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Reliability, Availability And Maintainability Analysis Based On Failure Data: Case Study On Vehicles

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This Extended Abstract presents a reliability, availability, and maintenance (RAM) analysis framework to evaluate the performance of trucks used in Polish Military Forces. A vehicle is a technical system composed of essential subsystems connected in series. A reliability study was conducted for each subsystem based on Mean Time Between Failure (MTBF) data. The Mean Time to Repair (MTTR) indicator was used to assess subsystems maintainability, and availability to calculate its operational availability. To complete the RAM analysis, a Pareto Chart was used to identify critical vehicle subsystems, and a Fishbone Diagram aggregated the main causes of vehicle failure.

The occurrence of damage to a vehicle during the implementation of transportation processes generates disruptions to the operation of the entire system (Li et al., 2020). Reliability, availability and maintainability, in terms to vehicles, are among the main determinants of the efficiency of the operation of modern advanced transportation systems.

A motor vehicle can be viewed as a simple technical object or a system composed of subsystems, systems, mechanisms and components (Barde et al., 2019; Oszczypała et al., 2023). Due to the complexity of modern cars, current scientific research focuses on selected systems of technical objects (Jakkula et al., 2019). Based on the analysis of the literature, it should be concluded that the best representation of vehicle reliability is a series system, where the failure of one component affects the failure of the entire system.

RAM analysis refers to quantitative and qualitative reliability indicators, characterizing to what extent a system, subsystem and its components, will perform all assumed functions while maintaining readiness requirements. It is a tool of interest in various industries (James, 2021; Saraswat & Yadava, 2008).

The use of RAM analysis for military vehicles is motivated by the growing need to provide military transportation systems with tools to reliably assess the capability of transportation assets. In addition, the identification of vehicle "weak links" can be useful in operational prevention, leading to minimizing the risk of costly failures and long-term unplanned downtime in the use of the transport fleet.

This work discusses the application and use of RAM analysis in a case study of a transportation system. The following model assumptions are made:

- the rates of failure and repair are constant over a defined period of time;
- equipment or subsystems may only have one of two conditions: working or failure;
- failures of individual subsystems are independent processes;
- a vehicle is a technical system with a series reliability structure;
- repairs made to equipment result in the status of as-good-as-new (recovered as new).

The first stage of the study was the acquisition of operating records and the collection and processing of source data. Empirical data was compiled based on a research sample of 50 Iveco Stralis vehicles in operation for a period of three years (01.01.2019 – 31.12.2021) in Polish Armed Forces.

The vehicle in the performed analyses is treated as a single technical system composed of seven essential subsystems. Failure of any of the subsystems leads to vehicle inoperability. The reliability block diagram is shown in Figure 1.

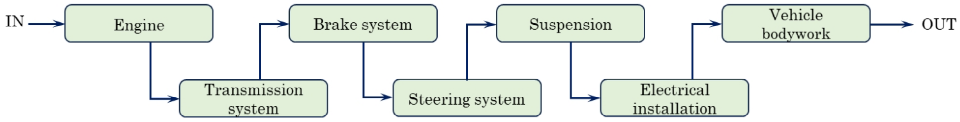

Fig. 1. Reliability block diagram of military trucks.

The failure data, form the basis for developing reliability models of technical objects. From this point of view, indicators defining intervals to failure or between failures were used (Tsarouhas, 2020). Based on operating time, Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR) data, selected indicators of individual vehicle components were estimated. Using these, the reliability of the facilities was quantified and compared. The relationships between the characteristics are shown in Figure 2.

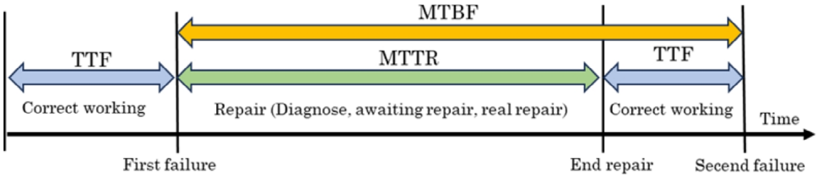

Fig. 2. Failure metrics timeline.

In order to supplement the analysis carried out, the failure rate of individual components of vehicle equipment was assessed. For this purpose, a Pareto chart was used, which made it feasible to present both relative and absolute distributions of the types of errors, problems and causes of vehicle. The root causes of vehicle unreliability were identified with the aid of brainstorming and evaluated in detail by cause-and-effect (or Ishikawa fishbone) diagram.

In conclusion, RAM analysis was used in this article to evaluate the performance of trucks as part of the Polish Armed Forces transportation system. The presented methods provide practical information for forecasting necessary management or maintenance actions. They are universal tools that can be used by those who manage the process of operating technical facilities. The presented methodology provides a basis for RAM analysis of technical objects using stochastic processes and metaheuristic approaches, namely genetic algorithm (GA) and particle swarm optimization (PSO).

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