New decision models to support planning of rolling stock use including preventive maintenances

The dynamics of economic and regulatory changes in Europe set new challenges for railway undertakings. One of their key resources is reliable rolling stock, the effective use of which is fundamental. Therefore, the research project concerns the decision support in the process of rolling stock operation planning to increase its technical availability. This can be achieved by appropriate allocation of rolling stock to transport orders in such a way as to minimize the total time of periodic inspections and repairs, which is known in the literature as preventive maintenance. Therefore, the aim of the project is to develop decision models based on operational research methods supporting the planning of railway rolling stock in an enterprise, taking into account preventive maintenance inspections. This approach is aimed at reducing the costs related to the quantity and time of periodic inspections and repairs, which are mandatory in the light of not only Polish legislation, while at the same time guaranteeing the required level of railway transport safety.

The railway undertaking is obliged to implement the vehicle maintenance process in accordance with the maintenance system documentation (MSD) of the rolling stock. The MSD defines the structure of the preventive maintenance cycle of a given railway vehicle, which is determined by the maintenance levels that indicate the order of occurrence of individual types of periodic inspections and repairs. Each level of maintenance has a defined time and kilometer allowance. It is a fixed period of vehicle operation that guarantees safety and efficiency of use. Performing a maintenance activity of a given level in a particular vehicle is obligatory when its mileage exceeds one of the measures for the given maintenance level, i.e. either time or mileage.

The cost and duration of preventive maintenance activities increases as the level of maintenance of a given railway vehicle also increases. The price and time range is very large and depends mainly on the type and series of the vehicle. For example, the duration of work on the level of PM1 may vary from 4 to 7 hours and costs about 1000 PLN, however, a much higher level of PM5 requires a sacrifice of at least two months, and its price exceeds 1 million PLN. For the structure of preventive maintenances in the rail sector, it is characteristic that a higher-level includes lower levels preventive maintenances. Therefore, performing a higher level implies performing lower levels, and therefore the mileages for these vehicle levels are reset. In addition, the levels of railway transport maintenance can be combined with each other, and the execution time should be done earlier. This aspect of the management of rolling stock reveals the diversity of planning subjections faced by rail transport companies.

In the search for answers supporting decisions in planning the effective operation of rolling stock, it is necessary to analyze possible configurations and choose the best solution. However, the problems under investigation belong to a group of computationally difficult (intractable) problems. Therefore, it is highly unlikely to develop algorithms for them that provide optimal solutions in a reasonable time for practical data instances (e.g. number of vehicles, planning time horizon). In the case of smaller problem instances, a possible approach, especially in theoretical terms, is the development of exact algorithms based on mathematical programming, branch and bound, etc. However, they are impossible to apply in practice, because their operating times are unacceptably long with a larger data set (instances) of the decision problem.

Therefore, it is reasonable in such cases, although requiring additional research, the use of metaheuristic algorithms (e.g. simulated annealing, evolutionary methods, particle swarm optimization, search with bans). Their characteristic is a targeted search for solutions optimizing the preferred criteria taking into account the existing constraints and assumptions. As a rule, the time of operation of such methods and the quality of solutions provided are acceptable to decision makers. However, the application of these methods requires defining the solution representation, evaluation functions, ways of searching the solution space, etc. In addition, their effectiveness depends on the mathematical model developed, which should be based on key elements of reality, fundamental from the point of view of the analyzed research problem, but also do not contain redundant information that could worsen the efficiency of searching for solutions through these algorithms.

The project will focus on the formulation of mathematical models of the studied problems, determination of their computational and memory complexity, deriving properties, and then construction of exact, heuristic and metaheuristic algorithms for them. The overall result of the research will be new decision models that will improve the quality of delivered solutions in a reasonable time for rolling stock maintenance plans, while meeting the legislative requirements of railway transport safety.