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RESEARCH TO IMPROVE PREVENTIVE MAINTENANCE OF TECHNICAL EQUIPMENT

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ABSTRACT

In order to achieve the strategic level of military equipment exploitation, according to NATO requirements, it is necessary to continuously adapt the specific maintenance activities. The main objectives pursued in the maintenance system modernization process are: to implement reliability-based maintenance, to use management methods, to present the functional scheme, and to identify the critical points in which to intervene with maintenance operations. The use of the Pareto method in the direction research studied in the paper estimates that the first two faults among those identified, namely the imbalance of the braking force on the axle and the defective service brake, represent a significant percentage of the total downtime of the Roman-DAC trucks used for the present study. According to the AMDEC data sheet, these two defects have a criticality index of 70 and 60, respectively, compared to the following identified defects, which present a criticality index of 18 and 20, respectively. In practice, the aim will be to eliminate, in particular, the identified causes that entail defects in the first and second categories. Using this research methodology, and by extrapolation to all technical equipment components, it is possible to identify solutions to improve preventive maintenance by ranking defects and performing maintenance operations on those components more often subject to damage, before they fail.

KEYWORDS: maintenance, sustenance, criticality, reliability, FMECA sheet, the Pareto method

1. Introduction

Each physical asset, such as vehicles, performs certain specific functions, and component failures are inevitable. Thus, the maintenance and repair of these assets is obvious. Maintenance is generally recognized as the largest controllable cost factor in any production facility and represents a challenge that causes management to reevaluate their maintenance strategies.

Maintenance can be defined as the practice of maintaining the equipment, machine system or object in its original state as far as possible. It is a means of achieving optimal value for equipment to perform its desired and designed functions. Thus, maintenance protects a machine so that it does not break down or wear out quickly (Turcu, 2017).

Equipment must be protected from the following negative influencing factors: wear (grease and oil are used to protect machines from wear); dirt (filters are used to stop dirt before entering inside and damaging parts); heat (cooling and lubrication systems protect machine from heat).

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Preventive maintenance consists of a set of activities meant to improve the overall reliability and availability of a system. All types of systems, from conveyors to automobiles and agricultural machinery, have provided manufacturer-expressed maintenance programs that try to reduce the risk of system failure and to lower the total cost of the system maintenance (Eti, Ogaji & Probert, 2006).

In general, preventive maintenance activities include inspection, cleaning, lubrication, adjustment, alignment and/or replacement of subsystems and secondary components that are broken by minimizing the overall rate of system failures.

The introduction of the system control plays a prominent role. In the past, various equipment-related processes were controlled by human operators, but now an automatic control system is used. At the managerial level, human operators still observe the process to detect process failures, unusual events, and/or sensor failures that can disrupt and cause serious damage to the entire process.

2. Practical Ways to Improve Maintenance Activities

2.1. The Current Context regarding the Importance of Maintenance of Military Technical Equipment

The maintenance of military technical equipment is a priority in theaters of operations and in training activities, and technical interventions carried out in a timely and qualitative manner provide the military with comfortable conditions for the performance of missions.

NATO's credibility requires the development of command and execution structures of the armed forces, a process in which all human, material and financial resources are transformed into operational capability and are at the heart of building and maintaining forces capable of serving the alliance's military interests.

In order to achieve the strategic level of military equipment exploitation required by the interoperability regulations of NATO, the maintenance centers are obliged to adapt their way of work, in accordance with the new Regulation on equipment life cycle management, which will improve the operation of the equipment throughout the life cycle, at the nominal parameters, with minimum downtime and costs related to repairs and maintenance.

In this sense, the adoption of one or some combined variants of maintenance strategies is a decisive option for each member state of the alliance in the management of all the resources involved in the process, but which must satisfy at least the compatibility level of the interoperability of the forces.

Specialized studies as well as technical-economic analysis of the management of technical equipment maintenance activities describe a series of maintenance strategies, which can be adopted by companies depending on the specific profile and resources (the strategy of the company's investment orientation, the strategy of restricting maintenance activities maintenance, the strategy of concentrating or diversifying the maintenance activity, the strategy of new machines, etc.). Among these, there is also the maintenance strategy based on reliability which is currently also regulated in the Romanian military system through various specific documents.

2.2. Reliability – Based Maintenance Analysis

The aim of this strategy is to recognize the critical working points of the equipment and components of vehicles in the first stage, so that through the efficient organization of human, material and technical resources it can be decided when a technical intervention is carried out (Eti, Ogaji & Probert, 2006).

The timing of the intervention will be determined based on the values of the component diagnostic parameters; this

category of parameters provides insufficient information, but it can narrow the scope of the study by specifying the location of the fault.

Basic diagnostic parameters are parameters specific to the phenomena that accompany the basic work processes, such as: pressures, vibrations, noise, chemical and thermal changes, etc. (Burlacu, Bandrabur, Dănuț & Duminică, 2005).

In the absence of diagnostic equipment, the literature provides effective methods for managing maintenance activities that allow identifying critical points in the work of teams, establishing a technical intervention program and issuing action plans to reduce the criticality of faults, such as: failure mode, effects and criticality analysis (FMECA); fault tree analysis; Pareto method; statistical control of the operation of machinery, etc. (Prasad, 2012).

In the second stage of the implementation of the strategy, situations are identified in which certain components and assemblies operate, but indicate an imminent failure.

Consequently, the purpose of maintenance based on operational reliability at this stage is to prioritize defects in functional failures and potential failures. Therefore, a potential failure indicates an identifiable physical consequence that is an imminent functional failure (Ekpiwhre & Tee, 2018).

The principle of the strategy based on operational reliability is to determine the symptoms that allow the degradation limit to be assessed so that the equipment is used to the maximum, but without a functional failure.

In the case of motor vehicles, the following critical points may be defined in the work of the assemblies and components which ensure the preparation of the vehicle as a whole: the engine; the transmission; the propulsion system; the braking system; the steering mechanism.

This classification can be certainly supplemented, but our analysis was limited to the above-mentioned sets concerning only those systems that provide the basic functions of the vehicle, like propulsion and traffic safety.

3. Case Study on the Application of Operational Reliability Based Maintenance Management Methods

The purpose of this section is to find ways to improve the maintenance system of military vehicles by using different management methods and by comparing the reliability of two military devices.

3.1. Establishing the Batch of Vehicles to Be Analyzed and the Technical Diagnostic Equipment

The research focused on the range of Roman-DAC trucks, manufactured and introduced for the endowment of military structures in a certain period of time.

The information for the study was collected from the technical inspection station authorized by the Romanian Auto Register belonging to the service center and was recorded in the technical checks carried out for the periodic technical inspection. For the relevance of the research, data obtained after testing the braking system were used.

The truck models from which the service needs of the brake system were monitored have 4 x 4 and 6 x 6 traction, have the engine between 135 and 256 hp, and transport capacity from 3 t to 19 t.

The DAC 444T truck is equipped with two axles and the DAC 665T truck has three axles. On both models the front axles are equipped with airoverhydraulic brake system and the rear axle/points have air brake system (http://www.roman.ro/fisa_ produs.php?prodfile=32&lang=ro).

The specificity of the test is that it refers to a batch of vehicles manufactured and introduced into the endowment of the military units over a long period of time.

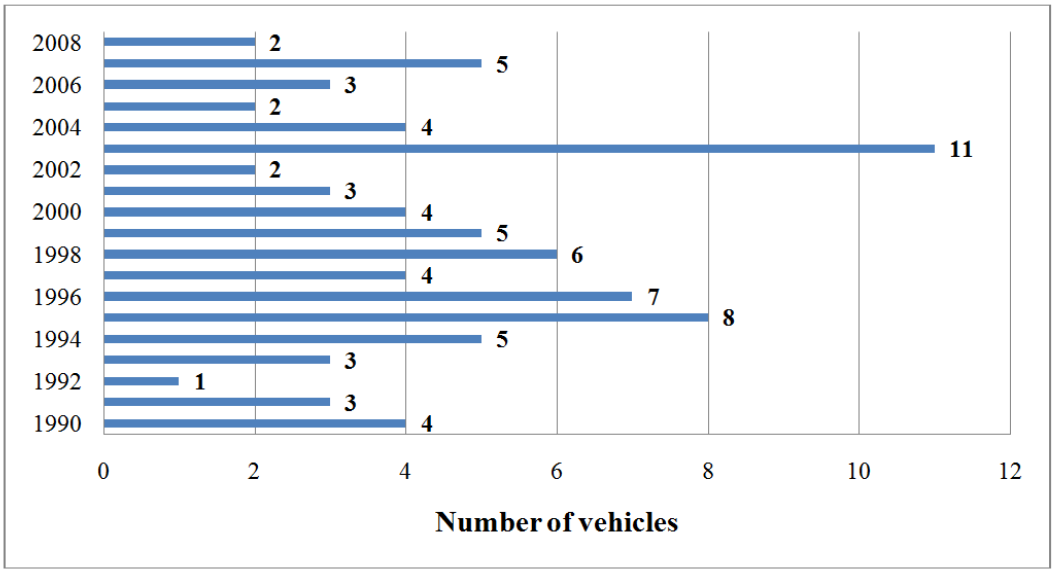


Figure no. 1: *Distribution of the number of trucks tested by year of manufacture*

According to chart 1, the largest number of trucks tested was eleven, in 2003, and the lowest number of trucks tested – one, produced in 1992.

Chart 2 shows the distribution of the number of trucks according to the verification years, the largest number is in 2018 and 2019. It is also noted that the decrease in the number of controls has been felt over the past two years due to the lack of purchase of diagnostic equipment from the maintenance center.

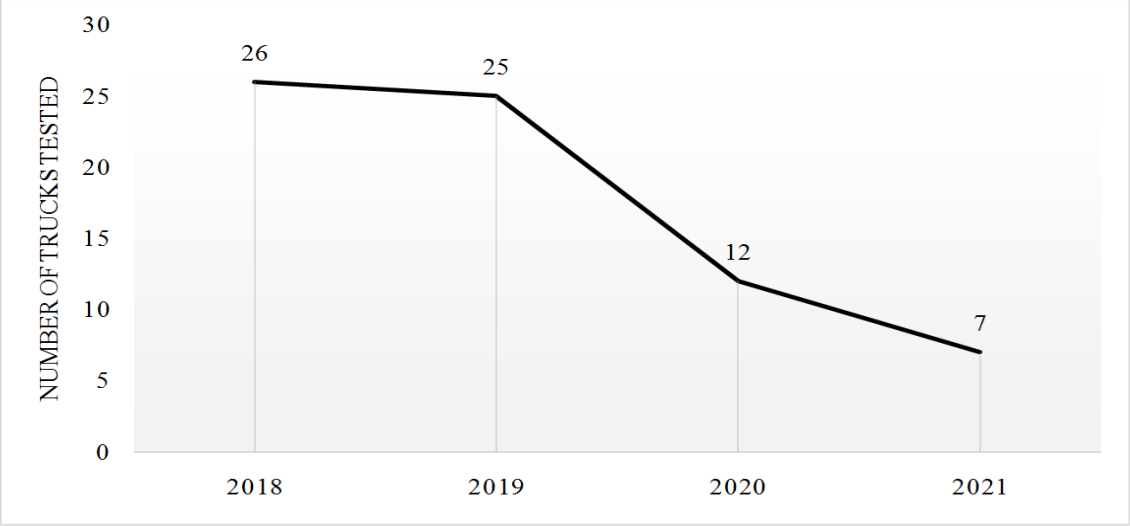


Figure no. 2: *Distribution of the number of trucks tested by the year of the periodic technical inspection*

This uneven distribution of test vehicles over the years of production and years of inspection cannot identify the frequency of failures and the causes associated with the use of established maintenance management methods.

The Pareto method will be used to determine the weight of brake system failures by reading the history of the data collected during the periodic technical checks (Figure no. 3).

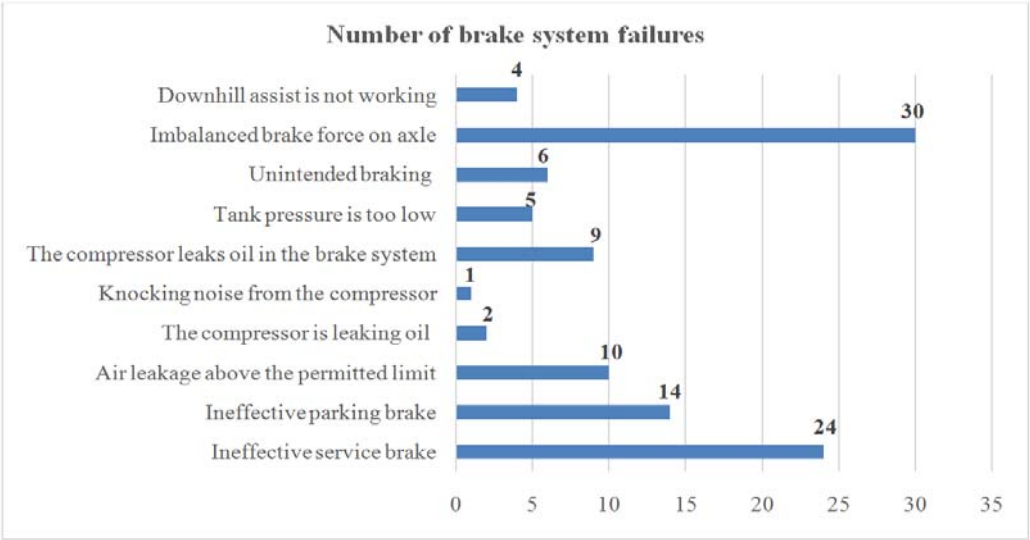


Figure no. 3: *Distribution of the number of failures at the braking system according to their type*

3.2. Applying of maintenance management methods Pareto and FMECA

The basic principle of the Pareto method is that *"80 % of faults are due to 20 % of the causes"*. As such, the types of faults are shown in Figure no. 4.

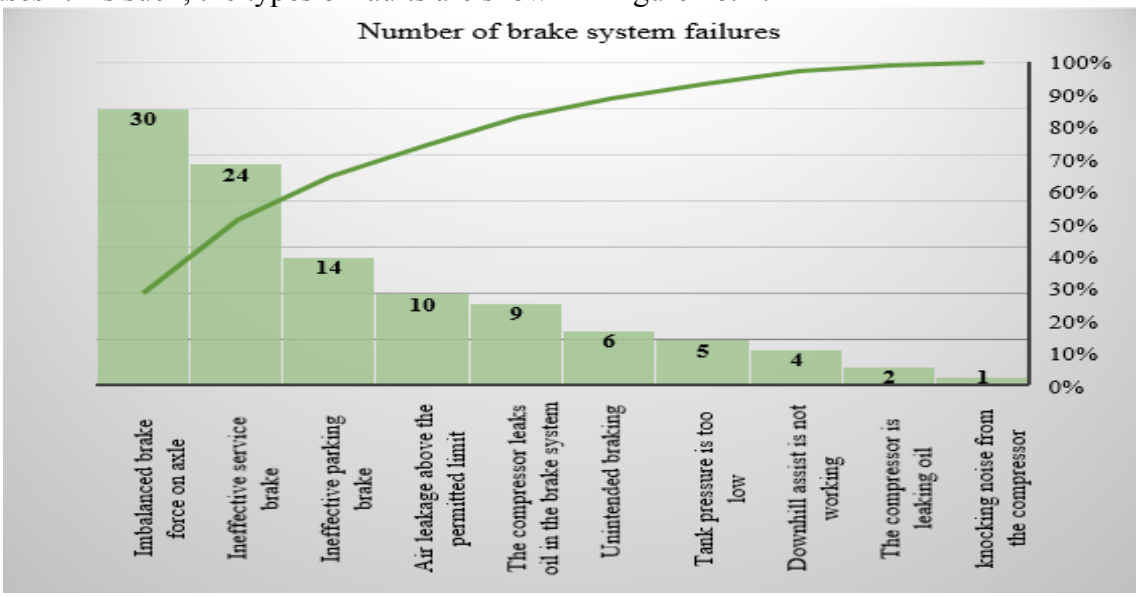


Figure no. 4: *Classification of the types of brake system failures according to their number*

Figure no. 4 shows failures that have a large impact on downtime, the PARETO method estimates that the first two failures (the brake force imbalance on axle, and the service brake failure) represent a significant percentage of the total downtime. These two failures can constitute the first group of repetitive failures with a large weight in total unavailability time.

Since the preferential treatment of failures that significantly affect downtime is important, they will be investigated after an FMECA analysis, and the following maintenance actions will aim to eliminate them.

The FMECA SHEET

For the application of the FMECA method to the present study, the authors used the methodology for choosing the coefficients for assessing the frequency of occurrence, the severity and the degree of detection of defects and for calculating the criticality index presented in their work by Verzea, Gabriel and Richet, 1999.

Table no. 1

FMECA SHEET – brake system failures

Subassembly	Primary possible failures	Possible main causes	Main effects	F	G	D	C
Brake system	Imbalanced brake force on axle	– leakage of oil drum; – the piston or receiver cylinder is seized; – expansion of the drums as a result of heating.	Irregular trajectory	7	5	2	70
	Ineffective service brake	– inadequate pressure in the air installation; – fluid leaks from the front brake cylinders; – fluid loss (leaktight connections or broken pipes); – air in the system; – damaged or inflated flexible connections.	Increase of braking distance	6	5	2	60
	Ineffective parking brake	– inadequate pressure in the air installation; – relay valve failure.	It cannot be parked on an inclined plane	3	3	2	18
	Air leakage above the permitted limit	– loose compressor drive belt, or dirty by lubricant; – faulty compressor valves.	Self restraints wheels	3	2	2	12

Interpretation of the FMECA sheet

In the FMECA failure sheet, the first two are accidental damage, with a moderate severity of unavailability (imbalance of brake forces on the axle and inefficient service brake) and have a critical index of 70 and 60, respectively.

Analyzing the causes of the two main defects, it can be found that they have their origin in non-timely execution of maintenance or technical overhaul operations. The nature of the causes, following Table no. 1, generally boils down to leaks, lack of space between mating parts, material aging and the presence of impurities in the working fluids.

These causes can lead to serious accidental situations and their remedy requires corrective maintenance work with high spare parts and labor costs compared to the costs of preventive maintenance.

The third and fourth category of failures would be light accidental failures associated with a reduced severity unavailability (inefficient parking brake and air loss over the allowed limit), which is felt by the criticality value of 18 and 12, respectively.

In practice, the aim will be to eliminate the identified causes that determine defects in the first and second categories.

On the other hand, importance will be given to eliminate the causes of the failure in group three, with a critical index of 18, and the causes of the failure in group four in the analysis of the failures of installations although the defects are rare, the severity of the effects is low, the value of criticality being 12.

4. Conclusion

The study carried out by the authors for the reference period and on the batch of technical equipment considered, respectively military vehicles, includes data to which the authors had access and which could be processed with the help of the two methods of management of maintenance activities.

The entire research approach constitutes a model that can be used for any type of technical equipment, in the present case choosing a component system of a military cargo transport vehicle that has a major influence on the safety of road traffic, namely the braking system.

Using both Pareto and AMDEC methods, it is found that the results obtained are the same, which confirms the correctness of their application and the agreement between the statistical data taken from practice (Pareto method) and the elements of theoretical analysis (FMECA method).

Thus, the management methods of maintenance activities correctly applied to technical equipment, allow the real ranking of component defects and consequently, to prevent their production, the correlation of technical interventions with the maintenance plans for each individual technical equipment. Consequently, the preventive maintenance works will have the standard character required by both the instructions and the programmed rhythmicity.

The results obtained following the ranking of defects for each component system can constitute for maintenance managers elements of orientation and forecasting of the activities of preparation and execution of preventive maintenance works.

REFERENCES

Burlacu, G., Bandrabur, C., Dănuț, N., & Duminică, T. (2005). *Reliability, Maintainability and Availability of Technical Systems*. Bucharest: MatrixRom, 161-162.

Ekpiwhre, E.O., & Tee, K.F. (2018). Reliability based maintenance methodology for sustainable transport asset management. *Pollack Periodica, An International Journal for Engineering and Information Sciences, Vol. 13, no. 1*, 99-112.

Eti, M.C., Ogaji, S.O.T., & Probert, S.D. (2006). Reducing the cost of preventive maintenance (PM) through adopting a proactive reliability-focused culture. *Applied Energy, Vol. 83, Issue 11*, 1235-1248.

Prasad, M. (2012). Applying Failure Mode, Effects and Criticality Analysis (FMECA) for Ensuring Mission Reliability of Equipment. *IDSA Issue Brief*, Institute for Defence Studies and Analyses, New Delhi.

Turcu, E. (2017). *Analysis and Prevention Models in Proactive Maintenance*. Doctoral Thesis, "Politehnica" University of Bucharest, Faculty of Engineering and Management of Technological Systems.

Verzea, I., Gabriel, M., & Richet, D. (1999). *Managemetul activității de mentenanță*. Bucharest: Polirom Publishing House, ISBN 973-683-335-6.

http://www.roman.ro/fisa_produs.php?prodfile=32&lang=ro