Maintenance plan compliance.	21	23	25	21	19	19	23	23	21.7
16. Cost of spare parts inventory.	19	19	15	19	15	15	17	21	17.5
17. Spare parts cost per ERV.	15	15	15	19	15	15	17	17	16
18. Maintenance cost per ERV.	17	19	15	17	19	15	17	15	16.7
19. Payment maintenance cost.	17	17	17	19	15	15	17	17	16.7
20. Maintenance cost per unit output.	15	19	17	19	15	19	17	15	17
21. Percentage of returned customers.	21	23	23	25	21	25	23	21	22.7
22. Total maintenance cost ratio.	17	17	15	17	19	15	15	17	16.5
23. Total maintenance cost.	19	15	17	19	15	15	19	17	17
24. Breakdown maintenance cost.	17	19	17	19	15	19	17	15	17.2
25. Percentage of employees with technical training.	15	15	15	17	19	15	17	17	16.2
26. Training cost per salary.	17	19	17	19	15	17	19	17	17.5
27. Number of qualifications acquired.	19	17	17	19	15	19	17	15	17.2

A total of eight core MPIs were selected by the top management committee that was assigned by the Jordanian Aircraft Maintenance Corporation Chief Executive Officer (CEO) to evaluate these MPIs. As its obvious from figure 2 below that 5 indicators were scoring above 20, one MPI was selected to indicate how the company is committed with the health and safety environment, three indicators were selected to measure the maintenance work efficiency, one indicator was selected to measure company maintenance cost, one indicator was selected to measure the employee satisfaction and two indicators were selected to measure the customer satisfaction, all the selected MPIs are explained below:

1. **Health and safety environment**: The number of accidents and incidents was selected to indicate the safety performance of the maintenance teams in the company. It is considered one of the lagging indicators, which may identify trends or clusters of incidents that can be tackled to prevent workplace deaths, injury and disease. Number of accidents and incidents information also provides feedback on the effectiveness of controls and structures of work, allowing continual improvements to be made.
2. **Maintenance cost:**The cost of outsourcing maintenance services is a lagging indicator and one of the issues that the company struggles to decrease it. Most of the maintenance services are done in-house by the company rather than outside, however there are stilloutsourced services.
3. **Maintenance work efficiency**: The percentage of rework tasks, maintenance plan compliance and number of quality complaints are selected to measure how the company's maintenance work efficiency. The percentage of rework tasks is an excellent indicator that represents the effectiveness and efficiency of the maintenance process. Maintenance plan compliance (also called plan attainment) is to measure maintenance team approach to successfully executing all the project planned maintenance in line with the agreed plan. The number of customer quality complaints is a measure of how happy the customer is with the provided services. When a customer makes a complaint, he or she is voicing a concern in relation to the company maintenance services. Their feedback can be used to improve the company provided service.
4. **Customer satisfaction**: High satisfaction means a customer is more likely to recommend your business and leave a positive review. The percentage of new

added customers is a measure of how much the company is attracting new customers. The percentage of satisfied customers is the percentage of customers who come back to ask for service. The percentage of these customers is incredibly valuable since customers, who come back to ask for service again and again, are more likely to refer the company services to friends.

5. **Employee satisfaction**: Employee satisfaction is the term used to describe whether the company employees at different levels are happy and fulfilling their desires and needs at work. The percentage of satisfied employees is the only indicator which was selected by the committee to represent this category.

4.3. Suggested or Developed MPM Framework

MPIs are managed separately because each indicator has different features. This research provides a way to develop a framework that quantitatively evaluates the present level of each department with the purpose of optimizing the performance of future maintenance processes.

In this work, the suggested framework that can comprehensively and quantitatively measure the maintenance performance of aircraft MRO was developed by applying the maintenance excellence index utilized by Peters [34] and the European plan for aviation safety (EPAS 2022-2026, 2021) [35]. This approach measures the current performance level via setting the target level in the main MPIs and allocating scores to each level.

TheJordanian Aircraft Maintenance Corporation suggested MPM framework presented, in Table 9, which reflects eight essential MPIs: Maintenance plan compliance, percentage of returned customers, Outsourcing maintenance costs, Rework tasks, Number of incidents and accidents, Number of complaints, Percentage of new add customers and Employees satisfaction.

The evaluation scores of the level of MPIs reflect the global level or the cases investigated in the benchmarking of the company. The recommended scores were assigned by experts in the company. The highest score(the target level) was assigned 10 points, and the lowest level was assigned 4 points. In addition, the MPIs were weighted to reveal their importance. The weights can be according to the priority or importance of the MPI. In our case study, the assigned committee decided to give the same weight to all selected essentialMPIs to facilitate calculations, but other MROs might have different weights for differentMPIs. MPMs are conducted once per month or per year to measure the level of each department's progress based on the overall score. As there are differences between different industries and businesses, the evaluation level, scores, and weights can be modified and applied after an independent review by the company.

As shown in Table 6 the performance level of each MPI can be measured usingequation (1), based on the value of the results and according to the suggested framework there will be a score for the result as shown in the Performance level score column, this score will be multiplied by the weight value of that specific indicator, each indicator will be calculated with the same method, finally there will be 8 score values.

The overall score value will be the summation of all the 8 score values, the result of this summation will be the performance value and it will be compared according to Table 10 to see the classification of this overall score. Managers will take a decision based on the final result which will provide them with the area that needs their concentration and direction.

$$\text{Performance score} = \sum \text{Performance level score} * \text{weight} \quad (1)$$

Each indicator in Table 9 has an assigned leading or lagging indicator, this is a very critical aspect of the indicator which represent when this indicator measurement will be due for evaluation, also this aspect provides the decision makers with predictive information about maintenance process before it goes more effective.

Table 5. The selected core Goals

MPI	Source	Evaluator 1	Evaluator 2	Evaluator 3	Evaluator 4	Evaluator 5	Evaluator 6	Evaluator 7	Evaluator 8	Average Score
Cost of outsourcing services.	Old system	25	23	21	23	19	23	21	25	22.5
Number of accidents and incidents.	Old system	23	23	25	23	25	23	25	23	23.75
Number of customer quality complaints.	Old system	23	25	21	19	25	23	21	21	22.25
percentage of WO assigned for rework.	literature	21	23	23	21	21	25	23	21	22.2
percentage of returned customers	literature	25	23	23	21	19	25	23	21	22.5
Percentage of employee satisfaction	literature	23	19	23	25	23	25	23	21	22.7
maintenance plan compliance.	literature	21	23	23	25	21	25	23	21	22.7
Percentage of new added customers.	literature	25	23	23	21	19	25	23	21	22.5

Table 6. Suggested MPM framework for the Jordanian Aircraft Maintenance Corporation

MPIS	Maintenance plan compliance	Percentage of new added customers	Outsourcing maintenance costs	Rework tasks	percentage of returned customers	Number of incidents and accidents.	Number of complaints	Employees satisfaction.	Performance level score
MPI target	100%	10%	0%	0%	100%	0	0	95%	10
Performance level	95%	9%	1%	1%	95%	1	1	90%	9
	90%	8%	2%	2%	90%	2	2	85%	8
	85%	7%	3%	3%	85%	3	3	80%	7
	80%	6%	4%	4%	80%	4	4	75%	6
	75%	5%	5%	5%	75%	5	5	70%	5
	70%	4%	6%	6%	70%	6	6	65%	4
Weight	1	1	1	1	1	1	1	1	
Leading / Lagging	Leading	Leading	Lagging	Leading	Leading	Lagging	Lagging	Lagging	

Four leading indicators were presented in the suggested MPM framework to be performance drivers and four lagging indicators were included for measuring the outcome of maintenance process and can determine the actions required to meet the arranged goals.

4.4. Suggested evaluation criteria

MPM framework (Table 6) for the Jordanian Aircraft Maintenance Corporation is developed to measure the performance of maintenance in a comprehensive and quantitative manner using the selected eight key MPIs. Steps ofthe evaluation method of the eight key MPIs are:

Maintenance plan compliance. The maintenance plan compliance is a leading indicator that calculates the percentage of completed maintenance tasks to the total number of the tasks for each project (equation 2) and used to compare it with the target value that was assigned by the committee.

$$\text{Maintenance Plan Compliance} = \frac{Number\ Completed\ Tasks}{Total\ Number\ of\ Tasks} \times 100\ \% \quad (2)$$

Maintenance plan compliance should be assigned a targeted value by the company top management. For this study, it was decided to be 100 percent at the end of the project.

The percentage of newly added customers is a leading indicator defined as the number of new customers has been added to the customer database. This indicator needs to be evaluated every month to evaluate the performance of the related departments for effectiveness. The number of new added customers is a measure of the Jordanian Aircraft Maintenance Corporation customer growth. The percentage of new added customer is calculated using equation3:

$$\text{Percentage of new added customers} = \frac{Number\ of\ new\ customers}{Total\ customer\ numbers} \times 100\ \% \quad (3)$$

The percentage of newly added customers does not represent a global level in this paper or in the literature, so its target goals must be assigned by the committee. The percentage of new added customers is targeted at 10 percent every year.

This indicator is a broad measurement of the overall customer experience and customer satisfaction. Customers who find the company services useful, helpful, and/or enjoyable will likely return again and again to make additional purchases. The Percent of Returning Customers measures the value of customer loyalty. The Percentage of newly added customers is calculated by equation 4:

$$\text{Percentage of returned customers} = \frac{(\#)\ \text{Returning Customers}}{(\#)\ \text{Total Customers}} \times 100\ \% \quad (4)$$

The percentage of returned customers does not represent a global level in this work or in the literature, and their own goals must be set. The percentage of returned customers is targeted at 100 % every year.

This lagging indicator refers to percentage of cost that is incurred due to the employment outsourcing maintenance, the Jordanian Aircraft Maintenance Corporation is striving to decrease this cost as much as possible to reach zero value for each project. This indicator should be evaluated for each project. The formula that refers to this indicator is:

$$\text{Percentage of outsourcing costs} = \frac{Cost\ of\ outsourcing\ maintenanc}{Total\ project\ cost} \times 100\ \% \quad (5)$$

The Percentage of rework tasks is a lagging indicator that evaluates the level of maintenance effectiveness by comparing the number of tasks that need to be reworker to the total tasks for that project (equation 6). This indicator is an excellent indicator represent the maintenance effectively and can be measured by the formula:

$$\text{Percentage of rework tasks} = \frac{Number\ of\ reworked\ tasks}{Total\ number\ of\ project\ tasks} \times 100\ \% \quad (6)$$

The target value was assigned for the Percentage of rework tasks by the Jordanian Aircraft Maintenance Corporation CO management level is zero for each project.

The Number of incidents and accidents is a lagging indicator defined as the sum of the incidents and accidents that were faced during maintenance process. This indicator is considered very critical one as it measures how the JORAMCO is following the safety precautions produced by authorities.

The number of incidents and accidents has a global level in literature and its agreed with the JORAMCO to be targeted zero value every year. The number of incidents and accidents can be measured by the number of registered incidents or accident for each year.

Thenumber of complaints is a lagging indicator to represent the customer satisfaction with maintenance services provided by the Jordanian Aircraft Maintenance Corporation. This indicator should be evaluated every year, and it measures the performance level of the related departments. A high number of complaints means there are deficiencies in the maintenance quality which should be monitored and controlled. The number of complaints can be measured by counting the newly registered complaints by customers, stakeholders, and shareholders. This indicator has a global target level in papers and literature and its zero value for every year.

The percentage of satisfied employees is a lagging indicator to evaluate how well the employees are satisfied with the Jordanian Aircraft Maintenance Corporation environment.

Many actions show that employee satisfaction is a major factor for employee motivation, employee high commitment, and positive employee morale. The suggested the Jordanian Aircraft Maintenance Corporation evaluation formula for this indicator is equation 7:

$$\text{Percentage of satisfied employees} = \frac{Number\ of\ satisfied\ employee}{Total\ number\ of\ employee} \times 100\ \% \quad (7)$$

Percentage of satisfied employees has no global target level; hence, the Jordanian Aircraft Maintenance Corporation management level has assigned a target for this indicator to be 95%.

To make it very clear the following example will explain how this calculation can be conducted, all the numbers used in this example are just for clarification they are not real numbers. Equation 1 is used to calculate the maintenance plan compliance and it was assumed to be 85%, by comparing it to the suggested framework it will have the score of 7 and its weight is 1 so the performance score will be 7 for this indicator. Now it was assumed for the other 7 indicators the following values: percentage of new added customers 9, outsourcing maintenance cost to be 9, rework tasks to be 10, percentage of returned customers to be 9, number of incidents and accidents to be 9, number of complaints to be 10 and employee satisfaction to be 9. Table 7 below summaries all the data required for the example.

4.5. Classification and utilization of the MPI

The purpose of the MPM is to accurately assess the current level of the company and to ensure that all employees strive to achieve goals. The MPI of the Jordanian Aircraft Maintenance Corporation, which is a framework for assessing maintenance performance, is a tool that can measure overall performance of maintenance. The introduction of appropriate valuation methods is necessary to improve the practical level of maintenance with these tools. The MPI, presented in Table 8, is evaluated by the overall score of the eight MPIs. Depending on the evaluation scores, the level of each department and its team is determined, and its weak points can be identified. To improve the Jordanian Aircraft Maintenance Corporation maintenance efficiency and achieve positive results by using the MPIs, it is required to categorize the scores of the MPI and to build opportunities for each team or all teams to challenge the highest rating.

In this framework, MPI marks are split into five grades based on the percentage they indicate. J, O, R, A and M. J grade is classified as excellent, an O grade is rated as good, a R grade is rated as average, an A grade is rated as below average, and an M grade is rated as poor. Table 8 shows the MPI grade by percentage and MPI score.

Table 7. summary of example

MPI	Performance level	Performance level score P	Weight W	Performance score = P*W
maintenance plan compliance	85%	7	1	7
percentage of new added customers	9%	9	1	9
Outsourcing maintenance costs	1%	9	1	9
Rework tasks	0%	10	1	10
percentage of returned customers	95%	9	1	9
Number of incidents and accidents.	1	9	1	9
Number of complaints	0	10	1	10
Employees satisfaction.	90%	9	1	9
$Performance\ score = \sum Performance\ level\ score * weight$				**72**

Table 8. Maintenance Performance Indicators grades and scores

Grade	Classification	Performance level	MPI score
J	Excellent	100–90	75–80 points
O	Good	89–80	70–74 points
R	Average	79–70	65–69 points
A	Below Average	69–60	60–64 points
M	Poor	59–50	59 oints or less

If the maintenance performance score was calculated for each department and each team, we will be able to develop maintenance activities one level higher than the present level (Table 6). Thus, we can gain the maximum benefit from the MPI framework. Moreover, based on Table 8, the score 72 of MPI means that the performance is (O) Good and the decision makers can find out that the maintenance plan compliance indicator is the one which lower the overall performance of the company and to improve company performance, a necessary improvement needed to take place by the responsible department of that indicator.

5. Conclusion

1. It was proved that a performance measurement framework for aircraft MRO based on its vision and maintenance strategy can be built.
2. It was found that the MPIs used by the Jordanian Aircraft Maintenance Corporation company are mostly used as indicators of normal business characteristicsand not linked to the company strategy, and they didn't have a predefined target.
3. SMART (Smart, Measurable, Attainable, Realistic, and time-bound) analysis approach proved to be suitable for the selection of the appropriate MPIs JORAMCO performance measurement system.
4. Five new indicators have been added to the Jordanian Aircraft Maintenance Corporation current system from literature and three were from the current system met the assigned criteria. The eight indicators were: Cost of outsourcing services, Number of accidents and incidents, Number of customer quality complaints, percentage of WO assigned for rework, percentage of returned customers, Percentage of employee satisfaction, maintenance plan compliance and Percentage of new added customers.
5. One of the major results that were achieved by this approach is that it has eliminated 7 of the old MPIs used by the old system as they were not connected directly to the company vision and maintenance strategy. These MPIs were selected based on individual choice of department managers.
6. MPM framework, which was developed, could comprehensively evaluate, and quantify each maintenance performance by using the MPI.
7. This MPM framework can be applied to each department and related team of the Jordanian Aircraft Maintenance Corporation.

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