NaSTech
JOURNAL OF NATURAL SCIENCES AND TECHNOLOGIES
2024, 3 (1), pp. 266-275, DOI: 10.5281/zenodo.12705614

USE OF GPS MONITORING IN TRANSPORT LOGISTICS

[1]Sofiia Khrustalova, [1]Viktoriia Nevliudova, [1]Kirill Khrustalev, [1]Rauf Allakhveranov,
[1]Viktor Kosenko, [2]Alexander Mrochko

[1]Kharkiv National University of Radio Electronics, Kharkiv, Ukraine
[2]ISMA University of Applied Sciences, Riga, Latvia.

ABSTRACT

The subject of this study is the methods, tools and automated systems for monitoring the transport logistics of an enterprise. The object of research is the process of monitoring and controlling the targeted use of motor vehicles. The purpose of the study is to increase the efficiency of vehicle operation at the enterprise. To achieve this goal, the following tasks have been solved: review and analysis of existing methods, tools and automated systems for monitoring the transport logistics of enterprises; selection of components of the monitoring system; development of a structural diagram and algorithm for the automated system for monitoring the transport logistics of an enterprise; modeling of the process of monitoring and controlling the target use of vehicles based on GPS technology. The following methods are used in the work: methods of determining the coordinates of objects, methods of data transmission and processing. The following results have been obtained: a general description of the automated system for monitoring the transport logistics of an enterprise has been carried out, its composition and main tasks have been determined, wireless data transmission technology and system components have been selected, a structural diagram and algorithm for the automated monitoring system have been developed, a database management system has been selected, an entity-relationship model of the developed database has been created, and the system for monitoring the transport logistics of an enterprise has been implemented as a software tool. Conclusions: the use of the proposed automated system for monitoring the transport logistics of an enterprise allows optimizing costs and controlling the misuse of fuel, monitoring the location of the vehicle in real time, and protecting the vehicle from theft. Another important factor is improving the quality of the company's work. Route optimization not only improves efficiency and reduces business costs, but also allows you to control the level of service, which is especially important for cargo transportation when you need to deliver goods safely and as quickly as possible. Thus, the developed system minimizes the cost of additional functionality and significantly improves the efficiency of its operation and profitability by increasing the system's functionality.

Keywords: transport logistics; monitoring; GPS technology; automation; sensor.

1. INTRODUCTION

Today, satellite monitoring systems are increasingly used by transport companies and enterprises of various industries [1-7]. The process of motorization requires solving a number of issues aimed at further development of the material and technical base and improvement of operational efficiency. Currently, new, modern opportunities for monitoring the activities of motor transport enterprises are emerging, available to a wide range of users, automated systems and modules for transport monitoring that can solve a wide variety of tasks in real time. Online traffic management allows you to always have accurate and reliable information about the real location of the vehicle on the routes. You can compare the lists of real routes displayed on the map with a report that lists the route points or with a complete list of the addresses passed. It is easy to draw conclusions about the misuse of company-owned vehicles, as well as theft or damage to cargo and fuel. The company's satellite fleet management system is a modern solution for monitoring and protecting vehicles, drivers, and transported goods. It is a tool that optimizes the use of the vehicle fleet and transportation processes at the enterprise, and thanks to this, it is successfully used in many companies in various industries. Thus, the development of an automated system for monitoring the transport logistics of an enterprise will help to solve the following problems in production:

– analysis of the costs of operating cars, special equipment, other vehicles and equipment;
– instant calculation of optimal transportation routes
– reduction of accidents through constant monitoring of traffic and driving quality;
– control of vehicle fuel consumption, which allows to detect cases of fuel theft by unscrupulous employees;
– exclusion of falsification in reports on the use of fuels, spare parts and consumables.

2. ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Thanks to GSM/GPRS technology, satellite vehicle tracking systems can be divided into two main types: passive and active. In both systems, the vehicle is equipped with an on-board device that has at least a GPS receiver, a GSM module, and an input/output circuit board used to connect various types of sensors, such as a panic button, door opening/closing sensors, temperature sensor, etc. The output circuits allow the operator to remotely control the vehicle, i.e. turn off the engine, turn on the alarm, turn on the speakerphone in the cab, etc.

Passive satellite vehicle tracking systems allow storing all data in an internal nonvolatile memory, including the vehicle's route, speed, fuel consumption, parking, sensor status, etc. When the vehicle returns to the company's fleet, the data is read from the on-board unit's memory and all data is analyzed at the automated workstation of the company's dispatcher. This is the so-called post-analysis. The advantage of passive systems is the lower cost of the system, but the big disadvantage is the inability to monitor vehicles in real time.

Active vehicle monitoring systems allow you to quickly monitor all vehicles, connect with drivers from the company's dispatch center, and monitor all vehicle sensors online. The dispatcher can view the amount of fuel or current speed of each vehicle at any time, monitor compliance with route tasks, and the status of input/output circuits. This allows you to avoid dangerous places and prevent attempts at unauthorized use of vehicles by company drivers.

The configuration of both systems should be flexible enough to allow the connection of additional equipment: panic buttons, speakerphones, smart card readers, semi-trailer presence detectors, etc. In the case of active systems, there is a server that hosts the software. Satellite vehicle monitoring systems help to solve the following typical problems in production: analysis of the costs of operating cars, special equipment, other vehicles and equipment; instant calculation of optimal transportation routes; reduction of accidents by constantly monitoring the mode of movement and driving quality; control of vehicle fuel consumption, which allows to identify cases of fuel theft by unscrupulous employees; elimination of falsification in reports on the use of fuels and lubricants (F&L). These problems are typical for all transport companies, without exception, and here the management needs an effective tool to control the use of transport by the company. In this case, satellite vehicle tracking systems will be appropriate to prevent the misuse of vehicles. Satellite vehicle tracking systems can be used in the following industries: cargo transportation and logistics; agriculture; road construction; public transport and passenger transportation; utilities; mining, quarrying and mining equipment; river and sea transport.

Today, the following modern satellite vehicle tracking systems are available:

– TELETRACK GPS monitoring system is an information and management system designed to solve the problems of transport monitoring using the GPS satellite system [8]. The system consists of on-board equipment and software. The on-board device is installed on the vehicle and, based on signals from the GPS satellites, determines the speed, location and direction of movement of the vehicle, as well as reads data from various sensors and transmits them via mobile communication channels and the Internet to the dispatcher's computer (Fig. 1);

–

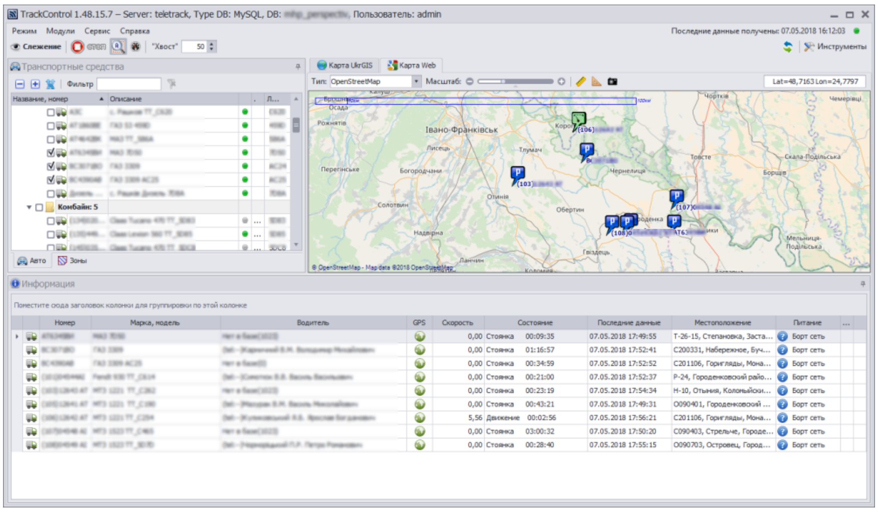

Fig. 1 The working window of the TrackControl system GPS program

– Hecterra is an agricultural monitoring system. This is a simple but effective solution for GPS monitoring of the agricultural sector, which allows you to track field work. The product provides employees and managers of agricultural enterprises with transparent data on fields, crops and their processing;

– NimBus, a solution for monitoring public passenger transport. The service combines the basic functionality of a satellite monitoring system and special tools for monitoring the movement of route vehicles: creating stops, optimizing routes, distributing vehicles by flights, monitoring the passage on schedule, detailed reporting, and a flexible system of access rights;

– Logistics service helps to solve such problems as transportation organization, optimization of transportation processes and cost reduction [9]. Logistics consists of two applications: a web version and a mobile version. The web version provides efficient administration and control of transport logistics: placing, planning and distributing orders, optimizing routes, as well as tracking and coordinating the delivery process. The mobile version of Logistics is designed for couriers or other mobile workers (Fig. 2)

NaSTech
JOURNAL OF NATURAL SCIENCES AND TECHNOLOGIES
2024, 3 (1), pp. 266-275, DOI: 10.5281/zenodo.12705614

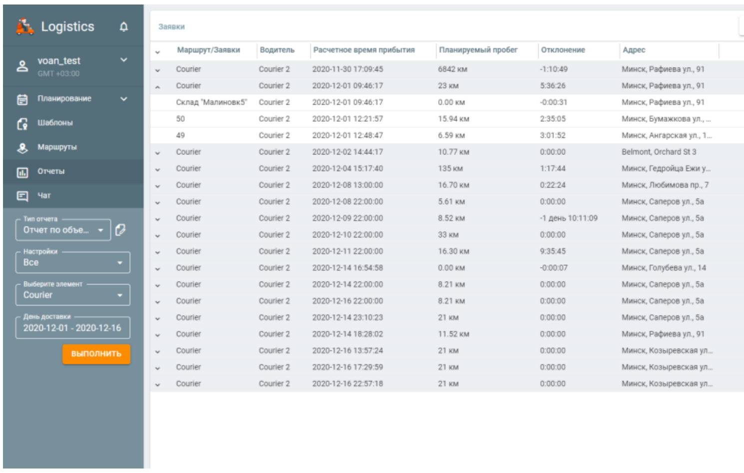

Fig. 2. The working window of the Logistics system GPS program

3. METHODS OF CONTROLLING THE INTENDED USE OF TRANSPORT VEHICLES

On-board equipment is mounted on the vehicle - a GPS tracker that receives signals from GPS satellites and, based on the information received, calculates its location, speed, direction of movement, etc.

There are four types of GPS vehicle tracking systems:

– autonomous systems that operate online (real-time);
– autonomous systems that work offline;
– systems with a subscription fee (software and maps are owned by the client);
– systems with a subscription fee (the software and maps are held by the operator, the so-called WEB-interface).

Combined options for building GPS monitoring systems are also possible. Such systems allow you to additionally monitor traffic parameters and various sensors, including fuel sensors. Since the topic of economy is very acute nowadays, let's dwell on fuel control in more detail. Fuel in GPS monitoring can be controlled by several methods that differ in measurement accuracy, price, and what we get as a result [10].

The calculation method is the simplest and cheapest method that does not require intervention in the fuel system, but at the same time the most inaccurate. It is enough to enter the standard fuel consumption for a particular vehicle equipped with a GPGPSS controller into a computer program. The program will increase the standard mileage costs according to the satellite system, and as a result, fuel consumption will increase over time. Despite the primitive nature of the method, it is still much more accurate than the same calculation based on odometer mileage data, which is easy to fake. It should also be borne in mind that the fuel consumption data will not be taken into account by itself, but in combination with the actual mileage of the car displayed on the map. In other words, the dispatcher will see whether all flights were performed in accordance with the tasks, whether the car followed the specified route, or whether there were "left" flights. It should be noted that the calculation methodology does not allow you to see the place and time of refueling or draining.

A fuel level sensor is a device designed to measure and control fuel in a car. Connecting a standard fuel sensor to the GPS controller will allow you to track fuel consumption with a certain accuracy and see the fact of refueling or draining, if such places are small. A more accurate method is to connect the fuel level sensor to the on-board GPS controller. There are also options that differ in accuracy and price. The easiest way is to connect the standard car sensor. There are also no obstacles in the fuel system. However, the error will be quite large: for domestic cars with mechanical float sensors up to 20%, for foreign cars about 10%. Wear and tear of the sensor also matters. It is much more accurate to install a high-precision electronic level sensor in the fuel tank. The most common are capacitive and ultrasonic sensors. They have no moving parts that do not wear out. The error of these sensors is approximately the same and is set at 1-2%, and the price is much less than one full truck refueling. That is, if when connected to a standard sensor, you can see the place and time of refueling or draining fuel, then with a high-precision sensor, you can see how many liters were used.

4. INFORMATION TRANSMISSION TECHNOLOGIES IN SATELLITE VEHICLE MONITORING

Thanks to wireless technology, the modern user of digital and mobile devices is not bound by wires. We don't need to carry around a bunch of cables to access the Internet, call a friend, or transfer a file to another device. they surround us and help make our lives easier. There are different ways to transmit information, from radio waves to optical and infrared emitters. Here are the most common types of wireless technologies in terms of signal coverage that we encounter every day: WPAN. Personal networks - Bluetooth, ZigBeeWi-Fi; WLAN. Local networks - Wi-Fi; WMAN. City-scale networks - WiMAX; WWAN. Global networks - GPS, EDGE, HSPA, etc.

Wireless technologies use the surrounding space instead of a cable as a data transmission medium. At the same time, they provide the user with significant mobility due to a wide (depending on the type) range. they are actively expanding, signal stability is increasing, data transfer speed is growing, and costs are decreasing. The need for the development of such technologies is not diminishing due to the emergence of mobile and portable devices in our lives. Personal and local data transmission technologies are something that accompanies us on a regular basis. They allow personal computers, laptops, wireless accessories, mobile devices, and smart home gadgets to communicate with each other (Fig. 3). WPAN networks operate at the smallest radius, which can be as small as 10 centimeters or several meters. Bluetooth and ZigBee are vivid examples. Such networks are designed to locally connect devices to each other or transfer information between them [11]. WLAN networks are larger, although they are also local. Home Wi-Fi is a WLAN network based on the IEEE 802.11 standard. The term Wi-Fi does not decipher in any way, the original name from which the abbreviation originated has long been abandoned. WLAN networks work with a larger radius than WPAN. The data transfer rate is much higher, and the security is better.

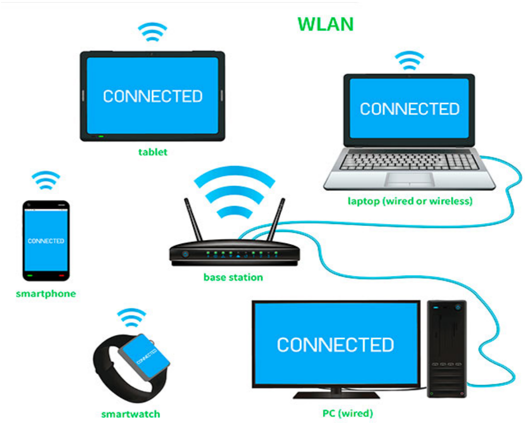

Fig.3. An example of the interaction of devices in the network WLAN

Urban and global wireless networks are capable of covering the largest areas. WMANs cover the city, WWANs can extend to an even larger area. And you also constantly encounter them in everyday life. Mostly with WWAN if you use cellular communication. WMAN networks, of which WiMAX is the main representative, can stretch over an entire city. This is essentially the same Wi-Fi, only stretched. WiMAX provides a broadband connection for many devices over a long distance. It works on roughly the same technology as Wi-Fi, just more powerful. WWAN networks include GPS, EDGE, 3G, GPRS, GSM, and more. When you make calls from a mobile phone or access a non-Wi-Fi network from a smartphone, you are working with WWAN networks. They work on the principle of either packet data transmission or channel switching. Usually, they are well encrypted, but their security is far from maximum. With such global reach, it is simply impossible to get rid of all security problems. There are different ways to implement the system. The first is the transmission of GPRS information via the Internet to a server in the network, which allows you to connect only the program installed on your computer and view the information. The advantages of which are that the information is displayed on several computers in real time. It is also possible to control outputs if the equipment allows, for example, to turn off the engine. Disadvantages: you will have to pay for the server, but it will be much less. The first option is the most suitable for small businesses that do not want to spend money on hiring IT specialists to maintain the server or system. In turn, the second option is the transfer of GPRS information via the Internet to a server installed in the company or office. The information is displayed on the server and on some computers in real time. Advantages: the ability to control outputs. No need to pay for the server. The disadvantages are that the server has to work around the clock. You must have an external IP address. The second option is used by enterprises with a large fleet of vehicles or those companies that, due to their specific nature, cannot afford to transfer their event transportation data to a third-party company. Organizations of this kind, as a rule, already have a staff of IT specialists, and possibly also everything necessary to locate facilities on their territory. A typical GPS monitoring system consists of three parts: terminals installed on vehicles, servers, and client workstations. Terminals are specialized trackers containing a GPS module and a cellular communication module (GSM or CDMA). Server functions can be performed either by a regular PC with server software installed for relatively simple monitoring systems or by a distributed cluster system with specialized software for complex business-oriented monitoring systems. Unlike workstations, the server should always be turned on, as it is the one that accumulates route data. It is also important to maintain the integrity of the information and back it up in time to keep the monitoring information up-to-date. In rare cases, the client software can be combined into one program with the server part, but as a rule, it is allowed to simultaneously connect several workstations to one server. In some systems, by installing specialized software on client

JOURNAL OF NATURAL SCIENCES AND TECHNOLOGIES
2024, 3 (1), pp. 266-275, DOI: 10.5281/zenodo.12705614

computers, it is possible to obtain operational information via web channels. Most GPS or GLONASS controllers and trackers have similar capabilities: calculate their own position, speed and direction of movement based on signals from the GPS or GLONASS satellites; connect external sensors via analog or digital inputs; read data from onboard equipment with a serial port or a more specialized CAN interface; store a certain amount of data in internal memory for the period of no communication; transmit the received data to a server center where it is processed. Previously, due to the poor coverage of the territories by GSM/3G mobile networks, controllers were widely used that accumulated data in the internal memory. After the object returned to its new location (vehicle fleet), the data was transferred to the server via wired channels or via Bluetooth or Wi-Fi. Many of the existing GPS trackers and controllers have an open protocol for interacting with the server, and also allow you to configure operating modes via SMS, CSD or GPRS connection. The received data can be accumulated in local devices and then transferred to the central base upon returning to the park, or transmitted to the central server in real time via a cellular communication channel.

5. RESEARCH MATERIAL AND RESULTS

The automated system for monitoring the transport logistics of an enterprise consists of the following elements (Fig. 4):

– fuel level sensor, used to measure the fuel level in the fuel tank;

– speed sensor is used to determine the speed of rotation and speed of movement of vehicles;

– coordinate determination scheme, allows to determine the location of the vehicle; - radio channel unit, transmits data to the central control panel;

– microcontroller unit, the central control link of the system;

– a real-time timer designed to calculate time intervals;

– an operational storage device designed to store the measured data;

– vehicle interface unit, which connects the projected part with other vehicle systems.

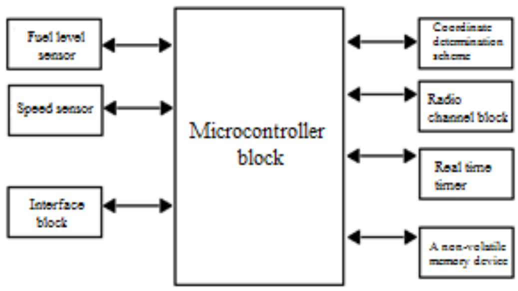

Fig.4. Block diagram of the GPS monitoring system

A fuel control sensor is a flow sensor that is installed on the fuel line and measures the volume of fuel that passes through it [12]. The information is then transmitted directly to the on-board controller (Fig. 5). The main fuel sensors: –ultrasonic. They take level data by ultrasound without direct contact with fuel. Installed on the outside of the control tank; – capacitive. An immersed digital sensor is installed in the fuel supply mechanism, which looks like a pipe with two walls and a fuel level reading and transmission unit. Installation in 1 tank, if there are several of them, then it is installed in each fuel tank; – CAN controllers. Reading fuel information via the vehicle's CAN bus; – flow meters. Flow meters monitor the level of fuel that was poured directly into the car.

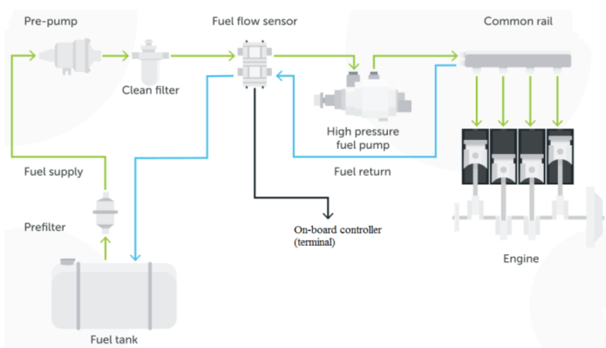

Fig. 5. Schematic diagram of the fuel consumption control sensor

To solve this problem, we propose to use the Arduino Uno board (Fig. 6). Arduino Uno is a device based on the ATmega328 microcontroller (datasheet). It includes everything you need for convenient work with the microcontroller: 14 digital inputs/outputs (6 of them can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz resonator, a USB connector, a power connector, a programming connector (ICSP) and a reset button. To start working with the device, it is enough to simply supply power from an AC/DC adapter or battery, or connect it to a computer using a USB cable.

Fig.6. Arduino Uno R3 board [13]

The system is based on a small NEO GPS chip from u-blox with a contact pitch of 0.1 mm (Fig. 7). The chip is capable of tracking up to 22 satellites on 50 channels with a high sensitivity level of -161 dB with a power consumption of 45 mA.

Since the operating voltage of the NEO-6M chip is from 2.7 to 3.6 V, the module is equipped with a MIC5205 voltage regulator with an output voltage of 3.3 V.

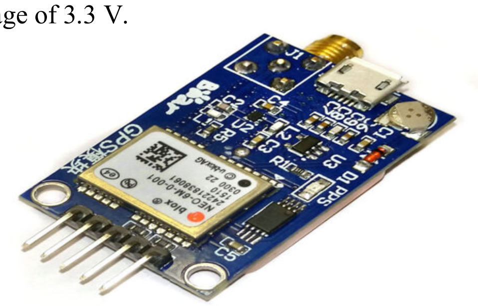

Fig.7. NEO-6M GPS module [14].

The device is controlled by the Arduino Uno board using the built-in microcontroller - ATmega328. All radio elements are connected to the digital outputs of the board. The main principle of the device is that the operator can control the electric motor with an impeller for steam circulation and heating of the heating element.

The system works as follows. The GPS receiver determines the current coordinates of the device, the speed of movement, captures the signal from the satellite through its antenna, and transmits it to the microcontroller. At the same time, it receives additional information from various vehicle systems and sensors, such as the fuel level sensor (Fig. 8) and the rotation speed sensor (Fig. 9). All data is pre-processed and filtered. The GSM transmitter sends them to the server via an antenna, after which we can see the data using the software.

Fig.8. Module for determining the fuel level [15]

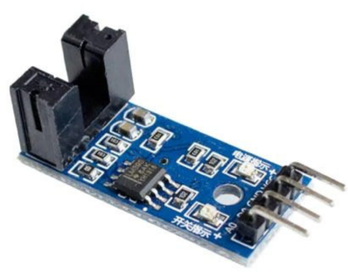

Fig.9. Module for determining rotational speed [16]

To implement an automated system for monitoring the transport logistics of an enterprise in the form of a software tool, the Ruby object-oriented programming language was used. The PostgreSQL database management system was chosen, which provides many different features, is quite reliable and has good performance characteristics, is freely distributed and has open source code. The data modeling (ER-modeling) of the system was carried out, and the entity-relationship model was designed, since it provides a graphical representation of logical objects-entities and their relationships in the database structure. The entity-relationship model of the developed database is shown in Fig. 10.

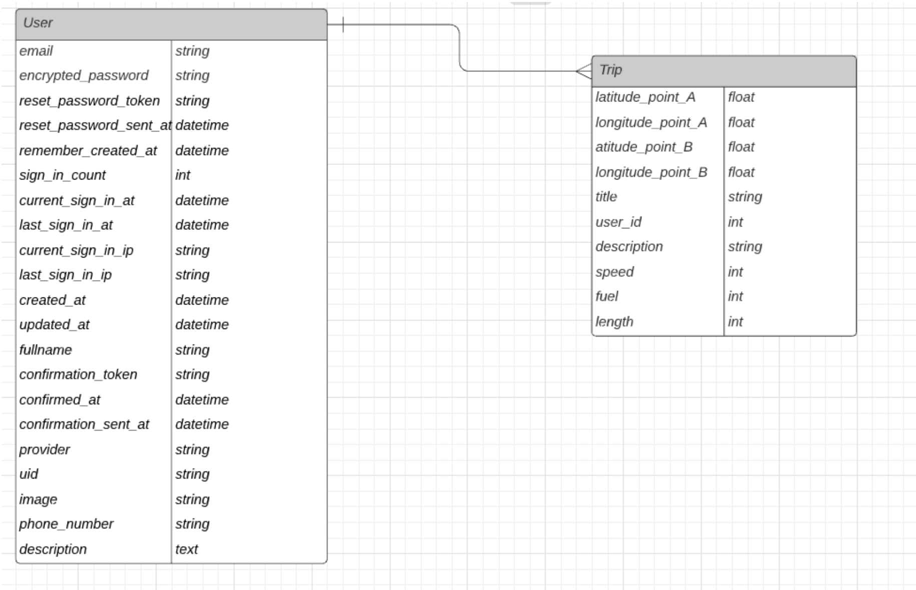

Fig. 10. ER-model of the database

After describing the subject area, analyzing the purpose and functions of the developed software tool, we can distinguish the following entities, presented in Table 1, a description of the attributes of the Trip entity, which contains information about the user of the vehicle, is given in Table 2.

Table 2 Description of the attributes of the Trip entity, which contains information about the vehicle user.

Name	Type	Description
latitude_point_A	float	Latitude of the first point
longitude_point_A	float	Longitude of the first point
latitude_point_B	float	Latitude of the second point
longitude_point_B	float	Longitude of the second point
title	string	Name
user_id	int	Secondary key
description	string	Description
speed	int	Speed
fuel	int	Fuel
length	int	Distance

Table 1 Description of the attributes of the User entity, which contains information about the vehicle user.

Name	Type	Description
email	string	User mail
encrypted_password	string	Encrypted password
reset_password_token	string	Change password
reset_password_sent_at	datetime	Date of sending a password change request
remember_created_at	datetime	Saving your password
sign_in_count	int	Login
current_sign_in_at	datetime	Current login time
last_sign_in_at	datetime	Last login time
current_sign_in_ip	string	Current login IP
last_sign_in_ip	string	Last login IP
created_at	datetime	User creation time
updated_at	datetime	User update time
fullname	string	Full name
confirmation_token	string	Confirmation token
confirmed_at	datetime	Confirmation time
confirmation_sent_at	datetime	Time of sending confirmation
provider	string	Company name
uid	string	Additional serial number
image	string	Image
phone_number	string	Phone number
description	text	Description.

Rubymine IDE was chosen to develop the program code. Rubymine is a programming environment, also called an integrated development environment (IDE), with a specialization for the Ruby language. RubyMine is based on the IntelliJ IDEA by the same developer. It supports all the main libraries used in Ruby applications.

The developed software works as follows: all attributes related to the car are added to the trip creation form. After that, they are updated using the sensors (Fig. 11).

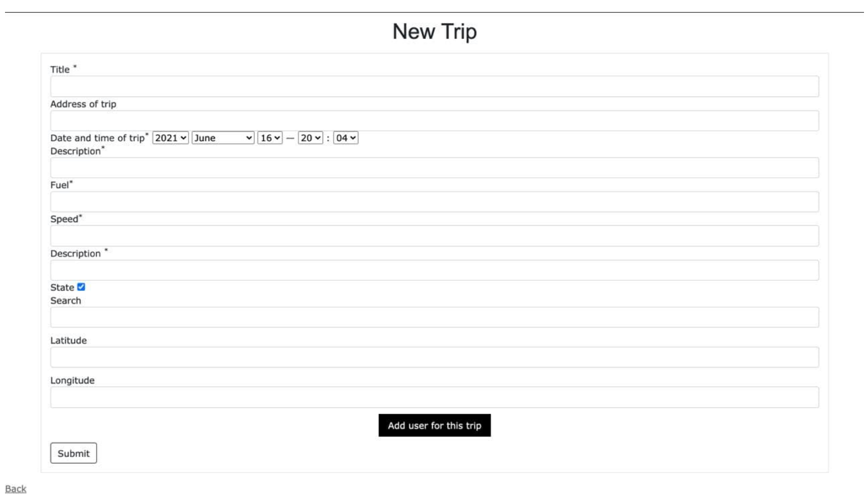

Fig. 11. Form for creating a trip

Next, a modal window opens with a user selection form (Add user for this trip) (Fig. 12).

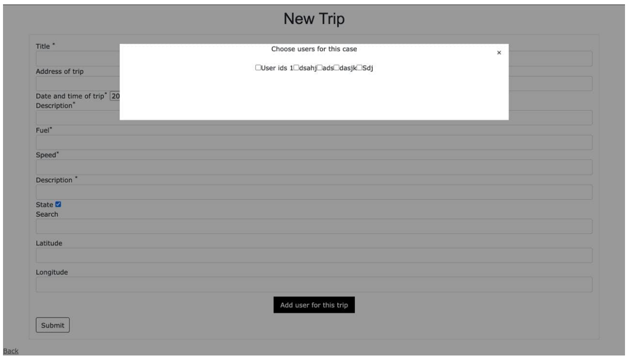

Fig. 12 User selection form

After selecting a user, we connect to an existing trip with all possible trip data and a map. The trip data is saved in PDF format in the appropriate sequence. The following is the window of active and inactive trips, from where we can get to the trip information form (Fig. 13).

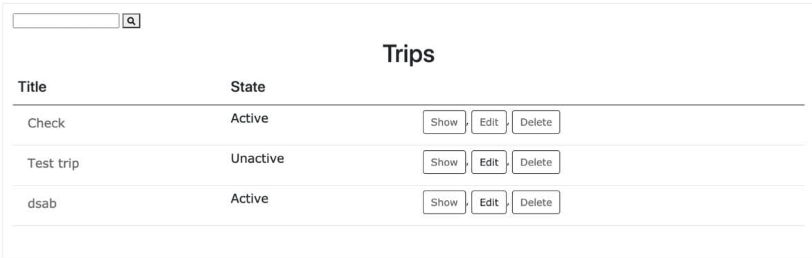

Fig. 13. List of active and inactive pages

There is also a form for adding a new user to the system (Fig. 14) and a list of all users in the system (Fig. 15).

Fig. 14. Form for creating a new user

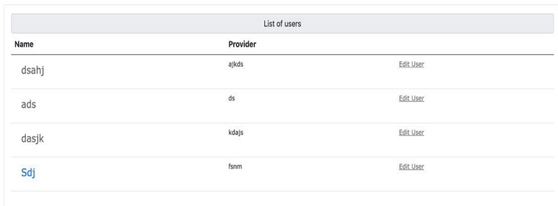

Fig. 15. List of all users in the system

The aim of the study is to improve the efficiency of vehicle operation at an enterprise. To achieve this goal, the following tasks have been solved: a review and analysis of existing methods, tools and automated systems for monitoring the transport logistics of enterprises; selection of components of the monitoring system; development of a structural diagram and algorithm for the automated system for monitoring the transport logistics of enterprise; modeling of the process of monitoring and controlling the targeted use of vehicles based on GPS technology.

Thus, the application of the proposed automated system for monitoring the transport logistics of an enterprise allows to increase the efficiency of vehicle operation at the enterprise by optimizing costs and controlling the misuse of fuel, monitoring the location of the vehicle in real time, and protecting the vehicle from theft. Another important factor is to improve the quality of the company's work. Route optimization not only improves efficiency and reduces business costs, but also allows you to control the level of service, which is especially important for cargo transportation when you need to deliver goods safely and as quickly as possible. Implementation of such a system minimizes the cost of additional functionality and significantly improves the efficiency of its operation and profitability by increasing the system's functionality..

REFERENCES

1. Díaz-Rodríguez, J. G., et al. (2021). Mechanical properties for long fibre reinforced fused deposition manufactured composites. *Composites Part B: Engineering*.
2. Rath, U.; Pandey, P.M. Experimental Investigations into Extrusion-Based 3D Printing of PCL/CIP Composites for Microwave Shielding Applications. *J. Thermoplast. Compos. Mater.* **2022**, *35*, 998–1021. [**Google Scholar**] [**CrossRef**]
3. Arrigo, R.; Frache, A. FDM Printability of PLA Based-Materials: The Key Role of the Rheological Behavior. *Polymers* **2022**, *14*, 1754. [**Google Scholar**] [**CrossRef**] [**PubMed**]
4. Kurakula, M.; Koteswara Rao, G.S.N. Moving Polyvinyl Pyrrolidone Electrospun Nanofibers and Bioprinted Scaffolds toward Multidisciplinary Biomedical Applications. *Eur. Polym. J.* **2020**, *136*, 109919. [**Google Scholar**] [**CrossRef**]
5. Goyanes, A.; Kobayashi, M.; Martínez-Pacheco, R.; Gaisford, S.; Basit, A.W. Fused-Filament 3D Printing of Drug Products: Microstructure Analysis and Drug Release Characteristics of PVA-Based Caplets. *Int. J. Pharm.* **2016**, *514*, 290–295. [**Google Scholar**] [**CrossRef**] [**PubMed**]
6. Panraksa, P.; Udomsom, S.; Rachtanapun, P.; Chittasupho, C.; Ruksiriwanich, W.; Jantrawut, P. Hydroxypropyl Methylcellulose E15: A Hydrophilic Polymer for Fabrication of Orodispersible Film Using Syringe Extrusion 3D Printer. *Polymers* **2020**, *12*, 2666. [**Google Scholar**] [**CrossRef**]
7. Schmidt, L.M.; dos Santos, J.; de Oliveira, T.V.; Funk, N.L.; Petzhold, C.L.; Benvenutti, E.V.; Deon, M.; Beck, R.C.R. Drug-Loaded Mesoporous Silica on Carboxymethyl Cellulose Hydrogel: Development of Innovative 3D Printed Hydrophilic Films. *Int. J. Pharm.* **2022**, *620*, 121750. [**Google Scholar**] [**CrossRef**]
8. Moroni, S.; Khorshid, S.; Aluigi, A.; Tiboni, M.; Casettari, L. Poly(3-Hydroxybutyrate): A Potential Biodegradable Excipient for Direct 3D Printing of Pharmaceuticals. *Int. J. Pharm.* **2022**, *623*, 121960. [**Google Scholar**] [**CrossRef**]
9. Nevliudov, I., Yevsieiev, V., Maksymova, S., & Chala, O. (2023). A small-sized robot prototype development using 3D printing. In *Proceedings of the XXXI International Conference on CAD in Machinery Design Implementation and Educational Issues* (p. 12). October 26-28, 2023.
10. Nevliudov, I., Nikitin, D., Badanyuk, I., Strelets, R., & Korotun, Y. (2023). Factor Analysis of Photopolymer Resins for 3D Printing. *Journal of Natural Sciences and Technologies*, 1(1), 166-172. https://doi.org/10.5281/zenodo.8088615