UDC 656.136:004(043.3)
DOI: 10.15587/1729-4061.2024.298843

CONSTRUCTION OF SYSTEMIC INTERACTION BETWEEN TOOLS OF REMOTE MONITORING OF THE TECHNICAL CONDITION AND OPERATION MODES OF A TRUCK VEHICLE

Igor Gritsuk
Corresponding author
Doctor of Technical Sciences, Professor*
E-mail: gritsuk_iv@ukr.net
Igor Khudiakov
PhD, Associate Professor*
Mykyta Volodarets
PhD, Associate Professor
Department of Road Transport
Pryazovskyi State Technical University
Universytetska str., 7, Mariupol, Ukraine, 87555
Dmytro Pohorletskyi
PhD, Associate Professor*
Nadiia Pohorletska
Postgraduate Student
Department of English Philology and Word Literature named after Professor Oleg Mishukov
Kherson State University
Shevchenko str., 14, Ivano-Frankivsk, Ukraine, 76018
Yevhen Ukrainskyi
PhD
Department of Organization of Aviation Works and Services
National Aviation University
Liubomyra Huzara ave., 1, Kyiv, Ukraine, 03058
Igor Petrov
Doctor of Technical Sciences, Professor
Department of Sea Transportation
Odesa National Maritime Academy
Didrikhsona str., 8, Odesa, Ukraine, 65052
Pavlo Nosov
PhD, Associate Professor, Head of Department
Department of Innovative Technologies and Technical Devices of Navigation**
Askar Tazhenov
Master's Degree, Head of Department
Department of Committee of Administrative Police
Ministry of Internal Affairs of the Republic of Kazakhstan
Tauelsyzdyk ave., 1, Astana, Republic of Kazakhstan, 010010
Mikhaylo Litvinov
Ship Engeneer
Abu Dhabi National Oil Company (ADNOC) Headquarters
Corniche road west, 898, Abu Dhabi, United Arab Emirates, 80048
*Department of Ship Power Plants Operation**
**Kherson State Maritime Academy
Kanatna str., 99, Odessa, Ukraine, 65039

Parameters of the technical condition of transportation means in modern transport-logistics and infrastructure systems are an integral element of their communication support. This is enabled by the use of remote information monitoring technologies in control processes. The object of this study is the processes of vehicle remote monitoring in terms of determining the technical condition. The work addressed the task of improving the process of vehicle technical operation through the construction of a model of the remote monitoring system of its technical condition. A remote version of the information-analytical monitoring system was implemented. The work considers the system interaction of the means of remote monitoring of the state of a vehicle to ensure control under the operating conditions of the driver's work and rest modes. Road, transport, climatic conditions, etc. were taken into account. Considering these features, an information and analytical model of the system for remote monitoring of vehicle condition was built. Features of the subject area of the system are described using a DFD diagram. A structured information model of the information-communication system has been constructed, which has the ability to actually provide vehicle remote monitoring, the driver's work and rest modes, and his/her physical condition. The results, subject to the use of the V2I information model in the field of transport, allow remote monitoring of the vehicle technical condition. Specifically, to analyze the influence of changes in the physical condition and modes of work and rest of drivers on changes in the vehicle operating parameters

Keywords: vehicle, remote monitoring, technical condition, modes of work and rest of the driver

Received date 08.12.2023
Accepted date 12.02.2024
Published date 28.02.2024

How to Cite: *Gritsuk, I., Khudiakov, I., Volodarets, M., Pohorletskyi, D., Pohorletska, N., Ukrainskyi, Y., Petrov, I., Nosov, P., Tazhenov, A., Litvinov, M. (2024). Construction of systemic interaction between tools of remote monitoring of the technical condition and operation modes of a truck vehicle. Eastern-European Journal of Enterprise Technologies, 1 (3 (127)), 47–63. doi: https://doi.org/10.15587/1729-4061.2024.298843*

1. Introduction

Much attention has always been paid to the process of obtaining parameters of the condition [1–3], speed of movement and fuel consumption of freight vehicles [4–6] during their operation. However, their simultaneous analysis was not carried out depending on the driver's work and rest regimes (DWRR), the driver's physical condition (DPC) and operating conditions [7–10]. Information about the DPC and DWRR parameters under operational mode is currently not available. It is received by technical services late [11–14], most often after the end of the route. It is after the completion of the route that the transport company has the opportunity to check compliance with the conditions of DWRR and analyze its impact on vehicle technical condition [15–18]. Therefore, in the practice of operation of freight vehicles, there is a need to provide remote monitoring and analysis of the impact of changes in DPC, DWRR on the technical condition of vehicles [19–21].

The use of information and telematics systems is now quite widespread in the automotive industry, as well as in mechanical engineering in general [21–25]. They are termed intelligent systems because, in addition to collecting information, they process and analyze it. They can also give recommendations depending on the tasks of vehicle operation.

Usually, operational control over the technical condition of trucks collects and analyzes not only data on mileage and location but also many other parameters – load, fuel consumption, speed, tire pressure, etc. [26, 27]. There are a number of shortcomings in the existing systems and programs of integrated control over cargo vehicles. First, the impossibility of assessing the impact of DPC on compliance with DWRR [28]. Secondly, it is impossible to assess the influence of parameters of the vehicle technical condition, DPC, and DWRR on fuel consumption [29]. Thirdly, it is complicated rational management of vehicle operation parameters under operative mode, taking into account road and operating conditions [30], etc.

Therefore, it is a relevant task to investigate ways to eliminate the above-mentioned shortcomings. Results of such studies are needed in practice because they allow obtaining information about the influence of DPC, DWRR, qualifications, and experience of drivers on the technical condition of vehicles based on remote monitoring of the specified groups of parameters. Given this, the quality of managing vehicles under operational mode by means of ITS could improve.

2. Literature review and problem statement

Work [31] describes an information system for the interaction between the vehicle and infrastructure; however, not enough attention is paid to taking into account the transport and road conditions of vehicle operation. In [32], the system of training and safety of a vehicle under the conditions of intelligent transport systems was considered; however, little attention was paid to the influence of vehicle performance during its operation. In work [33], the general concept of the development of intelligent transport systems is considered, but it lacks an analysis of the dependence of fuel consumption of vehicles, parameters of the technical condition of vehicles and DWRR. In work [34], attention was paid only to the cyber protection of vehicles, but it has all the above-mentioned disadvantages. In work [35], issues of development and construction of intelligent transport systems are considered; however, as in most other works, the systems and programs presented in them have shortcomings in terms of integrated control over vehicle operation. But a characteristic feature of the above papers is that the issues related to the formation of the system interaction of remote monitoring tools remained unresolved. Enabling and observing the modes of work and rest and the physical condition of the driver, taking into account the vehicle technical condition during operation, taking into account road, transport, climatic conditions, etc. The reason for this was the objective difficulties associated with the unpreparedness of vehicle operation infrastructure and monitoring tools for system interaction as part of software-analytical systems under operational conditions. An option to overcome the relevant difficulties may be a full-fledged development on the updated infrastructure and monitoring hardware base of the V2I information model of the system of remote control over the technical condition of vehicles and DWRR. Elements of this approach are used in [36]. However, for the full implementation of such an approach, it is necessary to rationally form the subject area of the information system of operational remote control over the technical condition of vehicles and DWRR. The method of system interaction of parameters in the middle of it and to construct a general information model of the subject area of the system and the structure of its functional capabilities and, of course, to confirm its efficiency. All this gives reason to assert that it is expedient to conduct a study on the development of the V2I information model. That could improve the quality of the cargo transportation process and its level of safety.

3. The aim and objectives of the study

The purpose of our study is the construction under operating conditions, taking into account road, transport, climatic conditions, etc., of the system interaction of the means of remote monitoring of vehicle technical condition with the control of compliance with DWRR, DPC regimes, and taking into account their influence. This will make it possible to enable high performance and fuel efficiency of the vehicle. Control is carried out with simultaneous consideration of DWRR and DPC.

In order to achieve the set goal, it is necessary to solve the following problems:

– to form the subject area of the model of system interaction of parameters and the information system of operational remote control of the technical condition and DWRR and DPC;

– to build a model of remote monitoring and system interaction of state parameters;

– to construct a general information model of the subject area of the system of remote operational control of the technical condition of cargo vehicles and DWRR and DPC;

– to design the structure of functional capabilities of the monitoring system and to consider the features of information exchange between elements of the vehicle technical condition control model;

– to present the results of remote implementation of control over the technical condition of vehicles using an information-analytical model.

4. The study materials and methods

The object of our study is the processes of operation and remote monitoring of the technical condition of a cargo vehicle with a trailer during operation.

The subject of the study is to determine ways of remote control over the technical condition of a cargo vehicle with a trailer under real operation conditions and methods of their systematic implementation by means of intelligent transport systems (ITS).

The main hypothesis of the study assumes the possibility of increasing the efficiency of the operation of a cargo vehicle with a trailer due to unification on the basis of a system approach and the formation of variants of the schemes of the information system for monitoring the technical condition of vehicles with a trailer, DWRR, and DPC, the application of the provisions of graph theory, databases and sets under the conditions of modern infrastructure by means of ITS.

Accepted assumptions in the development of the object of research: the search for optimal information exchange in the processes of remote monitoring of the technical condition of a cargo vehicle with a trailer during operation.

The research methods used in our research are based on the methods of experimental research, information exchange, a systematic approach to the formation of variants of the schemes of the information system for monitoring the technical condition of vehicles with a trailer, DWRR, and DPC; graph theory, databases, set theory, regression analysis, etc.

5. Results of constructing the systemic interaction between means of remote monitoring of vehicle technical condition

5. 1. Forming the subject area of the operational remote monitoring information system

Vehicle monitoring systems that exist today do not have the ability to take into account the influence of DWRR and DPC on the technical condition of vehicles during operation [8–11, 20–24, 28–38].

Improvement of the model of control and management of operating modes of the vehicle, its technical condition, aims to increase the reliability of the information received.

At the same time, the performance parameters of the vehicle, DPC, and DWRR are determined. As a result, it should show how the quality of truck operation management might improve owing to intelligent transport systems (ITS). This is possible through the correction of operating conditions of the vehicle and modern information and telecommunication technologies, using a probabilistic mathematical model and serial specialized equipment [8–11, 20–24, 38–45].

Management of operating modes and technical condition of a vehicle with an internal combustion engine (ICE) [8–11, 42–45], according to the proposed method of remote control, is carried out using the constructed scheme of information exchange between elements of the information and analytical system (Fig. 1).

This system includes [8–11, 20–24, 45–50]:

– system sensors;

– OBD-II system lines;

– OBD-II adapter (scanner);

– connection to the paired device using USB, Wi-Fi, or Bluetooth, and through the installed on-board IC;

– installed additional on-board sensors;

– tracker (scanner-communicator controller);

– a means of registration of DWRR;

– means of connection via GPS, a-GPS, SBAS (Satellite based Augmentation System), GLONASS, Internet, or a local network with a Web server, GPRS (hereinafter Internet);

– database;

– software;

– intelligent software system «CMV».

After receiving operational information, it is transmitted to the participants of the transport operation process and to the automated workplace of the internal network (AVMVM) via the Internet.

They also provide the functionality of ICC [8–11, 20–24, 33–40]:

– identification of the vehicle in the stream;

– the possibility of working with software systems that use different interfaces;

– operation of a vehicle with an internal combustion engine;

– system interaction and information exchange with vehicle sensors, which are connected using special wired communication lines – K-line, L-line, and CAN lines;

– data transfer;

– functional interaction.

All this is used for:

– determination of parameters of vehicle's technical condition;

– maintenance and repairs;

– the possibility of evaluating the performance of the vehicle;

– determination of hourly (urgent) conditions of operation of the vehicle;

– formation of geozones;

– operational safety;

– working with services and maps;

– connections to software applications of the server;

– data processing;

– informing, eliminating, and transferring information about errors and malfunctions in vehicle operation to the external storage;

– assessment of the impact of DWRR on the vehicle technical condition.

One of the features of our information system for monitoring cargo vehicles is the equipment for checking the physical condition of the driver and DWRR. Information from which is transmitted to the modern ICC to determine the impact of these parameters on the vehicle technical condition. Most of the parameters are measured by the on-board ICC of the cargo vehicle, after which it registers them on a remote computer [46–49]. Corresponding reports on speed and fuel consumption, driving modes, vehicle coordinates (with specified geozones), DWRR, and driver's physical condition are also generated. ICC, using a probabilistic mathematical model, evaluates vehicle technical condition. In accordance with the vehicle performance requirements, the operating conditions are adjusted and the influence of the DWRR parameters and the physical condition of the driver on the vehicle technical condition is analyzed.

As a result, using the probabilistic mathematical model of ICC and serial specialized equipment, control over the technical condition of TK, DWRR, DPC, and safe operation of vehicles is executed. Also, owing to the possibility of remote adjustment of truck operating parameters, it is possible to improve the quality of managing the rational operation of trucks using ITS tools.

A data flow diagram (DFD – Data Flow Diagram) [8–11, 20–24, 50–57] was used to define the subject area of the information model for remote monitoring of the technical condition of freight vehicles during operation. Data flow diagrams are one of the main means of modeling the functional requirements of future software. With their help, these requirements are broken down into functional components and represented in the form of a network connected by data flows [8–11, 20–24, 52–57]. These tools demonstrate the transformation of their inputs into outputs, and the discovery of relationships between these processes.

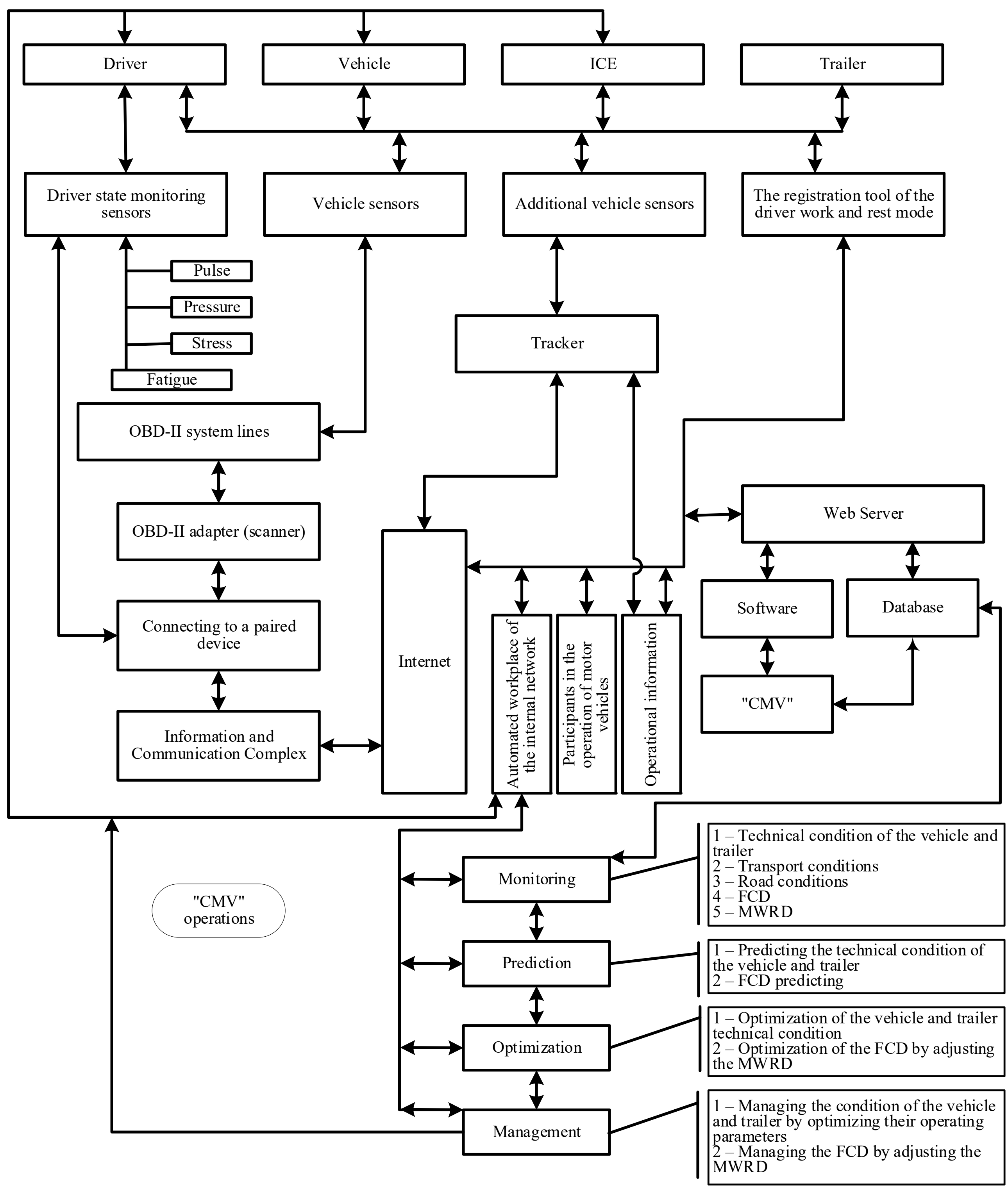


Fig. 1. Block diagram of remote information exchange between elements of the constructed information and analytical system of operational control over vehicle technical condition: where AVMVM is an automatic workplace of the internal network of the system; CMV is a module of operational control over vehicle technical condition

Such a system model describes the transformation of fully processed information and looks like a hierarchy of data flow diagrams. At the same time, each subsequent level of the hierarchy specifies the asynchronous process of information processing. This happens until the next process is defined as elementary.

The built diagram (Fig. 2) of DFD data flows represents the highest descriptive level of the vehicle monitoring system. With the help of the decomposition of the objects that make up this diagram, further refinements of the model were carried out.

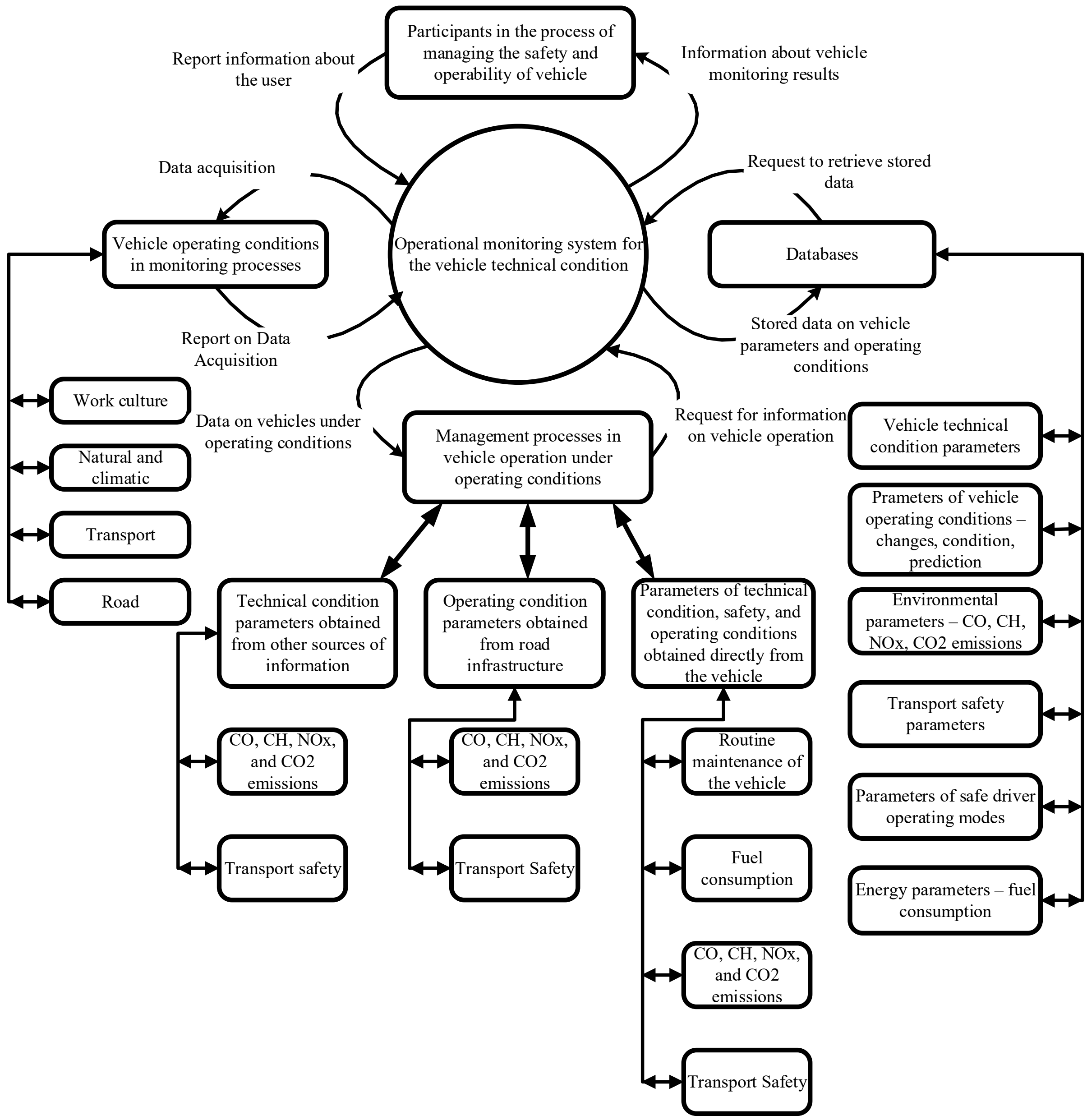


Fig. 2. DFD diagram of the vehicle monitoring information system functioning

5. 2. Construction of a model of remote monitoring and system interaction of state parameters

The study of the system «Truck vehicle – Truck trailer – DPC – DWRR – Conditions of operation of vehicles on the route – Infrastructure of vehicle operation» was carried out on the basis of a general approach based on the construction of a model of remote control over the technical condition of a cargo vehicle, DWRR, DPC. It consisted of the system interaction between the main components of the monitoring process. Specifically:

– vehicle and trailer with driver and ICC;

– operational conditions of the vehicle (transport, road, atmospheric and climatic conditions, and culture of vehicle operation) [8–11, 20–24, 58];

– transport infrastructure and road infrastructure (Fig. 2).

The construction of a model for monitoring the parameters of vehicle condition in interaction with the parameters of DWRR, DPC is shown in (1):

$$\left.\begin{array}{l} Q_{(vehicle+trailer)} \xrightarrow{F_{(vehicle+trailer)}} \\ Q_{(MWRD)} \xrightarrow{F_{(MWRD)}} \\ Q_{(FCD)} \xrightarrow{F_{(FCD)}} \\ Q_{(OC)} \xrightarrow{F_{(JC)}} \end{array}\right\} Q_{VOP}, \qquad (1)$$

where $Q_{(vehicle+trailer)}$ is the set of models of the condition of vehicle with a trailer, $Q_{(MWRD)}$ is the set of models of DWRR, $Q_{(FCD)}$ is the set of models of DPC, $Q_{(OC)}$ is the set of models of operating conditions; $F_{(vehicle+trailer)}$ – functional representation of models of the state of vehicle with trailer, $F_{(MWRD)}$ – functional representation of models of DWRR, $F_{(FCD)}$ – functional representation of DPC models, $F_{(OC)}$ – functional representation of models of operating conditions of the vehicle.

The construction of the model for managing the vehicle technical condition in interaction with DWRR, DPC is shown in (2):

$$Q_{V\,OP} \longrightarrow \begin{Bmatrix} Q'_V \\ Q'_{MWRD} \\ Q'_{FCD} \end{Bmatrix} \longleftarrow Q_{C.VOP}, \tag{2}$$

where the process of correction $Q_{C.VOP}$ – a set of vehicle control models has the possibility of correction due to: Q'_V – variability in terms of speed, fuel consumption, vehicle condition; Q'_{MWRD} – operating modes of the truck crew; Q'_{FCD} – crew change procedures, technological stops of the vehicle for crew rest.

5. 3. Construction of a general information model of the subject area of the remote operational control system

The database model of the information system for the operational monitoring of the vehicle technical condition and the modes of operation of the crew under operational conditions was built [8–11, 20–24, 58]. The model of the subject area M_g of the remote system for monitoring the parameters of the condition of a cargo vehicle includes the following components: DWRR control (tachograph), tracker, and DPC registration tools. It is represented as the following set of constituents and components of the information system:

– parameters of the technical condition of the MTZ vehicle;

– DWRR regimes M_{tg};

– additional parameters of the state of the vehicle, trailer, environmental indicators of the vehicle M_{tr};

– the physical condition of the driver M_{FCD}.

The general form of the formulas is:

$$M_{gen} = \begin{Bmatrix} M_v \\ M_{tg} \\ M_{tr} \\ M_{FCD} \end{Bmatrix}_V = \begin{Bmatrix} \left\langle O_V, V_{V\,in.}, V_{V\,out.}, F_V, H_V, P_V, R_V \right\rangle \\ \left\langle O_{tg}, V_{tg\,in.}, V_{tg\,out.}, F_{tg}, H_{tg}, P_{tg}, R_{tg} \right\rangle \\ \left\langle O_{tr}, V_{tr\,in.}, V_{tr\,out}, F_{tr}, H_{tr}, P_{tr}, R_{tr} \right\rangle \\ \left\langle O_{FCD}, V_{FCD\,in}, V_{FCD\,out}, F_{FCD}, H_{FCD}, P_{FCD}, R_{FCD} \right\rangle \end{Bmatrix}, \tag{3}$$

For the functional of the domain model (3), it is possible to write the following dependences: $V_{V\,in}=\{v_{Vl}|\epsilon L_{Vin}\}$ – as for sets of input information elements; $V_{V\,in}=\{v_{Vl}|\in L_{V\,in}\}$ – as for sets of initial information elements; $V_{V\,in}\cup\in V_{V\,in}$ – as for complete sets of information elements; $F_V = \left\{ f_{Vi} \mid i_V = \overline{1, I_V} \right\}$ – as for sets of usage functions; $H_V = \left\{ h_{Vj} \mid j_{Vg} = \overline{1, J_V} \right\}$ – as for sets of data processing tasks of the parameter control system; $P_V = \left\{ p_{Vk} \mid k_V = \overline{1, K_V} \right\}$, where P is the set of users (composition and number of personnel), which should enable monitoring of the parameters of the vehicle, DWRR, tracker, DPC in the vehicle status system; $R_V = \left\{ r_{Vy} \mid y_V = \overline{1, Y_V} \right\}$ written for the set of possible relations of the system. Also, by analogy, it is recorded for implementation for M_{tg}, M_{tr}, M_{FCD}.

The formalized construction (description) and analysis of the system of remote technical control of vehicle condition, with the use of the DWRR, DPC, tracker controls and their analytical description was performed using Boolean adjacency matrices. The relations of R_V, R_{tg} and R_{tr}, R_{FCD} among constituent components M_V, M_{tg} and M_{tr}, M_{FCD} (3) of the subject area of vehicle system are described accordingly.

The following types of complex relations between the sets of the system $\{F,H,P,O,V,R\}$ were selected for the subject areas of the vehicle state (cargo with trailer). The obtained relationships are entered into the appropriate tables to describe the main subject area of the experimental system for controlling the parameters of the vehicle, the tracker, and means of control over DWRR and DPC.

The main formulas are given below in a general form:

$$F_V H_V = \left\| f_V h_{V\,ij} \right\|; \tag{4}$$

$$F_V P_V = \left\| f_V p_{V\,ik} \right\|; \tag{5}$$

$$F_V O_V = \left\| f_V o_{V\,im} \right\|; \tag{6}$$

$$F_V V_V = \left\| f_V v_{V\,il} \right\|; \tag{7}$$

$$H_V P_V = \left\| h_V p_{V\,jk} \right\|; \tag{8}$$

$$H_V O_V = \left\| h_V o_{V\,im} \right\|; \tag{9}$$

$$H_V V_V = \left\| h_V v_{V\,jl} \right\|; \tag{10}$$

$$O_V V_V = \left\| o_V v_{V\,ml} \right\|. \tag{11}$$

By analogy, we distinguish the types of relations formed for the implementation of the subject area of vehicle, means of monitoring DWRR and DPC in the system of the state of cargo vehicle. By using Boolean adjacency matrices, which precisely determine the correspondence of relations R_V between the main components of the subject area (M_V), it was possible to form an analytical description of the semantics of the system. Matrix elements that have a relationship (joint relationships) between components are equal to 1, and if not, then they are equal to 0 in this case. Within the information model, a set of relationships (joint relationships) between the main components of the subject area of cargo vehicle with a trailer M_V is defined [8–11, 20–24, 58].

The set of structural elements of the system for monitoring the state of vehicle was determined in the following form: elements of the sets of information elements of automation objects (V) as a product with elements of the sets of automation objects (O) and were indexed accordingly. As a result of the determination, a set of elements of the system of monitoring the vehicle condition with a trailer was obtained:

$$D_V = \left\{ d \middle| l_V = 1.67 \right\}, \tag{12}$$

$$P_V\left(D_V\right) = 67, \tag{13}$$

$$D_{tg} = \left\{ d \middle| l_{tg} = 80.99 \right\}, \tag{14}$$

$$P_{tg}\left(D_{tg}\right) = 20, \tag{15}$$

$$D_{tr} = \left\{ d \middle| l_{tr} = 120.134 \right\}, \tag{16}$$

$$P_{tr}\left(D_{tr}\right) = 15, \tag{17}$$

$$D_{FCD} = \left\{ d \middle| l_{FCD} = 1.11 \right\}, \tag{18}$$

$$P_{FCD}\left(D_{FCD}\right) = 11. \tag{19}$$

The definition of the set of precedence $C(d_i)$ and reachability $F(d_i)\forall d_i\in D$ was made possible by the coincidence of the semantic reachability matrices A and the semantic adjacency matrix B.

The single entries in each i-th column of the matrix correspond to the elements of the precedence sets C(di), and the single entries in each i-th row of the semantic reachability matrix A correspond to the elements of the set $F(d_i)$. The identification of basic types of structural elements, such as information elements and groups, is possible owing to the analysis of the precedence set $C(d_i)$. Precedence set structures $C(d_i)=0$ correspond to information elements with hanging vertices on the organized graph G of the system.

The resulting sets of precedence and reachability for each selected structural element in the system of remote monitoring of the parameters of vehicle condition (truck with trailer) were carried out by calculation:

$$\forall i_{V1}, i=1,\ldots,59\ C(d_i)=\varphi; \tag{20}$$

$$C_{V1}(d_{V61})=\left\{\frac{d_i}{i}=1,\ldots,18,60\right\}, \tag{21}$$

$$C_{V1}(d_{V62})=\left\{\frac{d_i}{i}=19,\ldots,25,60\right\}, \tag{22}$$

$$C_{V1}(d_{V63})=\left\{\frac{d_i}{i}=26,\ldots,30,60\right\}, \tag{23}$$

$$C_{V1}(d_{V64})=\left\{\frac{d_i}{i}=31,\ldots,36,60\right\}, \tag{24}$$

$$C_{V1}(d_{V65})=\left\{\frac{d_i}{i}=37,\ldots,42,60\right\}, \tag{25}$$

$$C_{V1}(d_{V66})=\left\{\frac{d_i}{i}=43,\ldots,58,60\right\}, \tag{26}$$

$$C_{V1}(d_{V67})=\left\{\frac{d_i}{i}=59,60\right\}. \tag{27}$$

$$\forall i_{VFCD}, i=61,\ldots,67\ F(d_i)=\varphi; \tag{28}$$

$$\forall i_{V1}, i=1,\ldots,18\ F(d_i)=\{d_{V61}\}; \tag{29}$$

$$\forall i_{V1}, i=19,\ldots,25\ F(d_i)=\{d_{V62}\}; \tag{30}$$

$$\forall i_{V1}, i=26,\ldots,30\ F(d_i)=\{d_{V63}\}; \tag{31}$$

$$\forall i_{V1}, i=31,\ldots,36\ F(d_i)=\{d_{V64}\}; \tag{32}$$

$$\forall i_{V1}, i=37,\ldots,42\ F(d_i)=\{d_{V65}\}; \tag{33}$$

$$\forall i_{V1}, i=43,\ldots,58\ F(d_i)=\{d_{V66}\}; \tag{34}$$

$$\forall i_{V1}, i=59\ F(d_i)=\{d_{V67}\}; \tag{35}$$

$$F_{V1}(d_{V60})= \\ =\{d_{V61},d_{V62},d_{V63},d_{V64},d_{V65},d_{V66},d_{V67}\}. \tag{36}$$

By analogy, for the model of remote control over vehicle state parameters, we perform for other subsystems.

During the formation of values for the elements of the information system for monitoring vehicle condition, it is necessary to determine the sum of the elements of each of the j columns of the matrix A. The j-th element of the structural set of the system is informative if $\sum_{i=1}^{P(D)} a_{i,j}=0.$ In the opposite case, it is a group element (group), specifically:

$$\begin{cases} \sum_{i=1}^{67} a_{iV1}=\sum_{i=1}^{67} a_{iV2}=\sum_{i=1}^{67} a_{iV3}=\ldots=\sum_{i=1}^{67} a_{iV60}=0, \\ \sum_{i=1}^{67} a_{iV61}>0, \sum_{i=1}^{67} a_{iV62}>0, \sum_{i=1}^{67} a_{iV63}>0, \\ \sum_{i=1}^{72} a_{iV64}>0, \sum_{i=1}^{72} a_{iV66}>0, \sum_{i=1}^{72} a_{iV66}>0, \sum_{i=1}^{72} a_{iV67}>0. \end{cases} \tag{37}$$

The definition of the set of information elements of the system D^d is as follows:

$$D^d_{V1}=\{d_{V1}-d_{V59}\}; \tag{38}$$

$$D^d_{tg2}=\{d_{tg80}-d_{tg93}\}; \tag{39}$$

$$D^d_{tr3}=\{d_{tr120}-d_{tr131}\}; \tag{40}$$

$$D^d_{FCD3}=\{d_{FCD151}-d_{FCD158}\}. \tag{41}$$

The sets of elements of the group (group elements) D^d were immediately defined:

$$D^d_{V1}=D\setminus D^d= \\ =\{d_{V61},d_{V62},d_{V63},d_{V64},d_{V65},d_{V66},d_{V67}\}; \tag{42}$$

$$D^d_{tg2}=D\setminus D^d=\{d_{tg95},d_{tg96},d_{tg97},d_{tg98},d_{tg99}\}; \tag{43}$$

$$D^d_{tr3}=D\setminus D^d=\{d_{tr133},d_{tr134}\}; \tag{44}$$

$$D^d_{FCD4}=D\setminus D^d=\{d_{FCD160},d_{FCD161}\}. \tag{45}$$

Also, common information elements existing for the system were determined for all groups of the subject area of the system of remote monitoring of the parameters of vehicle condition (truck with trailer). These elements, respectively, are «Information collection time» – d_{V60}, d_{tg94}, d_{tr132}, d_{FCD159}, are key precisely because of the semantic dependence in the issue of obtaining parameters for monitoring vehicle condition on the set time of collecting (receiving) information. Taking into account the peculiarities of the construction, an information system for remote monitoring of the state of vehicle was built, which has an appropriate set of keys for all components:

$$W_{1.1}=\{d_{60}\}, \tag{46}$$

$$W_{2.1}=\{d_{94}\}, \tag{47}$$

$$W_{3.1}=\{d_{132}\}, \tag{48}$$

$$W_{4.1}=\{d_{174}\} \tag{49}$$

and, accordingly, the system of monitoring the condition of vehicles with installed means of monitoring DWRR and DPC has the appropriate sets of attributes:

$$W_{1.2}=\{d_i/i=1,\ldots,59\}, \tag{50}$$

$$W_{2.2}=\{d_i/i=80,\ldots,93\}, \tag{51}$$

$$W_{3.2} = \{d_i / i = 120, ..., 131\}, \quad (52)$$

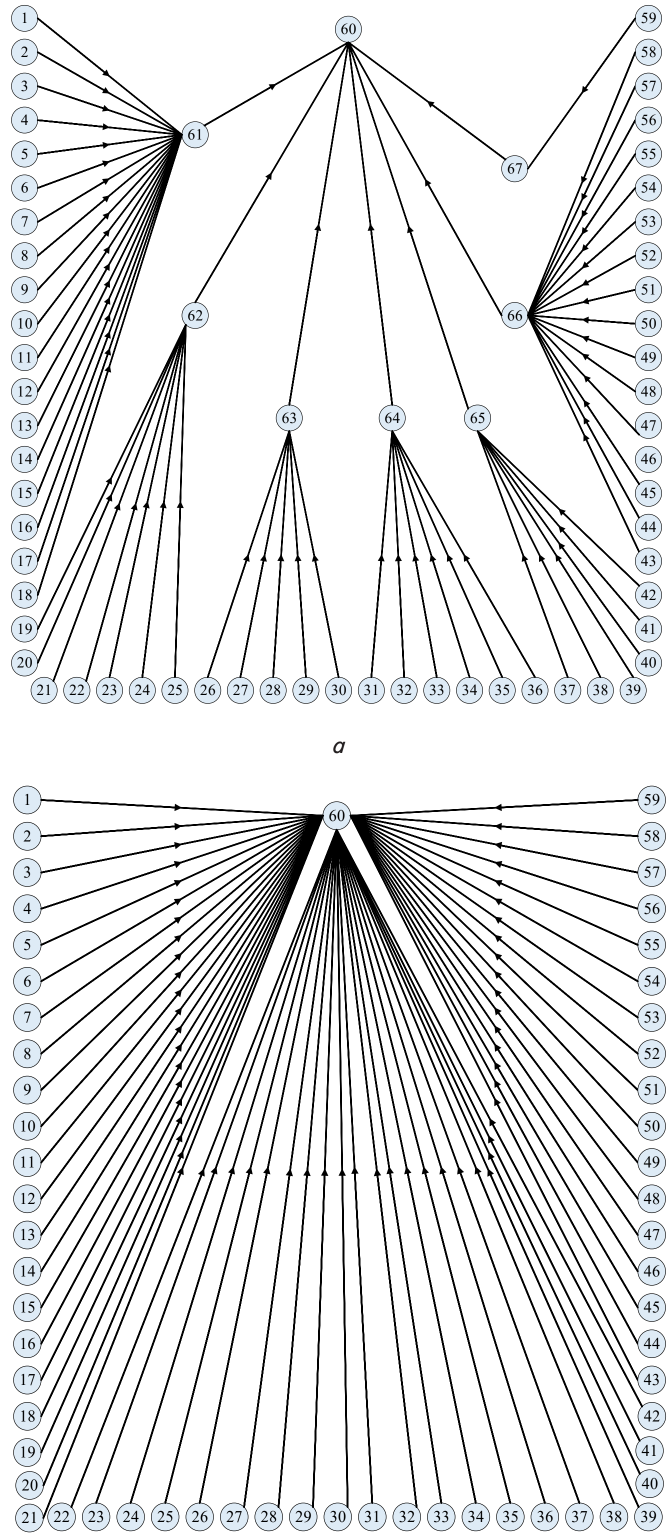
$$W_{4.2} = \{d_i / i = 151, ..., 158\}. \quad (53)$$

A relational model of the remote parameter control system was built. It is based on the canonical form for the structure of the received data base, according to the set of possible values of the main parameters of the state of vehicle with a trailer in interaction with the values of DWRR and DPC. After the analysis, the obtained information makes it possible to build a relational database data management system. In Fig. 3, we show the organized graphs of the system of operational monitoring of the state of vehicle. The general organized graph G of the canonical structure of the vehicle condition control system model is shown in Fig. 4.

The form of the constructed function that characterizes the operation of the model of vehicle remote monitoring condition in accordance with changes in the parameters of DWRR and DPC is represented below:

$$K\left\{\begin{array}{l}\left\{\begin{array}{l}F_{tC}\left(\begin{array}{l}\overline{H_{tC}}, t, \Delta t, \overline{X}_i(t),\\ \overline{X}_i(t-\Delta t), ..., \overline{X}_i(t-n\Delta t),\\ DK_{Vi}, DK_{FCDi}, DK_{MWRDi}\end{array}\right) = \lambda_{CV},\\ \Psi_l^{mi}\left(e_Q, r\right)^J = \lambda_{CV},\end{array}\right.\\ \left\{\begin{array}{l}H_{tC} = f\left(G_{Vavgi}, t, s, v_V\right),\\ DK_{Vi} = f\left(t, s, v_V\right),\\ DK_{FCDi} = f\left(t, s, v_V\right),\\ DK_{MWRDi} = f\left(t_{reg}, t, s\right),\end{array}\right.\end{array}\right. \quad (54)$$

where F_{tC} – parameters of the state of vehicle with a trailer depending on the values of DWRR during remote monitoring; $\overline{H_{tC}}$ – characteristic of the control body(s) vector as a function of the average operational fuel consumption of a motor vehicle with a trailer ($G_{Vavg\,i}$) depending on time (t); t is the current value of time; Δt is the interval between time measurements; at i=1, ... , m – parameters of the state (technical state) when enabling control over the state of vehicle and DWRR; n – number of intervals (number) from past measurements; DK_{Vi} – control results and identification of malfunctions of vehicles with trailers (indicators, codes); DK_{FCDi} – monitoring and analysis of DPC values (crew members) during operation of the vehicle; DK_{MWRDi} – results of control and analysis of DWRR during the operation of a motor vehicle with a trailer; s – route length; t_{reg} – regulatory and legal regimes of DWRR; m_i – number of measurements; l – connection of means of observation and facilities for enabling the processes of monitoring and correcting vehicle technical condition, DPC and DWRR under the conditions of operation of vehicle with a trailer; Ψ – conditional mapping operator; e_Q is a set of conditional mappings of the properties of sub-objects of the system for m_i precisely on J in l; r is the set of relations between the properties of sub-objects of the system for m_i exactly according to J in l; J is a task for the system; λ_{CV} is a system for implementing the processes of monitoring the state of vehicle and the modes of operation of the crew during vehicle operation (the system for implementing the monitoring processes λ_{CV} is a collection of sets of conditional mapping of the properties of sub-objects of the system e_Q and their ratios r for m_i on J in l.



a

b

Fig. 3. Organized graphs of the system of operational monitoring of vehicle condition parameters: *a* – organized graph *G* of the constructed information structure of the system model; *b* – organized graph *G* of the constructed canonical structure of the system model

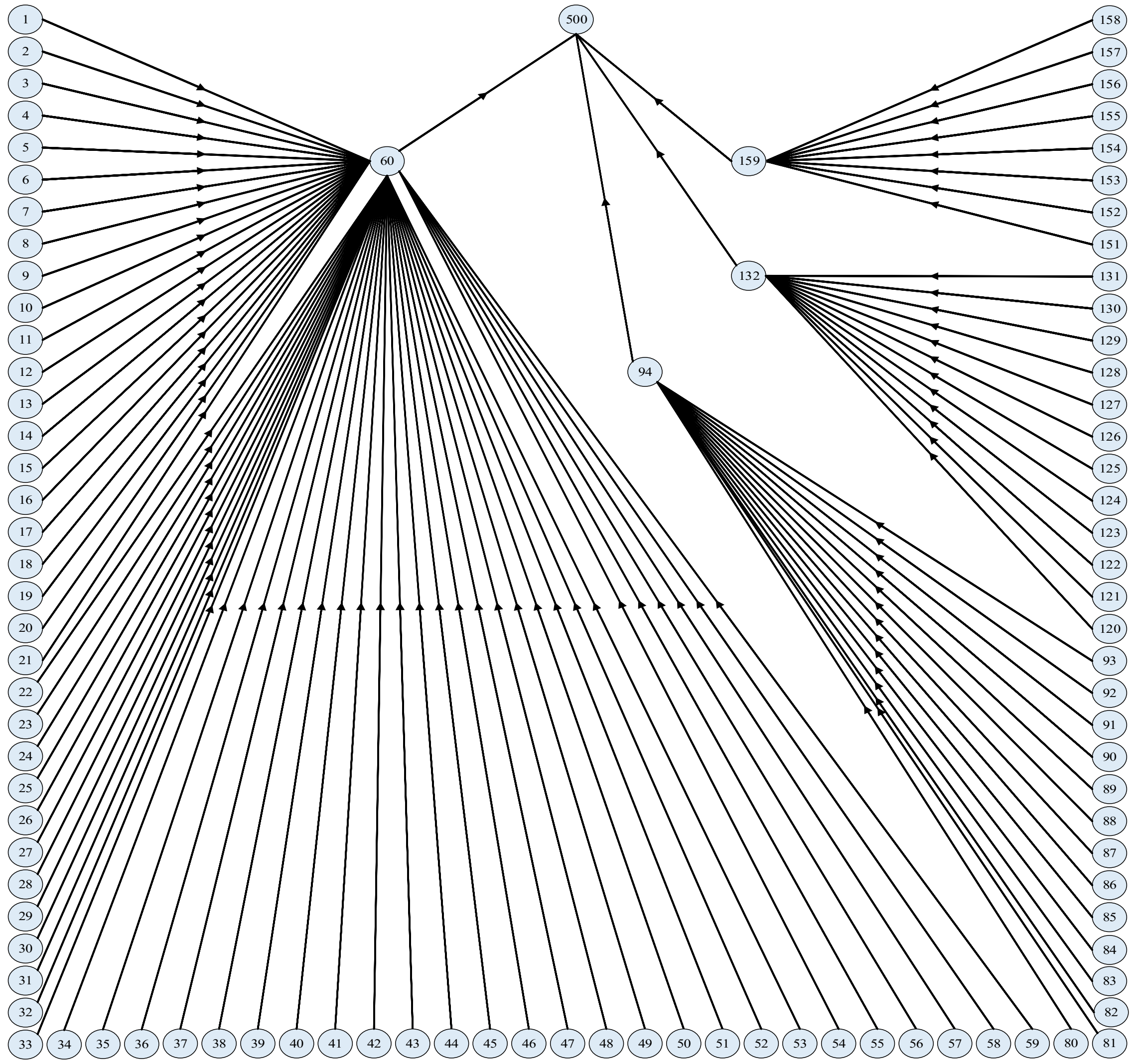


Fig. 4. General organized graph *G* of the canonical structure of the constructed model of a vehicle condition monitoring system

5. 4. Design of the structure of functional capabilities for the monitoring system

The interrelationship and structure of the functional capabilities of ICC for monitoring the condition of vehicle, DPC, DWRR owing to the on-board part of ICC are shown in Fig. 5.

The main functions of ICC, which are the basis of system interaction:

– guaranteeing the determination of the location of the vehicle (tracking the position of the vehicle) in space;

– guaranteeing control over parameters of the state of vehicle with a trailer, DPC, DWRR in the processes of operating the vehicle;

– guaranteeing the safety of movement of the cargo vehicle.

The main functions of the ICC function owing to the guaranteed performance of the functions of the system of interaction of the design features of VTZ and the constituent elements of ITS (Fig. 5):

– laying the route;

– interaction with maps;

– the process of identification of the truck driver;

– vehicle condition parameters (technical parameters);

– DPC;

– monitoring of received parameters from sensors connected by K-line, L-line, CAN, and their protocols;

– monitoring of DPC parameters and the condition of vehicle;

– analysis and transfer of data on violations of DWRR, DPC, traffic regulations;

– data related to system errors and malfunctions of vehicles with a trailer, values of pollutants transmitted to the external information storage, etc.

Subsequently, this information is analyzed and distributed among the objects of automation of vehicles, which form a list of databases of states of vehicles and their operating conditions based on ITS and infrastructure, specifically the following basic information modules:

– collection and transmission of current information about the condition of motor vehicle;

– collection and transmission of current information regarding fuel consumption of vehicles;

– collection and transmission of current information on enabling the limit values of emissions of pollutants in the exhaust gases of the vehicle engine;

– collection and transfer of current information regarding the results of diagnostics of the technical condition of vehicles with trailers;

– collection and transmission of current information from a vehicle with a trailer regarding the parameters of the vehicle's technical condition;

– collection and transmission of current information regarding compliance with the operating conditions of the vehicle;

– collection and transmission of current information regarding the identification of vehicle;

– collection and transmission of current information regarding DPC;

– collection and transmission of current information regarding identification of vehicles, tachograph, and crew members;

– collection and transmission of current information regarding violations of the traffic rules and DWRR by members of the vehicle crew;

– collection and transmission of current information regarding DWRR of vehicle;

– collection and transmission of current information regarding the speed of vehicles (means of registration of DWRR);

– collection and transmission of current information regarding the current working vehicle condition;

– collection and transmission of current information regarding the vehicle technical condition and trailer (equipment can be installed additionally);

– collection and transmission of current information regarding the registration of pollutant emission values (equipment can be installed additionally).

Owing to the exchange of information between the elements of the model of remote monitoring of cargo vehicles, which was carried out under manual, automated, and automatic modes, all parameters were obtained in real time.

Several channels were used to transmit the values of the monitoring parameters from the on-board part of the ICC vehicle to the operator's automated workplace (external server).

The first set, specifically aggregate I – the internal networks of vehicle (IN V) – included the vehicle with a trailer, the crew members of the vehicle, the engine of the vehicle, sensors in the OBD-II standard support system. Set II – the automated complex of remote control and inspection of the technical condition (AC RCITC) (Fig. 6) of the vehicle, trailer, ICE, DPC, DWRR – included the means of monitoring DWRR, DPC, a tracker, and an on-board intelligent diagnostic system. Set III – the external automated workplace of a technical service specialist (EAW TSSV) (Fig. 6) – included the workplace of an automated internal network, databases, and a Web server. Set IV – the system of automated determination of workability and management of vehicle operation (SADWMVO) – included the list of participants in the vehicle operation process, software (software) and directly the intelligent software package «CMV».

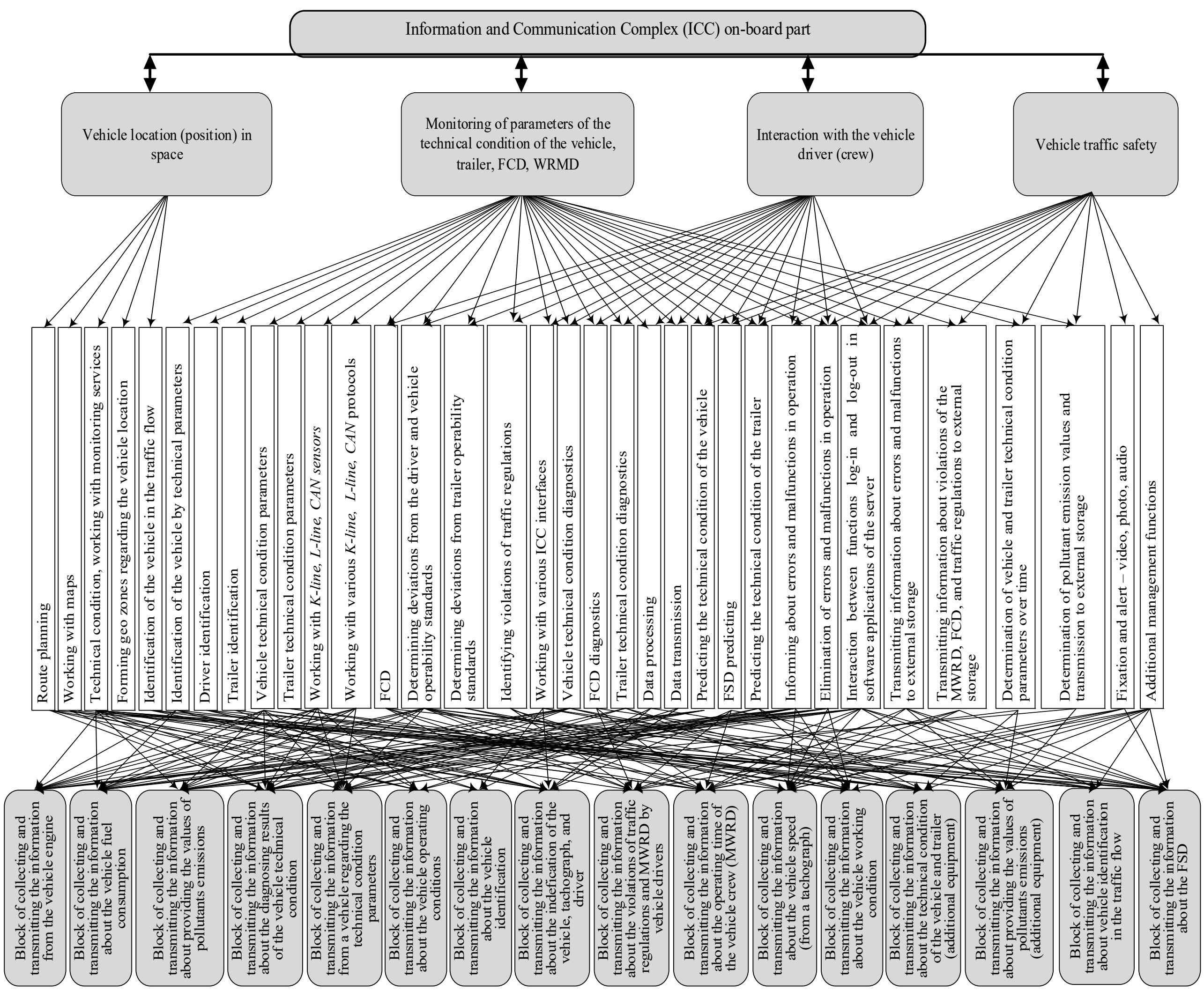


Fig. 5. Structure and relationship of functional capabilities of the on-board information and communication system

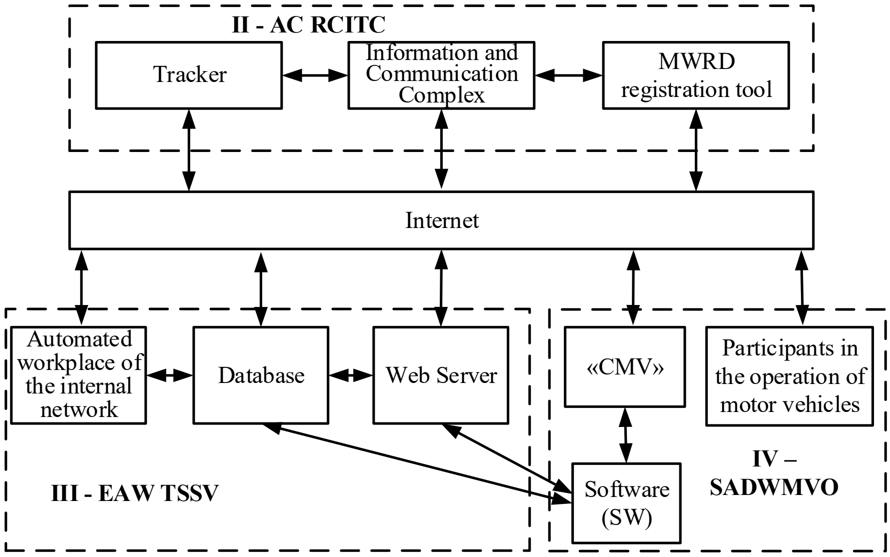


Fig. 6. Block diagram characterizing the information exchange between sets of elements of the system of operational monitoring of vehicle state

and DWRR. And when the programmed emergency values of these parameters are reached, notify the truck driver or the technical service. For this purpose, continuous two-way communication by ITS means is supported during the monitoring of vehicle.

During the construction of the system for operational monitoring of the condition of vehicles with a trailer during operation, its purpose was determined, specifically, the optimization of operation of the fleet of cargo vehicles. Such a system guarantees the implementation of system solutions in terms of monitoring vehicle and managing their life cycle during operation. Continuous monitoring of the technical condition of the cargo vehicle, DWRR, and DPC is also guaranteed.

When using the OBD-II connector (scanner-adapter) (for vehicles with a trailer that support the OBD-II standard), we have the opportunity to obtain information on changes in the parameters of the cargo vehicle (Fig. 1) of set I – IN V owing to additional sensors. These are such parameters as fuel consumption G_T, air consumption G_B, ICE speed n_v, vehicle speed V, angle of rotation θok of the control body, temperature of the coolant t °C of ICE, etc. When using the OBD-II adapter (scanner), the received information is transmitted to III – EAW TSSV with the possibility of connecting to a paired device. This happens with the use of Wi-Fi or USB, or Bluetooth, or ICC of the set (Fig. 6) II – automated system. But it should consist not only of a scanner-communicator controller (tracker) but also GPRS, IKK, SBAS, GPS, a-GPS, GLONASS, Internet, or a local network. And then transfer to the Web server, the database, and to the external automated workplace of the technical service specialist in the internal network of the system.

By analogy with the above, the parameters of DWRR are monitored. Information about DPC under operational conditions is obtained using additional sensors for control of crew members (regarding pulse, pressure, stress, fatigue, etc.). The automated workplace of the technical service specialist of the internal network of the system of remote monitoring of vehicles under operational conditions can be connected or disconnected from the system by software. The main difference between the indicated modes is the connection to the work of the information and analytical system «CMV» at the workplace of the technical service specialist of the internal network of the system and for the implementation of monitoring, analysis, and correction of the entire range of operating conditions of the trailer, DPC, DWRR.

Owing to the work of ICC, it was possible to accurately determine the location and condition of each cargo vehicle and transfer this information to the set III – EAW TSSV. ICC determines the location of the vehicle using navigation satellite systems and a GPRS receiver.

Clusters II, III, and IV have the ability to exchange information all the time, specifically to transmit digital, video, and voice data using GPRS, SBAS, GPS, a-GPS, the Internet, or a local network (Fig. 6). ICC has the ability to independently analyze the parameters of the technical condition of vehicle, DPC,

5. 5. Results of implementing the information and analytical model of a remote monitoring system

The basic technical-economic indicator characterizing vehicle operation is its speed. There is technical and operational speed [9, 45].

The operating speed of a vehicle is the average speed of the vehicle during the time it is on the route. In contrast to the technical speed of a vehicle, when calculating this speed, the full time of the vehicle's stay on the route is taken into account.

The operational speed of a vehicle is determined by the following formula:

$$V_o = S/t_r, \tag{55}$$

where S is the distance (mileage) covered by the vehicle; t_r – the time the vehicle is on the route, hours.

The technical speed of a vehicle is the average speed during the time the vehicle is in motion on the route it is determined by the following formula:

$$V_t = S/t_m, \tag{56}$$

where S is the distance (mileage) covered by the vehicle, km; t_m – the time of vehicle movement, taking into account stops while waiting for the opportunity to continue movement on the route, not taking into account the time of loading and unloading of the vehicle).

The value of the technical speed is influenced by vehicle technical condition, the condition and profile of roads, the intensity of traffic on the freight transportation route. Technical speed directly affects fuel consumption. Therefore, it is up to the driver (or network operator) to choose the most rational mode of movement, taking into account the listed factors, depending on his/her qualifications, DPC, DWRR. Today, there are the following basic means of researching fuel consumption and vehicle speed parameters. For this purpose, the peculiarities of the characteristics of the vehicle movement over the distance of the entire section of the route are determined. This can be implemented by dividing the route section into equal segments, or by dividing the section into segments taking into account geozones [45–55].

Coefficients characterizing the main technical and economic indicators of the vehicle and the driver were introduced.

The relative coefficient of change of movement speed (RCCMS) of the vehicle as the main criterion for determining groups of operating conditions [1, 3, 9–11]. It is determined by the following formula:

$$K_{v\,r}=S/(t_m \cdot V_{a1}) \approx 1.43 \cdot S/(t_m \cdot V_{\max}), \quad (57)$$

where V_{a1} is the speed of a motor vehicle with a trailer on the road of the 1st group (i. e., 0.7 $V_{\max}$).

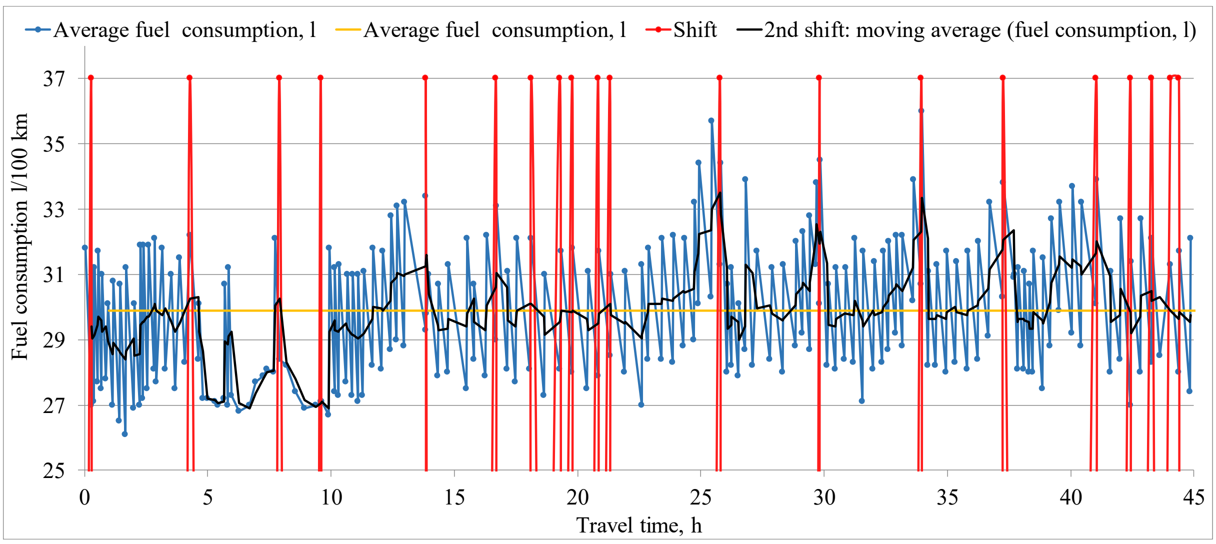
The coefficient of use of speed (CUS) is intended for evaluating the speed of movement of vehicles. It is determined by the following formula:

$$K_{v\,u}=V_{i\,\text{avg}}/V_{i\,\text{int}}, \quad (58)$$

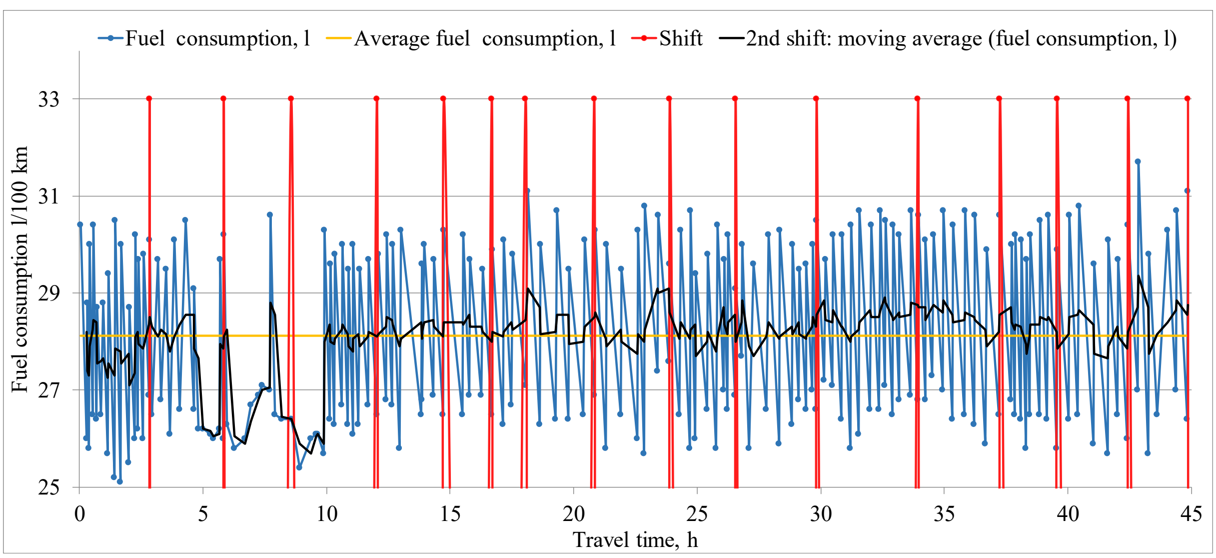
where $V_{i\,\text{avg}}$ is the average speed of a vehicle on the i-th section, $V_{i\,\text{int}}$ is the set speed limit of a vehicle on the i-th section of the route.

The described method for processing parameters of remote control over a vehicle was previously described in [8–11, 20–24, 45]. In contrast to the previous options for processing parameters of remote control over vehicles, the CMV system allows for remote monitoring of the state of the vehicle, DPC, compliance with DWRR, environmental indicators and compliance by the vehicle with the speed regime on the route.

As a result of our study, a diagram was constructed characterizing the change in fuel consumption indicators for the vehicle in relation to time in the process of movement and DWRR indicators (Fig. 7).



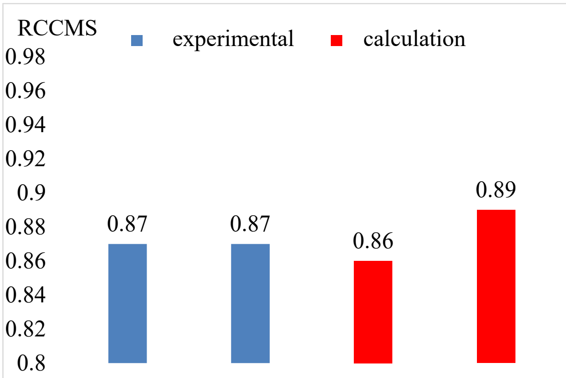
a



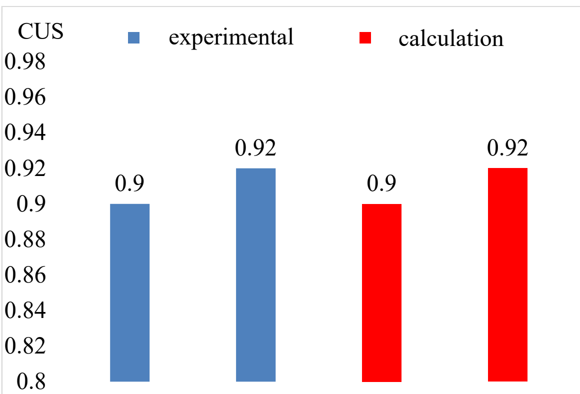
b

Fig. 7. Dependence of fuel consumption in relation to time during the movement of a vehicle with a trailer: *a* – experimental results of changes in fuel consumption by a vehicle depending on the time of its movement and DWRR; *b* – calculated results of changes in the fuel consumption by a vehicle depending on the time of its movement and the optimal ratio of DWRR

Fig. 8 shows a change in the value of RCCMS and CUS after improvement of DWRR.



a



b

Fig. 8. Change in the value of the relative coefficient of change in the speed of a vehicle and the coefficient of use of the speed of a vehicle as a result of the improvement of the driver's work and rest modes: *a* – relative coefficient of change in the speed of a vehicle; *b* – coefficient of utilization of the vehicle speed

After the calculated determination of the optimal DWRR, and as a consequence, the improvement of DPC, subject to the condition $\upsilon \rightarrow$const, the entered coefficients changed as follows:

– RCCMS of the vehicle within the population centers on the route remained unchanged and, between the population centers on the route, changed from 0.86 to 0.89;

– vehicle's CUS within the population centers on the route changed from 0.9 to 0.92 and, between population centers on the route, changed from 0.9 to 0.92.

6. Discussion of results of implementing the information-analytical model of the remote monitoring system of a cargo vehicle

The proposed information system for monitoring cargo vehicles [38–45] has a number of features. The main thing is that it is able to perform the DWRR check during the determination of the parameters of the technical condition of the cargo vehicle with the help of a modern on-board information and communication system.

The constructed model of system interaction makes it possible to remotely receive information on changes in the parameters of technical condition, DWRR, and DPC in real time and has the possibility of correcting it in order to achieve rationalization of fuel consumption over the entire distance of the route. An information-analytical system for control and correction of parameters of the state of vehicles with a trailer was formed based on the application of the morphological matrix when the conditions of operation of the vehicle with a trailer are changed.

The subject area of the model of the system of operational remote control and correction of parameters of the technical condition and modes of operation of the cargo vehicle has been formed. It was represented as a set of components and modules of the information system. These are parameters of the vehicle technical condition; DWRR; additional parameters of vehicle condition, trailer, environmental indicators of the vehicle and DPC.

The structure of the functional capabilities of the monitoring system and information exchange between the elements of providing remote monitoring of the technical condition of vehicles under operational conditions has been designed. The main feature of such a monitoring system is that the parameters of the vehicle technical condition are determined taking into account the parameters of DPC and DWRR. Depending on the received data, it is possible to adjust one or another parameter.

With the help of the obtained data and the formed fuel consumption trend, it was experimentally proven that the fuel consumption (Fig. 7) after 3–3.5 h. of continuous management of cargo vehicles with a trailer – increases.

The implementation of our method is based on the continuous implementation of remote control of the state of vehicle and DPC, taking into account the operating conditions using ITS tools.

Further advancement of the information system is possible with the help of the decomposition of objects (Fig. 2) included in its composition. Based on this, further refinement of the model is possible.

It is impossible to optimize the values of sets of models of parameters of control and correction of the condition of vehicle, DPC, and DWRR purely analytically. This is due to the fact that the fuel consumption of a motor vehicle with a trailer during operation is directly dependent on the features of the route, the complexity of the road topography, the load factor of the motor vehicle, compliance with DWRR and DPC. The hardware for vehicle monitoring systems, as well as techniques and methods of implementing the vehicle and DPC monitoring itself, require further development. All of the above requires further development of the infrastructure and means of control to enable full functioning of the V2I information system.

In addition, the method of complete selection of parameters, which has been used so far to solve the problem of nonlinear programming, needs further refinement in terms of improving the mathematical apparatus.

7. Conclusions

1. Based on the formed subject area of the information system for operational remote monitoring over the technical condition and operating modes of a cargo vehicle, a DFD data flow diagram was built, which is one of the main means

for modeling the functional requirements of software for remote monitoring. With their help, these requirements are broken down into functional components and represented in the form of a network connected by data flows. As a result of the decomposition of the objects included in its composition, further refinements of the model were carried out. This made it possible to solve the following tasks of monitoring the state of a vehicle: collection of data from vehicle; data storage; the possibility of identification of vehicles on the route and in the remote monitoring system; the ability to build functional dependences over time; remote control over the parameters of vehicle technical condition and the possibility of forecasting them; monitoring of changes during operation; diagnosing the state of a vehicle and its comparison with the specified parameters.

2. A model of system interaction of parameters and a model of remote monitoring of the condition of a vehicle with a trailer during operation have been constructed. The use of these models allows remote operational monitoring of the technical condition of vehicles based on the system interaction of monitoring components, specifically the vehicle, operating conditions, transport infrastructure, and road infrastructure.

3. A general information model of the subject area of remote control and correction of the parameters of the technical condition and DWRR of vehicle has been developed. The components are the tracker and means of registration of DWRR and DPC. A list of features of the subject area of the information system model was described in the form of a DFD diagram. A set of elements of the remote monitoring model and their interrelationships are separated. Graphs of informational structural elements of systems of remote monitoring of the technical condition of vehicle in real time were built. With their help, a set of information elements of the subsystems of the model were determined, specifically, the vehicle and engine technical condition, DWRR, DPC, environmental and additional indicators of the vehicle. The general information element «Time of information collection» has been introduced, it applies to all information groups. This element is key due to the semantic dependence of the resulting data.

4. The structure of the functionality of the monitoring system, which was developed on the basis of the proposed models, made it possible to consider the peculiarities of the information exchange between the elements of providing real-time operational control of the state of vehicles.

A block diagram of information exchange between sets of elements of remote monitoring of vehicle state parameters in real time was constructed. The model of the system for remote monitoring of vehicle condition parameters in real time is intended for solving the production tasks of the operation of road transport and optimizing the operation of the fleet of cargo vehicles. Such a system guarantees system solutions for monitoring and managing the life cycle of vehicle during its operation. It also guarantees continuous monitoring of the state of the vehicle with a trailer, DPC, and DWRR, which makes it possible to control the change of parameters that are registered, as well as to build databases regarding the state of the vehicle and operating conditions.

5. The results of implementing the information-analytical model of the system for remote monitoring and operational control over the state of cargo vehicles confirmed the effectiveness of the proposed measures. During the calculated determination of the optimal DWRR, observing the stability of the speed of the vehicle, the changes of the investigated coefficients occurred as follows. The relative coefficient of change in the speed of vehicle movement within the population centers on the route remained unchanged, and between population centers on the route changed from 0.86 to 0.89. The coefficient of use of vehicle speed within the population centers on the route changed from 0.9 to 0.92 and, between population centers on the route, changed from 0.9 to 0.92. As a result of experimental studies and analytical calculations, it was established that the rational fuel consumption by a truck with a trailer, taking into account DWRR and DPC, is enabled on the route when the crew is changed every three hours.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

Funding

The study was conducted without financial support.

Data availability

The data will be provided upon reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

References

1. Komov, P. B., Volkov, V. V. (2005). Problemy orhanizatsiyi tekhnichnoi ekspluatatsiyi avtomobiliv u suchasnykh umovakh hospodariuvannia. Visnyk Skhidnoukrainskoho natsionalnoho universytetu im. Volodymyra Dalia, 6 (88), 128–132.
2. Grynkiv, A. V. (2016). The Use of Forecasting Methods in Managing the Technical State of Aggregates and Vehicle Systems. Agricultural Engineering, Industrial Engineering, Automation, 29, 25–32.
3. Smyrnov, Y., Borysiuk, D., Volobuyeva, T., Nastenko, M., Plakhtii, T. (2023). Model for devising and defining technical development projects of motor transport enterprises. Eastern-European Journal of Enterprise Technologies, 5 (3 (125)), 23–34. https://doi.org/10.15587/1729-4061.2023.289004
4. Troitskiy-Markov, T. Y., Sennovskiy, D. V. (2011). Principles for energy efficiency monitoring system. Monitoring Science and safety, 4, 34–39.

5. Davydenko, L. V., Davydenko, V. A., Komenda, N. V., Yarmolska, N. V. (2014). Energy monitoring functions of compound production systems and their objectives for increasing energy efficiency. The Herald of KhNTUA. Technical sciences. «Problems of energy supply and energy saving in agricultural sector of Ukraine», 153, 125–127.
6. Podrigalo, M., Klets, D., Sergiyenko, O., Gritsuk, I. V., Soloviov, O., Tarasov, Y. et al. (2018). Improvement of the Assessment Methods for the Braking Dynamics with ABS Malfunction. SAE Technical Paper Series. https://doi.org/10.4271/2018-01-1881
7. Khavruk, V. O. (2020). Analysis of the safety of motor vehicles and the current state of the mandatory technical control of motor vehicles in Ukraine. Scientific Notes of Taurida National V.I. Vernadsky University. Series: Technical Sciences, 5. https://doi.org/10.32838/2663-5941/2020.5/39
8. Alekseyev, V. V., Kurakina, N. I., Orlova, N. V., Minina, A. A. (2016). GIS monitoring of transport networks. Data +. Geo information systems for business and society, 2 (69).
9. Gritsuk, I. V., Volkov, V., Mateichyk, V., Grytsuk, Y., Nikitchenko, Y., Klets, D. et al. (2018). Information Model of V2I System of the Vehicle Technical Condition Remote Monitoring and Control in Operation Conditions. SAE Technical Paper Series. https://doi.org/10.4271/2018-01-0024
10. Golovan, A., Gritsuk, I., Popeliuk, V., Sherstyuk, O., Honcharuk, I., Symonenko, R. et al. (2019). Features of Mathematical Modeling in the Problems of Determining the Power of a Turbocharged Engine According to the Characteristics of the Turbocharger. SAE International Journal of Engines, 13 (1). https://doi.org/10.4271/03-13-01-0001
11. Gritsuk, I. V., Mateichyk, V., Tsiuman, M., Gutarevych, Y., Smieszek, M., Goridko, N. (2018). Reducing Harmful Emissions of the Vehicular Engine by Rapid After-Start Heating of the Catalytic Converter Using Thermal Accumulator. SAE Technical Paper Series. https://doi.org/10.4271/2018-01-0784
12. Lobo, S., Festag, A., Facchi, C. (2022). Enhancing the Safety of Vulnerable Road Users: Messaging Protocols for V2X Communication. 2022 IEEE 96th Vehicular Technology Conference (VTC2022-Fall). https://doi.org/10.1109/vtc2022-fall57202.2022.10012775
13. Yunck, T. P., Wu, S.-C., Wu, J.-T., Thornton, C. L. (1990). Precise tracking of remote sensing satellites with the Global Positioning System. IEEE Transactions on Geoscience and Remote Sensing, 28 (1), 108–116. https://doi.org/10.1109/36.45753
14. Hansen, P., Wolfe, B. (2004). Remote Diagnostics - the Next OEM Frontier. The Hansen Report on Automotive Electronics, 16 (10).
15. Bentler, P. (1993). EQS Structural Equations Program Manual Statistic. Los Angeles: BMDP Statistical Software Inc., 456.
16. Bakhsh Kelarestaghi, K., Ermagun, A., Heaslip, K., Rose, J. (2020). Choice of speed under compromised Dynamic Message Signs. PLOS ONE, 15 (12), e0243567. https://doi.org/10.1371/journal.pone.0243567
17. Karshyga, A., Tulegulov, A., Kalkenov, A., Aryngazin, K., Nurtai, Z., Yergaliyev, D. et al. (2023). Development of an intelligent system automating managerial decision-making using big data. Eastern-European Journal of Enterprise Technologies, 6 (3 (126)), 27–35. https://doi.org/10.15587/1729-4061.2023.289395
18. Potuzak, T. (2021). Methodology for Assessing of Communication Protocols for Distributed Simulation of Road Traffic. 2021 IEEE/ACM 25th International Symposium on Distributed Simulation and Real Time Applications (DS-RT). https://doi.org/10.1109/ds-rt52167.2021.9576152
19. Lebid, I., Luzhanska, N., Lebid, I., Mazurenko, A., Roi, M., Medvediev, I. et al. (2023). Development of a simulation model of the activities of a transport and forwarding enterprise in the organization of international road cargo transportation. Eastern-European Journal of Enterprise Technologies, 6 (3 (126)), 6–17. https://doi.org/10.15587/1729-4061.2023.291039
20. Volodarets, M., Gritsuk, I., Chygyryk, N., Belousov, E., Golovan, A., Volska, O. et al. (2019). Optimization of Vehicle Operating Conditions by Using Simulation Modeling Software. SAE Technical Paper Series. https://doi.org/10.4271/2019-01-0099
21. Kuric, I., Gorobchenko, O., Litikova, O., Gritsuk, I., Mateichyk, V., Bulgakov, M., Klackova, I. (2020). Research of vehicle control informative functioning capacity. IOP Conference Series: Materials Science and Engineering, 776 (1), 012036. https://doi.org/10.1088/1757-899x/776/1/012036
22. Vychuzhanin, V., Rudnichenko, N., Shybaiev, D., Gritsuk, I., Boyko, V., Shybaieva, N. et al. (2018). Cognitive Model of the Internal Combustion Engine. SAE Technical Paper Series. https://doi.org/10.4271/2018-01-1738
23. Hahanov, V., Gharibi, W., Litvinova, E., Chumachenko, S., Ziarmand, A., Englesi, I. et al. (2017). Cloud-Driven Traffic Monitoring and Control Based on Smart Virtual Infrastructure. SAE Technical Paper Series. https://doi.org/10.4271/2017-01-0092
24. Gritsuk, I., Volkov, V., Gutarevych, Y., Mateichyk, V., Verbovskiy, V. (2016). Improving Engine Pre-Start And After-Start Heating by Using the Combined Heating System. SAE Technical Paper Series. https://doi.org/10.4271/2016-01-8071
25. Borukayev, Z. H., Ostapchenko, K. B., Ericyuk, L. I. (2007). Computer Model of Energy Efficiency Monitoring: Aspects of Information Modeling. Power Engineering and Electrification, 1, 3–7.
26. Bugayko, D., Ponomarenko, O., Sokolova, N., Leshchinsky, O. (2023). Determining possibilities for applying theoretical principles of situational risk management in the aviation safety system. Eastern-European Journal of Enterprise Technologies, 6 (3 (126)), 55–66. https://doi.org/10.15587/1729-4061.2023.294763
27. Mateichyk, V. P., Volkov, V. P., Komov, P. B. (2014). Features of monitoring of vehicles state with using of вoard diagnostic complexes. Upravlinnia proektamy, systemnyi analiz i lohistyka, 13, 125–137. Available at: http://nbuv.gov.ua/UJRN/Upsal_2014_13%281%29__18

28. Kashkanov, V. A., Kashkanov, A. A., Kuzhel, V. P. (2020). Informatsiyni systemy i tekhnolohiyi na avtomobilnomu transporti. Vinnytsia: VNTU, 104. Available at: https://press.vntu.edu.ua/index.php/vntu/catalog/download/610/1083/2199-1?inline=1
29. Golovan, A., Rudenko, S., Gritsuk, I., Shakhov, A., Vychuzhanin, V., Mateichyk, V. et al. (2018). Improving the Process of Vehicle Units Diagnosis by Applying Harmonic Analysis to the Processing of Discrete Signals. SAE Technical Paper Series. https://doi.org/10.4271/2018-01-1774
30. Gritsuk, I. V., Zenkin, Y. E., Bulgakov, N., Golovan, A., Kuric, I., Mateichyk, V. et al. (2018). The Complex Application of Monitoring and Express Diagnosing for Searching Failures on Common Rail System Units. SAE Technical Paper Series. https://doi.org/10.4271/2018-01-1773
31. Rabinovich, E., Gritsuk, I. V., Zuiev, V., Zenkin E.Y., E., Golovan, A., Zybtsev, Y. et al. (2018). Evaluation of the Powertrain Condition Based on the Car Acceleration and Coasting Data. SAE Technical Paper Series. https://doi.org/10.4271/2018-01-1771
32. Quan, J., Zhao, Y., Tan, G., Xu, Y., Huang, B., He, T. (2018). A Study on Safety Intelligent Driving System for Heavy Truck Downhill in Mountainous Area. SAE Technical Paper Series. https://doi.org/10.4271/2018-01-1887
33. Zhang, H., Lu, X. (2020). Vehicle communication network in intelligent transportation system based on Internet of Things. Computer Communications, 160, 799–806. https://doi.org/10.1016/j.comcom.2020.03.041
34. Kelarestaghi, K. B., Heaslip, K., Khalilikhah, M., Fuentes, A., Fessmann, V. (2018). Intelligent Transportation System Security: Hacked Message Signs. SAE International Journal of Transportation Cybersecurity and Privacy, 1 (2), 75–90. https://doi.org/10.4271/11-01-02-0004
35. Kanchwala, H., Ogai, H. (2016). Development of an Intelligent Transport System for EV. SAE International Journal of Passenger Cars - Electronic and Electrical Systems, 9 (1), 9–21. https://doi.org/10.4271/2015-01-9132
36. Volodarets, M., Gritsuk, I., Ukrainskyi, Y., Shein, V., Stepanov, O., Khudiakov, I. et al. (2020). Development of the analytical system for vehicle operating conditions management in the V2I information complex using simulation modeling. Eastern-European Journal of Enterprise Technologies, 5 (3 (107)), 6–16. https://doi.org/10.15587/1729-4061.2020.215006
37. Tazhenov, A. D. (2021). The state of road safety and the prospect of introducing the function of unmanned vehicle control in the transport system of the Republic of Kazakhstan. Khabarshi – Vestnik, 4 (74), 201–209.
38. Khudiakov, I., Simonenko, R., Grytsuk, I., Mateichyk, V., Volkov, V., Bilousova, T., Volodarets, M. (2020). Peculiarities of remote identification of labor mode and rest of a driver in the vehicle information monitoring system. Collection of Scientific Works of the State University of Infrastructure and Technologies Series «Transport Systems and Technologies», 35. https://doi.org/10.32703/2617-9040-2020-35-15
39. Klets, D., Gritsuk, I. V., Makovetskyi, A., Bulgakov, N., Podrigalo, M., Kyrychenko, I. et al. (2018). Information Security Risk Management of Vehicles. SAE Technical Paper Series. https://doi.org/10.4271/2018-01-0015
40. Gorobchenko, O., Fomin, O., Gritsuk, I., Saravas, V., Grytsuk, Y., Bulgakov, M. et al. (2018). Intelligent Locomotive Decision Support System Structure Development and Operation Quality Assessment. 2018 IEEE 3rd International Conference on Intelligent Energy and Power Systems (IEPS). https://doi.org/10.1109/ieps.2018.8559487
41. Towards sustainable transport in the CEI-countries (1997). Declaration by CEI-Ministers. New York, 11.
42. Mikhalevich, M., Yarita, A., Leontiev, D., Gritsuk, I. V., Bogomolov, V., Klimenko, V., Saravas, V. (2019). Selection of Rational Parameters of Automated System of Robotic Transmission Clutch Control on the Basis of Simulation Modelling. SAE Technical Paper Series. https://doi.org/10.4271/2019-01-0029
43. Mateichyk, V., Saga, M., Smieszek, M., Tsiuman, M., Goridko, N., Gritsuk, I., Symonenko, R. (2020). Information and analytical system to monitor operating processes and environmental performance of vehicle propulsion systems. IOP Conference Series: Materials Science and Engineering, 776 (1), 012064. https://doi.org/10.1088/1757-899x/776/1/012064
44. Anfilatov, V. S., Emelyanov, A. A., Kukushkin, A. A. (2002). Systems Analysis in Management. Moscow, 268.
45. Khudiakov, I. V., Symonenko, R. V., Manzhelei, V. S., Chernenko, V. V. (2019). Osoblyvosti formuvannia ta analizu informatsiynykh struktur systemy monitorynhu parametriv tekhnichnoho stanu transportnykh zasobiv u vzaiemodii z takhohrafom. Systemy i zasoby transportu. Problemy ekspluatatsiyi i diahnostyky, 250–259.
46. Tazhenov, A. D., Abeuov, E. T. (2023). The concept and significance of road safety in the context of the prospective introduction of an unmanned road transport system in the Republic of Kazakhstan. Khabarshi — Vestnik, 1 (79), 252–260.
47. Tukey, J. W. (1977). Exploratory Data Analysis. Reading, Massachusetts: Addison-Wesley.
48. Kravchenko, M., Prokhorchenko, A., Zolotarov, S. (2023). Mathematical model of a railroad grain cargo ridesharing service in the form of coalitions in congestion games. Eastern-European Journal of Enterprise Technologies, 5 (3 (125)), 35–48. https://doi.org/10.15587/1729-4061.2023.289470
49. Daleka, V. X., Soroka, K. O., Budnychenko, V. B. (2012). Informatsiyni tekhnolohiyi na transporti. Kharkiv: KhNAMH, 364. Available at: http://eprints.kname.edu.ua/25620/1/2011%20печ%204Н%20%20Інфор%20техн%20посібник%20ред%20в%20друк1-7.pdf
50. Environmental criteria for sustainable transport. Report on phase 1 of the project on environmentally sustainable transport (EST) (1996). OECD, 88.

51. Road Transport Informatics Terminology (2002). Nordic Road Association, Technical Committee, 55.
52. Han, J., Kamber, M. (2006). Data Mining: Concepts and Techniques. Morgan Kaufmann, 800.
53. Breiman, L. (2001). Machine Learning. Machine Learning, 45 (1), 5–32. https://doi.org/10.1023/a:1010933404324
54. Amberg, B., Vetter, T. (2011). Optimal landmark detection using shape models and branch and bound. 2011 International Conference on Computer Vision. https://doi.org/10.1109/iccv.2011.6126275
55. Bakalar, G., Baggini, M. B. (2016). Automated remote method and system for monitoring performance of ballast water treatment system operation on ships. 2016 International Symposium ELMAR. https://doi.org/10.1109/elmar.2016.7731793
56. Shahin, M., Ali Babar, M., Zhu, L. (2017). Continuous Integration, Delivery and Deployment: A Systematic Review on Approaches, Tools, Challenges and Practices. IEEE Access, 5, 3909–3943. https://doi.org/10.1109/access.2017.2685629
57. Myhal, V. D., Bazhynova, T. O., Ivanov, A. A. (2019). Bortovi systemy intelektualnoho avtomobilia. Materialy Vseukrainskoi naukovo-praktychnoi konferentsiyi «Avtomobilnyi transport v ahrarnomu sektori: proektuvannia, dyzain ta tekhnolohichna ekspluatatsiya», 95–96. Available at: https://repo.btu.kharkov.ua/jspui/bitstream/123456789/16021/1/Avtomobilnyi%20transport%20v%20ahrarnomu%20sektori_2019-95-96.pdf
58. Jimoh, O. D., Ajao, L. A., Adeleke, O. O., Kolo, S. S. (2020). A Vehicle Tracking System Using Greedy Forwarding Algorithms for Public Transportation in Urban Arterial. IEEE Access, 8, 191706–191725. https://doi.org/10.1109/access.2020.3031488