Methodology for aviation MRO system management decision-making

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Abstract. The article considers the main methods for increasing the efficiency of aviation maintenance and repair (MRO) processes organization. A brief overview of these methodologies is presented and their key principles are highlighted. Based on the analysis of existing methodologies, a management decision-making technique based on the Stage-Gate project management technology and simulation modeling methods was proposed. This technique makes it possible to ensure the information availability for the after-sales services organization from other processes in a single information environment and make decisions on the transition to the next gate based on simulation models of aircraft maintenance at various gates. Keywords: maintenance, repair and overhaul (MRO); Stage-Gate; Discrete-Event Simulation; Product Life-Cycle.

1 Introduction

To ensure the aircraft's competitiveness in the market, it is necessary to ensure the quality of products and services at all product's life-cycle stages, which are shown in Fig. 1.

One of the most important stages in the aircraft's life cycle is the stage of operation. Ensuring the quality of aircraft's after-sales services is directly related to the quality of products and the company's ability to meet delivery schedules.

In the event of poor quality or untimely maintenance and repair (MRO) work, aviation products can periodically fail or operate with low productivity, which leads to defects and malfunctions. Most often, the occurrence of aircraft's failures leads to an imbalance in production processes. In this regard, the decrease in the production process efficiency leads to the defective products manufacturing, which reduces the company profitability and increases customer dissatisfaction.

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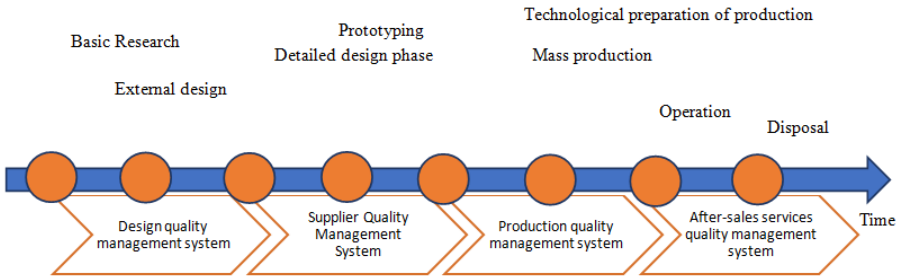

Fig. 1. The life cycle of high-tech products and quality management at all stages.

In order to effectively organize the aircraft's maintenance processes and reduce the maintenance time and costs, it is necessary to ensure the interaction and communication of departments in a single digital network and reduce the time for making the necessary management decisions at all aircraft's life-cycle stages [1].

This paper presents a brief overview of the existing methodologies for improving the quality of the after-sales services organization, and also proposes a methodology for making managerial decisions based on the Stage-Gate program management model and simulation methods, which will allow synchronizing all processes and effectively control the organization of the after-sales services system in a single information network [2].

Thus, the novelty of this paper's research is that nowadays there is no articles, in which the idea of the integration of Stage-Gate project management technology and simulation methods for organizing aircraft maintenance processes was discussed [3].

2 Model and method

In order to reduce maintenance costs and time and increase the aircraft's availability, various approaches are used to improve the efficiency of aircraft's after-sales services.

These methods could be classified into 2 main categories, shown in Fig. 2:

• engineering methods, which include the lean maintenance and reliability-centered maintenance methodologies,

• managerial – decision-making on the after-sales services system organization in the Stage-Gate methodology, as well as decision-making based on the discrete-event simulation results.

This section provides a brief overview of these methodologies and defines their basic principles.

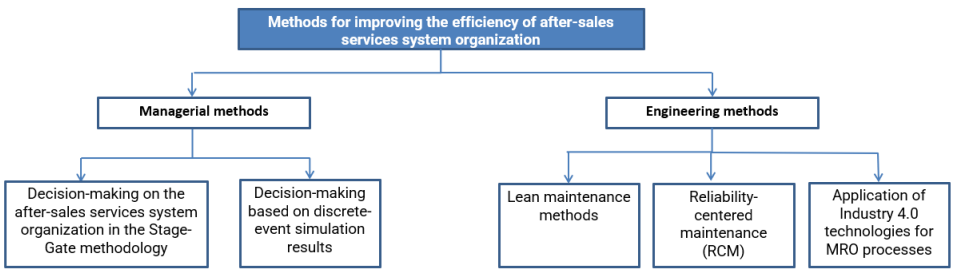

Fig. 2. Classification of methods for improving the efficiency of after-sales services system organization.

2.1 Lean maintenance methodology

The term "Lean maintenance" was appeared in the last decade of the 20th century and involves the implementation of lean manufacturing principles in maintenance and repair operations (MRO).

Many authors have thought about the concept of Lean maintenance and considered it from different points of view. Howard S. Cooper said the key goal of Lean Maintenance is to give your company nearly 100% uptime and equipment reliability as required, while reducing maintenance costs by more than 50%.

According to R. Smith, lean maintenance is a preventive maintenance activity that includes planned maintenance activities using total productive maintenance methods (TPM).

It is based on a combination of approaches, methods and tools of lean production and maintenance [3].

In another publication, lean maintenance is considered an evolution or update of the TPM philosophy. It is an approach based on continuous improvement through the implementation of waste management solutions, creating value for customers and stakeholders, and increasing the overall rate of return [4].

Thus, the concept of lean maintenance can be understood as a system that includes all the principles of maintenance and existing methods of lean production and is aimed at eliminating various wastes identified in the maintenance processes.

2.2 Reliability-Centered maintenance methodology (RCM)

The Reliability-Centered Maintenance methodology is based on a system improvement approach that provides cost-effectiveness in identifying and developing operation and maintenance strategies. This is done in order to manage the risks of system failures in a cost-effective manner and is particularly applicable in situations where financial resources are limited [5].

The RCM methodology is fundamentally different from other maintenance strategies in that it keeps the functionality of the system at the desired level. In summary, reliability-centered maintenance is a systematic approach to defining a planned maintenance program that consists of cost-effective tasks while maintaining critical company's functions.

An important aspect of this methodology is the prioritization of systems by assigning severity levels based on the failures effects. This aspect, in particular, is consistent with the fundamental goal of ensuring cost-effectiveness with the efficiency of directing resources to high-priority tasks. This is achieved by identifying necessary design and operational modifications and maintenance strategies according to priority levels.

The Reliability-Centered Maintenance methodology consists of seven main steps:

• Selection of systems and collection of information;

At this stage, it is necessary to determine whether the system's level is sufficient for this analysis, as well as to select the systems and the order of their analysis. Once systems are selected, information related to those systems is collected. The most preferred way is to collect key information and documentation from the start of the process.

• Determining the boundaries of the system;

Detailed and accurate definition of boundaries is of great importance in the analysis. The main reasons for this are knowing exactly what is included (and vice versa, not included) in the system, to ensure that none of the key system functions or equipment is ignored, and when defining boundaries, it is necessary to define system interfaces and interactions that establish system inputs and outputs [6].

• Description of the system and construction of a functional block diagram;

The logical step after choosing a system and defining boundaries is to further analyze and

document the necessary details of the analyzed systems. This step usually involves building a form to document the baseline of the system, which will eventually be used to set goals for project management.

• Definition of system functions and failures;

This step defines the features that should be saved by the system. It is important to note that these statements are intended to define system functions, not hardware. In addition to determining the functions of the system, at this stage it is also necessary to identify functional or system failures [7].

• Failure modes and effects analysis (FMEA);

Failure Modes and Effects Analysis (FMEA) is a fundamental tool used in reliability engineering. It is a method of systematic failure analysis that is used to determine failure modes, their causes, and therefore their consequences for system operation.

• Logical decision tree analysis (LTA);

The purpose of this step is to further prioritize the resources to be allocated for each failure mode. This step must be carried out because each failure mode and its effect on the entire system is not the same. Any logical scheme can be adopted for resource ranking.

• Task selection.

At this stage, we must allocate tasks and resources for project management, and this is where we can get the maximum economic benefits from RCM activities. Task selection requires that each task be applicable and effective. Here, "applicable" means that the task must be capable of preventing and detecting failures, while efficiency is related to the cost effectiveness of alternative project management strategies.

Thus, by applying the RCM methodology, organizations will achieve greater safety and environmental integrity, as well as improved operational performance. RCM also delivers greater maintenance cost efficiencies as it puts more emphasis on maintenance activities that increase company's productivity. In addition, through the implementation of RCM, a longer service life of expensive products and an extensive database will be achieved [8].

2.3 Decision making for the after-sales services system organization in the Stage-Gate methodology

The main idea of the Stage-Gate program management methodology is to effectively manage corporate projects for the development of new products through all stages of project development: from its idea (concept) to commercial launch and profit [9].

The Stage-Gate methodology breaks down the entire new product development process into a series of stages, each of which consists of prescribed cross-functional and parallel workflows. These stages of product development are shown in Figure 3.

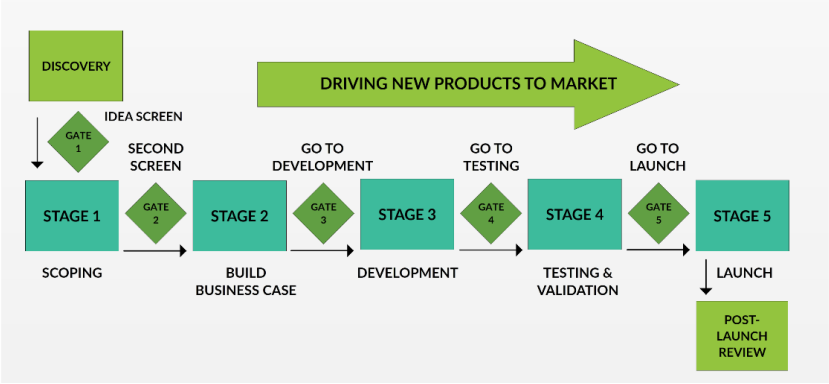

Fig. 3. Stage-Gate project management model.

It is important to note that the stages in this model are “cross-functional” (for example, there is no marketing or research and development stage). At the same time, each phase consists of a set of parallel actions carried out by personnel from different company’s departments, working together as a team and having their own leader [10-12].

Before each stage, there are “gates”, which serve to control the projects’ quality, determine its priority, decide on the continuation / termination of the project and allocate appropriate resources.

All "gates" have a common format: inputs (the result of the activity in the previous stage, which the project team presents to the meeting); criteria (issues or quantitative measures by which the project is evaluated in order to make decisions on its continuation / termination and priority); outputs (the result of the meeting - the decision made: action plan, date of the next meeting and necessary input information) [13-14].

Thus, the Stage-Gate project management methodology allows you to control the results of the program by setting clear criteria for moving to a new stage.

2.4 Application of simulation methods to analyze the effectiveness of the maintenance and repair system for aviation equipment

To analyze the aircraft’s maintenance process organization efficiency, simulation methods can be used to predict the behavior of complex systems and assess the possibility of achieving the specified performance indicators. In particular, this paper will consider discrete event modeling, which is one of the simulation types [15].

Discrete Event Simulation (DES) is the simulation of a system as it evolves over time, where state variables change instantaneously at discrete points in time.

DES has traditionally been used in industry. There has been a rapid development of manufacturing technologies as well as DES technologies. Several companies have invested heavily in new technologies to make manufacturing operations flexible [16].

Thus, DES software is a tool that allows managers to make the right decisions. The goal of every production manager is to improve productivity by reducing lead times, reducing WIP and high resource utilization. With the help of simulation techniques, they can evaluate the behavior of production processes under various given conditions. In addition, they can test different "what if" scenarios to determine the best physical configurations and operational policies.

The advantage of discrete event simulation lies in its ability to mimic the dynamics of a real system. Many models, such as high-performance optimization models, cannot account for real system dynamics. The ability to mimic the dynamics of a real system gives DES its structure, functions and a unique way of analyzing results [17].

In maintenance and logistics systems, there is a well-defined process that can be captured using a Discrete Event Modeling (DES) model. Vehicles and parts are modeled as simulation objects that have characteristics such as a descriptive name, running time, and a flag indicating whether the part is broken or not. The steps in the maintenance process, such as evaluating broken parts and replacing them, are modeled as functions that change the characteristics of the modeling objects. The amount of detail included in the simulation can vary, such as simulating the time it takes to land and taxi each aircraft, or finer details considering individual passengers and cargo within the aircraft. This accuracy depends on the problem and the amount of available resources.

3 Research and results

Based on the analysis of existing methods for improving the after-sales services system efficiency, the methodology was proposed by the authors for making management decisions

based on the Stage-Gate program management model and simulation methods , which will allow synchronizing all processes and quickly monitoring the organization of after-sales services system in an unified information network.

The basis of the proposed methodology is the formalization of the actions sequence that allow making decisions about the readiness to move to the next stage, depending on the status of maintenance work performed at various gates:

1. Building a structural aircraft's maintenance model at gate N;
2. Formation of an initial data list for the maintenance model in the Stage-Gate methodology on gate N;
3. Collection of initial data for maintenance process simulation at gate N;
4. Carrying out the maintenance process simulation at gate N;
5. Analysis of simulation results and decision-making on the start of work at gate N;
6. Performing maintenance and after-sales services tasks at gate N;
7. Making decisions on moving to the next gate (N+1) / finalizing the project at gate N.

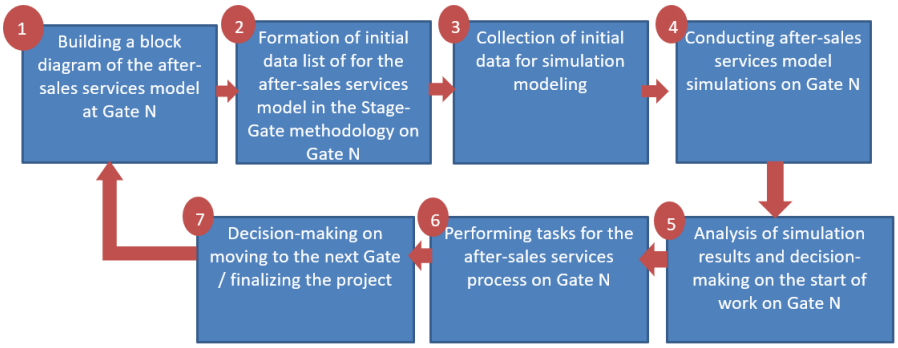

Fig. 4. Methodology for making managerial decisions based on the Stage-Gate methodology and simulation methods.

This technique will allow aviation program managers to monitor the organization of the after-sales services process in real time, which will significantly reduce the time for making management decisions.

4 Conclusion

The issue of improving the quality of aircraft's maintenance process organization was considered. The significance of this topic is due to the fact that at present, in order to ensure the aircraft's competitiveness, it is necessary to offer integrated solutions to the customer that allow the aircraft's operation with minimal downtime on the ground and maximum aircraft readiness for flight. In this case, it is extremely important to ensure the effective after-sales service system organization and apply modern methods and approaches to improve the aircraft's maintenance and repair processes.

The paper presented a brief overview of techniques such as lean maintenance and reliability-centered maintenance, and also identified the basic principles of these approaches. As a result of the literature analysis on these topics, it was found that the use of lean maintenance makes it possible to reduce wastes and optimize aircraft maintenance and repair processes, which directly affects the increase in aircraft availability for the customer. The implementation of a reliability-centered maintenance methodology helps to increase the service life of the product and reduce its maintenance cost.

Based on the analysis of existing methods for improving the after-sales services system efficiency, a method for making managerial decisions based on Stage-Gate project management technology and simulation of the aircraft maintenance process at various gates was proposed. Using this methodology, program managers will be able to evaluate the effectiveness of the current after-sales services system organization, identify bottlenecks and make decisions on the necessary changes.

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