Organization of the repair and maintenance in road sector with ontologies and multi-agent systems

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Abstract

This paper defines the problems and tasks of maintenance and repair of road-building equipment (DST). An approach that provides decision support (PDS) in the management of maintenance and repair of roads and vehicles based on the adapted and modernized method RCM2 is proposed. The structure of the system of organization of repairs and maintenance in the road sector with the use of ontologies and multi-agent systems is defined. A model of planning system maintenance and repair on the basis of agents as a multi-agent system, composition and structure of intelligent agents is developed. For scheduling maintenance and repair problems, it is proposed to use the method of Case Based Reasoning on ontologies. The results of the development and implementation of integrated software modules and organizational system Maintenance and DST is described.

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1. Introduction

Road management is very important for any country, as road networks are the foundations for the most frequently used of the four major mechanisms of transporting goods and people. Modernization of road infrastructure allows us to migrate to a new system of management, which is results-oriented and improves the efficiency of the industry. One of the objectives of the reformation is to improve management technologies, which include the best of modern approaches for the organization of maintenance and repair of equipment (MRO) to ensure maximum performance of the road-repair vehicle production program. For many road companies, equipment is not updated sufficiently, causing it to wear and reduces the resourcefulness of a machinery[1]. The most obvious solution, at first glance, is to update the hardware. However, the economic feasibility of such operations is not always convincing [2]. A more promising solution is a challenge for the development of the apparatus for the organization of the system of organization, planning and decision support for maintenance and repair of road-building machinery.

2. Decision on the organization of MRO

Often, in the organization of work on the maintenance and repair of road maintenance equipment, servicing according to actual condition is used. Less frequently, an approach that involves a more progressive planning, preventive maintenance and repair, in which repairs of equipment are made at regular intervals is used. This approach is not always efficient as it incurs extra costs.[3] Many industries use proven approaches like the Reliability-Centered Maintenance (RCM), in which the value of an asset is determined as well as the consequences of its failure. In the organization of road maintenance and repair techniques, RCM may be applied (Fig. 1) [4].

In general, the cost of maintenance and repair are equal to the sum of operating costs and production losses (including the failure of satisfying customers). This curve has the optimum point (see Fig. 2).[4] The meaning of this dependence is that at a certain value of total cost, an optimum value of cost and effect of repair activities is reached. A further investment may increase the effect, known for example, as the coefficient of plant availability [5].

The analysis of this relationship leads to the conclusion that in the management of maintenance and repairs, it is possible to develop an optimal plan of work (by cost/ benefit) that is essential to the success of the entire range of repair activities. The plan is dynamically changeable. Adjustments on it should be carried out periodically [6]. To improve efficiency in the process of road maintenance equipment, automation is necessary using an upgraded strategy RCM2 [7]. For this reason, an approach to support decision making (BPD) in the management of road maintenance and repair techniques is proposed. An Information Decision Support System (IDSS) is designed to perform the following functions: planning maintenance and repair of road vehicles, prioritization of road maintenance and repair of machines, as well as their constituent nodes. Given the specificity of the subject area, the architecture of the system was built by conducting road repairing works (Figure 3). Modules offered by IDSS knowledge base (ontology) include the database system and the functional modules (for monitoring the current state of technology, PPR, etc.) [8].
Fig. 1. RCM-logic approach

Fig. 2. The dependence of the production losses from the total cost of maintenance and repairs.
The system database and ontology are regularly updated. Ontology is regularly updated with new knowledge of professionals who are involved into the process control system maintenance and repair of road vehicles. These requirements are analyzed for consistency with the help of an IDSS expert stored in a knowledge base in form of new knowledge fragments, which are used to support decision-making and evaluate the quality of managing road maintenance equipment [9].

All figures should be numbered with Arabic numerals (1, 2, ..., n). All photographs, schemas, graphs and diagrams are to be referred to as figures. Line drawings should be good quality scans or true electronic output. Low-quality scans are not acceptable. Figures must be embedded into the text and not supplied separately. Lettering and symbols should be clearly defined either in the caption or in a legend provided as part of the figure. Figures should be placed at the top or bottom of a page wherever possible, as close as possible to the first reference to them in the paper [10].

Ontology was developed to improve the efficiency of decision making and solving the problem of road-building organization in the process of organizing MRO. Ontology provides a complete knowledge of the process of doing a repair of road vehicles, allows us to construct a hierarchy of concepts to formalize a system of expert judgment in the form of decision rules and form the basis of precedents problematic situations in the field of maintenance and repair and quality control of the process of repair of road vehicles. In the ontology paradigmatic relations between concepts are set, independent of the context of solving the problem and the rules for the variables syntagmatic relations of concepts that arise in a context of problem solving. Developing ontology solves the problem of sharing and reuse of knowledge by different users involved in the management of the quality of the repair of road vehicles [11].

Fragment of the developed ontology, reflecting a variety of classes of the repair of road machines and quality management, is presented in Figure 4.
3. Multi-agent model of MRO system for road construction machines

For monitoring, organizing an interactive and simplified process of managing objects with similar structures makes use of agents, which are grouped in multi-agent systems (MAS). MAS model, which was originally developed to represent the interaction of a set of objects of a similar structure has been successfully applied in many scientific fields [7]. The use of this model in the fields of robotics and data mining has led to the development of the concept of an agent as an object endowed with the rights of the user and is able to execute a similar range of applications. Thus, the agent is a complex system, which can be based on intelligent methods in multi-agent system interaction.[12]

Due to the heterogeneity and different geographic location of road construction machinery and equipment, application of agent technology is considered reasonable to solve the problems of maintenance and repair. Agents have characteristics that make them indispensable to the maintenance and repair tasks. The ability to react to dynamically changing conditions make multi-agent systems (MAS) flexible for use in road maintenance equipment, as road repair machine is quite autonomous, and the situation there changes dynamically. Agents have properties of flexibility, extensibility, and fault tolerance. In MSS, tasks are distributed between the agents, each of which is considered as a member of the group or organization. The distribution of tasks involves assigning roles to each member of the group, the definition of the measures of responsibility and experience requirements.

In using all the methods of making predictions about works on maintenance and repair of equipment as part of an automated system, using agents can improve the speed and quality of the preparation of plans for the maintenance and repair work on the equipment. According to this model, the following multi-agent system Maintenance is proposed. [13]

Distribution of solutions to problems among several agents is divided into the following stages: 1) the agent-manager machine analyzes the failures of internal nodes and determines the priority of repairing them, and 2) these tasks are distributed among the agents executing, and 3) each agent, the Executive complete their task, sometimes dividing it into sub-tasks, and 4) to provide an overall result, composition and integration of partial results corresponding to the selected tasks is performed, and 5) the agent-manager machine is used to determine
the priority for repair of road-building machinery, based on a scale of importance, which is obtained by the methodology of RCM.

![Diagram of architecture MRO road equipment system based on multi-agent](image)

To organize the output of recurring tasks of planning maintenance and repair the Case Based Reasoning (CBR) [Pal, Shiu, 2004] method is used. If the principle of regularity is not satisfied, then the order of maintenance and repair of units are performed on the basis of preliminary expert assessment of the importance of the node and the rules of MRO and other knowledge about the organization of the MRO. After successful completion of the planned MRO operation, information about this is stored in the knowledge base and it is possible to use such information in the future for planning [14].

4. Conclusion

An analysis of the problems and highlighting of the tasks involved in the organization of maintenance and repair equipment in the road sector is carried out. The basic methodology for the creation of MRO organizations in the road sector (servicing based on actual condition, planned preventative maintenance and RCM) is defined. Within the work, an approach to support decision making (BPD) in the management of maintenance and repair
of road vehicles based on the adapted and modernized method RCM2 is proposed. It is shown that the cost of maintenance and repair are equal to the sum of operating costs and production losses [15].

The structure of the system of organization of repairs and maintenance in the road sector with the use of ontologies and multi-agent systems is defined. The decision on the application of ontologies for knowledge management tasks for the organization of MRO is shown. The use of agent-based technology to address maintenance and repair is justified. The composition of agents and models of MRO planning systems as a multi-agent system is developed. A structure of intelligent agents with corresponding models is built. For scheduling maintenance and repair, the Case Based Reasoning method is used for output to ontology.

Implementation of the system is carried out by the regional state-owned enterprise to build and repair roads. Development of a complete integrated software and organizational systems is being done in stages. Currently, the system is implemented in an automated accounting system roadwork’s businesses and collects information on work carried out, which is considered in the prototype of the IDSS system. Authors appreciated to RFBR for supporting (project № 13-01-007913).

References