Service maintenance and repair of passenger cars in the concept of Digital Enterprise

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Abstract. The passenger rolling stock has a number of specific technical characteristics based on original design and technological solutions. The consequences of the passenger rolling stock failure cause unplanned downtime, resulting in: reduced productivity, traffic safety and quality of service, as well as financial losses. Determination of cost-effective maintenance and repair becomes one of the key tasks in the operation of passenger rolling stock. At present the tools for planning maintenance and repair of passenger rolling stock are static. They do not take into account dynamic information during the life cycle of the rolling stock. The planning tools are mainly a copy of the maintenance and repair organization manual. This article deals with the digital model of maintenance and repair of passenger rolling stock as a transformation of strategy from diagnostic to predictive. The modeling serves as a fundamental starting point in managing the life cycle of passenger rolling stock. The theory of passenger rolling stock life cycle is complemented by the theory of management, creating a model of service maintenance and repair. The digital model covers the life cycle of the passenger rolling stock from initial planning to a multitude of solutions, such as: separation in the mechanism of financing, service operator selection, definition of key performance indicators for the operator, setting fees, maximum profit, providing access to all operators of railway services. At the conceptual level, the fundamental aspects of the digital service model have been developed to forecast future events and make optimal plans, taking into account the multivariate and structural heterogeneity of data in the virtual networks. The modeling approach oriented to the global description of the business process and distributed management of service maintenance and repair is considered.

1. Introduction
The conducted researches in the field of maintenance and repair of passenger rolling stock are connected with the development of industrial sphere and growth of market potential. This is due to the requirement to increase the productivity of passenger rolling stock by increasing the time of failure-free operation, with a parallel reduction in investment costs.

Services oriented to preventive maintenance and modernization are considered as the primary factors characteristic of closed-cycle production [1]. The issues of modeling maintenance and repair in life cycle management while minimizing investment investments are presented in studies [2-5]. Service maintenance and repair should be carried out taking into account the needs of the owner of the rolling stock and ultimately be oriented to the life cycle. From set of possibilities of use of the passenger rolling stock depending on corresponding business environment there is a set of operation information.
Current planning for maintenance and repair of passenger rolling stock is static [6]. The dynamic component in the process of the rolling stock life cycle is not taken into account. The planning tools are a copy of the maintenance and repair organization manual. Work is planned at intervals determined by regulatory documents or the actual mileage of the rolling stock, not taking into account the peak demand for passenger transportation.

Based on the analysis of work, it is necessary to conduct a study in the planning of maintenance and repair of passenger rolling stock, depending on the dynamic and multipurpose components.

Based on the evolution of information and communication technologies - the transition to a "digital economy" is obtained interconnection through real and virtual objects and processes [7]. Creation of the specialized digital platform for an unobstructed exchange of information, possibility of its fast processing and as a consequence - possibility of acceptance of the administrative decision will allow organizations to correspond to quickly developing technologies in the global market.

One of the solutions of this problem is service maintenance and repair of passenger rolling stock on the basis of creation of digital board-shaped multi-purpose approach to optimization and adoption of management decisions. As a result, it is necessary to work out the digital infrastructure of the model.

2. Methods of research
The study of complex structural systems of business models, consideration of their structures, assessment of functioning scenarios with uncertainty and dynamics is based on simulation modeling. Simulation modeling will provide estimation of influence of initial parameters on a result of modeling with use of strategy of search of the best variant of model for the purpose of acceptance of the administrative decision.

The organisation of service maintenance and repair is based on the concept of modularity and division of business limits [8]. The composition of passenger trains, depending on the seasonality and the peak of transportation, are reshaped, are on the road or on the tracks of standstill. This characteristic of the rolling stock corresponds to the agent model, suitable for solving the problem of creating a digital platform.

The creation of a digital agent-based platform will be the starting point for studying various scenarios for the operation of passenger rolling stock in an open distributed system with support for management decision-making. The agent-based method is fully capable of implementing the modular approach of the structure for virtual reconstruction of interactive rules of participants (agents). Interaction of participants in maintenance and repair is shown in the diagram (Figure 1).

**Figure 1.** The scheme interaction of imitation model agents.

The simulation of maintenance and repair can be performed by four agents:
- Plant manufacturer / service company;
- Manager infrastructures;
- the owner of the rolling stock;
- rolling stock.

Modeling of the physical object of the passenger rolling stock is formed on the geographic information system with open information code OpenStreetMap, visualizing the spatial representation. In order to trace the causal connection of the modeled system, the agents work independently of each other.

The use of modeling agents is necessary for presenting real solutions in management, understanding the transport process in passenger traffic [9].

Operational structure of interaction of modeling agents at organization of service maintenance and repair (Figure 2), representing participating subjects and their information dependence. In the described structure the main participants of the process are identified:

**Figure 2.** Operational structure of interaction between process participants.

In the described structure the main participants of the process are highlighted:

1. The owner of the rolling stock, which controls the daily mileage of the passenger rolling stock, as well as the terms of service maintenance and repair, on the basis of the program provided by the manufacturer.
2. Infrastructure manager. Provides services for drawing up a traffic schedule for planning the route of rolling stock movement to the place of work and back in a regulated period of time, as well as monitors the movement on the railway network.
3. Manufacturer/service enterprises. Form a program of service maintenance and repair on the basis of regulations, as well as information about the daily mileage of the rolling stock.

The adopted structure of agent-based modeling will give an idea of the system being formed. The behaviour of an agent can be defined by various actions when certain events occur, which are considered in this case for passenger rolling stock in the maintenance and repair system.

A simulation model is, in fact, a model that builds a trajectory of changes in the system state. It
may be said that a simulation model is a set of rules according to which a system passes from one state to another. The rules are set by means of differential equations, state diagrams [10] of the system of maintenance and repair. Model output data allow analyzing the system behavior in given parameters for making management decisions.

The next stage of formation of the digital model of maintenance and repair is the description of functional architecture (Figure 3).

**Figure 3.** Functional architecture of the digital service and maintenance model.

The three-level architecture of the digital model is presented in the following way:

Enterprise level: required to collect data from the border nodes through assets, sensors and gateways, production unit workload, spare parts stock level. The information is formed in the database (database management).

Service maintenance and repair platform level: receives, processes and sends management commands from the enterprise level to the owner level, making calculations in accordance with the owner's requests. This level performs calculations according to the underlying algorithm, as well as assistance in making management decisions for the owner of rolling stock. Data monitoring and asset analytics are also performed.

Owner level: implements domain applications through a management decision making system and provides interfaces to end-users to implement functionalities (rolling stock management, maintenance and repair supply chain management, resource planning, investment planning).

The functional domains are grouped as follows:

Enterprise network: combines actuators, devices, C control systems and assets with a gateway that connects to other networks (service enterprises) and allows data transfer and flow control between them.

Network Access: Provides connectivity for data flows and management between the enterprise network and the service and maintenance platform layer;

Service network (cloud): provides a connection (usually using transport layer security protocols) between the service and repair board services and the rolling stock owner level.

The digital model also includes the following provisions:
• Public cloud: includes the components needed to integrate enterprise level manufacturing processes (process modeling, data analysis, production planning);
• private cloud: this is the core functionality that includes managing and storing operational and service data, adapting planned activities to real-time events in production, as well as helping to make management decisions in production processes.

3. Research results
Planning for maintenance and repair of passenger rolling stock involves many complex issues. The task of maintenance service is to maintain the passenger rolling stock in good working order with minimum investment.

The modular approach of agent-based modeling and simulation of production processes will ensure optimal adaptation of maintenance and repair of passenger rolling stock. The use of agent-based modeling is connected with the use of detailed description of production processes by means of creating an algorithm of agent action.

Cloud computing has become well known paradigms. There is a great demand for new system architectures. This is required to meet new emerging requirements in development and progress. Production maintenance and repair services can be conceptualized and organized as support for management decisions for each process participant based on a digital model and cloud computing.

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