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Use of containers-transformers and platooning in megacities — a way to environmental ecology improvement

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Introduction. Growth of cities and, accordingly, highways influences the quality of air, soil and water resources considerably. Dangerous emissions from cars in the form of sulfur compounds, nitrogen and carbon oxides, acid rain negatively affect people's health every day. In this regard, great importance is attracted to the transportation process optimization. One of the main problems of the transport and logistics services market is the transportation of empty cargo containers as returnable containers, which leads to unjustified fuel costs, labor resources, depreciation of vehicles, road congestion, and has a huge impact on the environment. Within the framework of the National Technology Initiative, approved by the Presidium of the Presidential Council for Economic Modernization and Innovative Development of Russia in 2018, in terms of the priority market direction — "Transport and logistics services" — a solution to the environmental problem is proposed through the use of smart automated containers-transformers equipped with an information system for remote administration, scenario management and mobile applications.

Problem Statement. It is necessary to develop a project that will eliminate technological barriers and optimize transport and logistics services. The implementation of this project should reduce the time of cargo delivery: loading/unloading, empty runs, breaks in work, optimize the delivery path, using newly created mobile applications based on modern high-level programming languages.

Theoretical Part. The SmartBoxCity container-transformer is a part of an information system that includes server and client software. Data exchange with the server is based on the information from the database on the states of the elements of the SmartBoxCity system. "Yandex. Routing" calculates routes and optimizes the operation of vehicles. The movement of motor vehicles is on "closed" optimal routes. Platooning in urban environments takes into account empty and loaded containers in real time, taking into account the dynamics of data.

Conclusion. A practical solution to optimizing the activities of transport companies is proposed, which reduces the time for loading/unloading up to 30%, the share of empty runs up to 25%, and logistics costs for transporting empty containers up to 75%. The organization of platooning creates conditions for optimizing urban mobility, saving fuel, and improving the environmental situation.

Keywords: container, platooning, mobile application, ecology.

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Introduction. Violation of the ecological balance of man and nature, modern environmental negative trends require a careful, scientifically based approach to many problems and, in particular, to the organization of the transport process. Many scientists are trying to solve the problems of improving the organization of traffic to reduce emissions of car exhaust gases into the atmosphere [1, 2]. One of the main problems of the transport and logistics services market is the transportation of empty cargo containers as returnable containers, which leads to unjustified fuel costs, labor resources, depreciation of vehicles, road congestion, and has a huge impact on the environment. In this paper, within the framework of the project that corresponds to the goals and objectives of the "Autonet" Roadmap of the National

Technology Initiative, approved by the Presidium of the Presidential Council for Economic Modernization and Innovative Development of Russia in 2018 (hereinafter referred to as the "Autonet" DC NTI), in terms of the priority market direction — "Transport and logistics services" — a solution to the environmental problem is proposed by using smart automated containers-transformers equipped with an information system for remote administration, scenario management and a mobile application.

Problem Statement. It is necessary to present a project developed in theoretical and technical terms that allows optimizing transport and logistics services and eliminating technological barriers, namely:

— reducing the share of empty vehicle runs by 3 or more times;

— reducing at least by 2 times the interruptions in work related to the human factor;

— reducing travel time by 50% thanks to automatic route optimization, taking into account the traffic load on the roads;

— organizing the mass use of the caravan movement of empty and loaded with folded containers-transformers vehicles;

— developing the software based on the GNU Linux OS using the high-level Python programming language.

Theoretical Part. The SmartBoxCity containers-transformers [3] create conditions for organizing platooning for cargo delivery when providing transport and logistics services to the vehicle [4-6].

The project is based on the end-to-end NTI technology — "Wireless Communication and Internet of Things Technologies", since the SmartBoxCity container-transformer is a part of an information system that includes the server and the client software.

The container is equipped with various sensors for measuring weight, temperature, humidity, opening. It is equipped with a built-in computer and a video monitoring system. Data exchange with the server is carried out by files that are formed on the basis of information from the database (DB) about the states of the elements of the SmartBoxCity system. Using the database, the Yandex.Routing system calculates routes and optimizes the operation of vehicles, and then generates a response file in accordance with the information received.

Server software extracts the information from the file, puts it in the database, and transmits it to the mobile application. The vehicle moves on "closed" optimal routes with constantly adjusted parameters. Taking into account the principles of platooning in an urban environment, there is a dynamic change in the data transmitted from the Yandex.Routing service: the position of the car, its tags, and the space available for the containers transportation. At the end of each stage of transportation, the data is updated in accordance with the new state of the vehicle and is again transmitted to the Yandex.Routing service.

When platooning, the effect of a "mobile warehouse" of small capacity is used — stacked containers and multiple use of the vehicle alternately as: unloaded (empty); container with cargo; moved folded containers (mobile warehouse of small capacity) or simultaneously performing the two functions listed above. The described platooning allows you to repeatedly use empty containers on orders, without placing them each time in a stationary warehouse.

Introduction of logistics to the "brain" system based on the program Yandex.Routing allowed us to solve this problem without visual control. There is no need for a lead driver. A caravan of cars is reduced to a caravan of containers that are temporarily attached to cars, transported in a platooning along the shortest routes formed by the system, and detached at the destinations.

In a folded position, the SmartBoxCity container-transformer is a compact parallelepiped, the storage or transportation of which requires a minimum volume [7-10].

When an application is received, a vehicle with containers can change the route by moving to the specified address or returning to the main route. The proposed type of platooning using the SmartBoxCity container allows you to use empty containers on orders, without placing them each time in a stationary warehouse.

Figure 1 shows the proposed scheme of platooning.

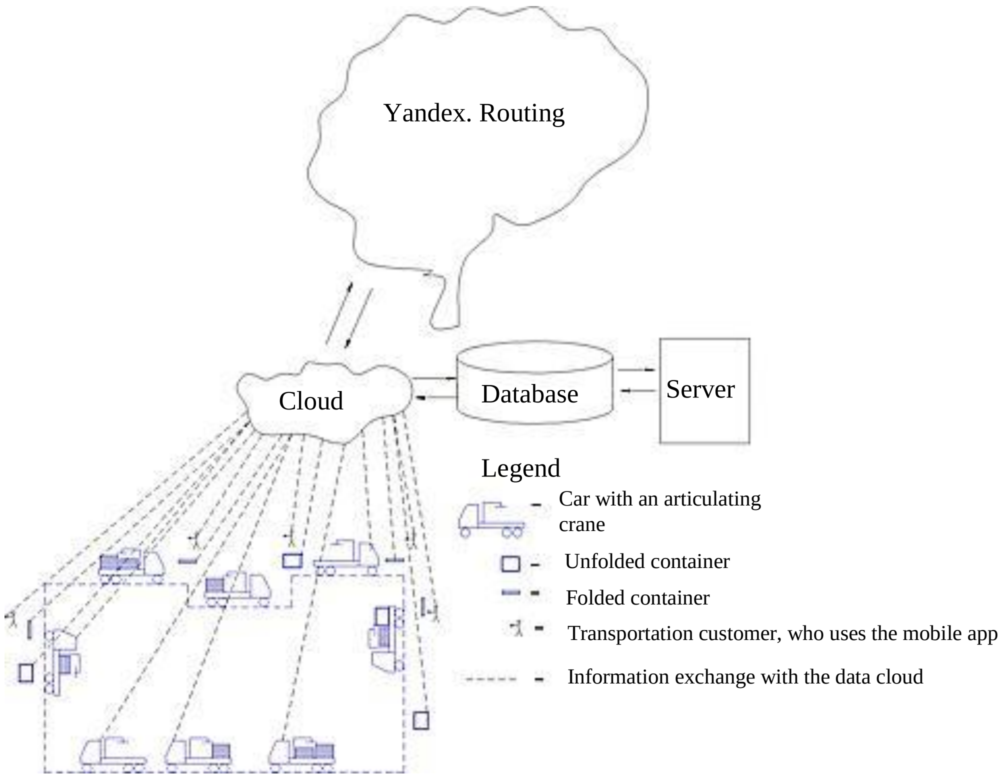

Fig. 1. The proposed scheme of platooning

Self-loading trucks carrying folded containers and empty self-loading trucks are distributed in a certain way in the serviced territory, depending on the forecasted traffic volumes. If there are no orders, the cars are either on-site or independently move to areas of high demand.

In the city conditions, the platooning is understood as a form of organization of vehicles movement, in which several cars take part in the delivery of cargo at once, alternately performing their functions. These vehicles are connected by modern means of communication. To improve the performance of the system and adjust routes, interaction is carried out in real time.

The SmartBoxCity container-transformer management software is designed to run on the RPLC-1000 programmable controller. Figure 2 shows the layout diagram of the controller. The controller has the following features:

— monitoring the status of discrete input signals;

— control of discrete (transistor) outputs;

— receiving and transmitting data via RS-485, RS-232, Ethernet interfaces;

— support for third-party hardware via modbus RTU, TCP, UDP;

— connect monitors to display information via the built-in HDM port;

— logging and storing logs on remote servers;

— direct connection of the controller to the Internet, connection to OpenVPN to create a private distributed network;

— support for ccTalk and SSP protocols. The MDB protocol is supported via an optional signal conversion device.

It is possible to connect external analog and digital I/O modules to the controller via Ethernet, RS-485 port or a special, built-in expansion bus. Table 1 shows the controller interfaces.

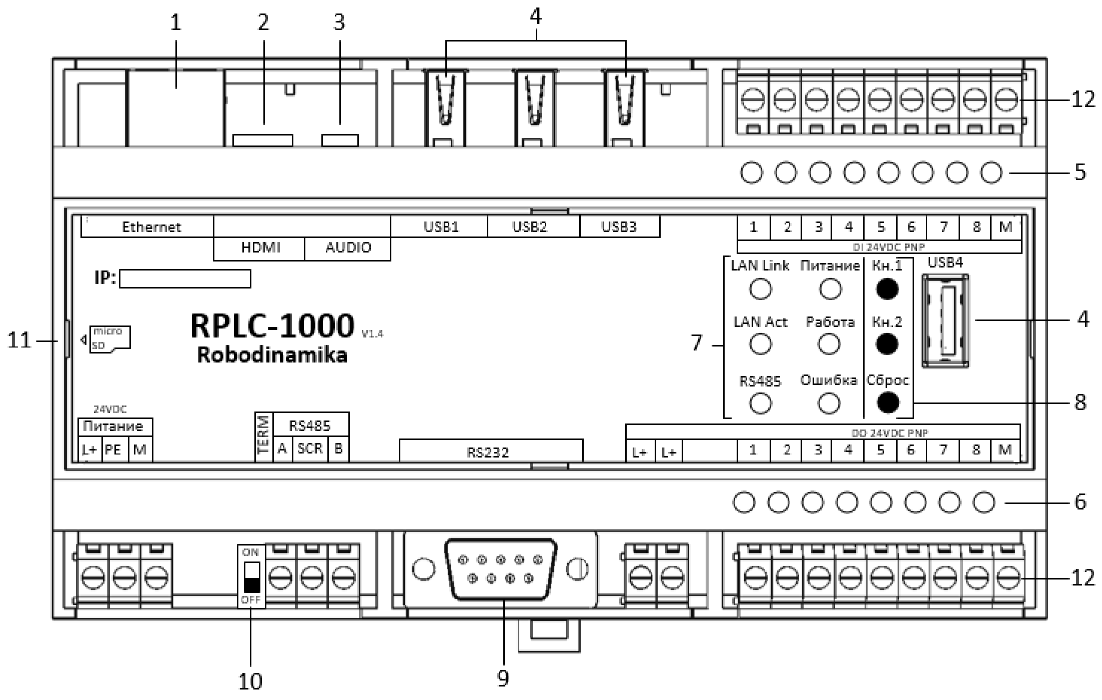

Fig. 2. Layout diagram of the RPLC-1000 controller

Table 1

Description of the controller interfaces

No.	Name	Description
1	Ethernet (RJ-45 connector)	The 100 Base-T Ethernet port is designed for connecting a PLC to a local network
2	HDMI (HDMI rev 1.3 & 1.4 connector)	Interface for transmitting digital video data and multi-channel digital audio signals
3	Audio (Audio jack 3.5 mm connector) *Option	Analog audio jack
4	USB1-USB4 (USB Type-A connector)	Ports for USB devices
5	LED input status indicators	Controller inputs status indication
6	LED output status indicators	Controller outputs status indication
7	LED PLC status indicators	Status indication
8	Built-in buttons	Reset button and two non-locking programmable buttons
9	RS-232 (DB9-M connector)	Serial interface for connecting devices
10	Switch of the terminator (matching resistor)	Switching on the matching resistor with a nominal value of 120 ohms
11	MicroSD slot	MicroSD card slot
12	Terminal blocks	For connecting the power supply of the device, digital inputs, actuators, RS-485 interface

Field tests performance. Full-scale tests of the SmartBoxCity prototype on transport were carried out using a sequential approach — from the "application" stage to the "completion" stage.

At the "application" stage, an order was made — a stand for simulating traffic for testing and calibration — according to the following parameters**:**

— departure point — Novocherkassk, Osenniy Tupik, 10 (Fig. 3);

— destination — Novocherkassk, Troitskaya str., 88 (Fig. 3);

— cargo length, width, height, weight and the number of pieces: 550×410×100, 48 kg, 6 pieces and 230×180×105, 10 kg, 2 pieces, total 308 kg (load on the floor of the container 3kN);

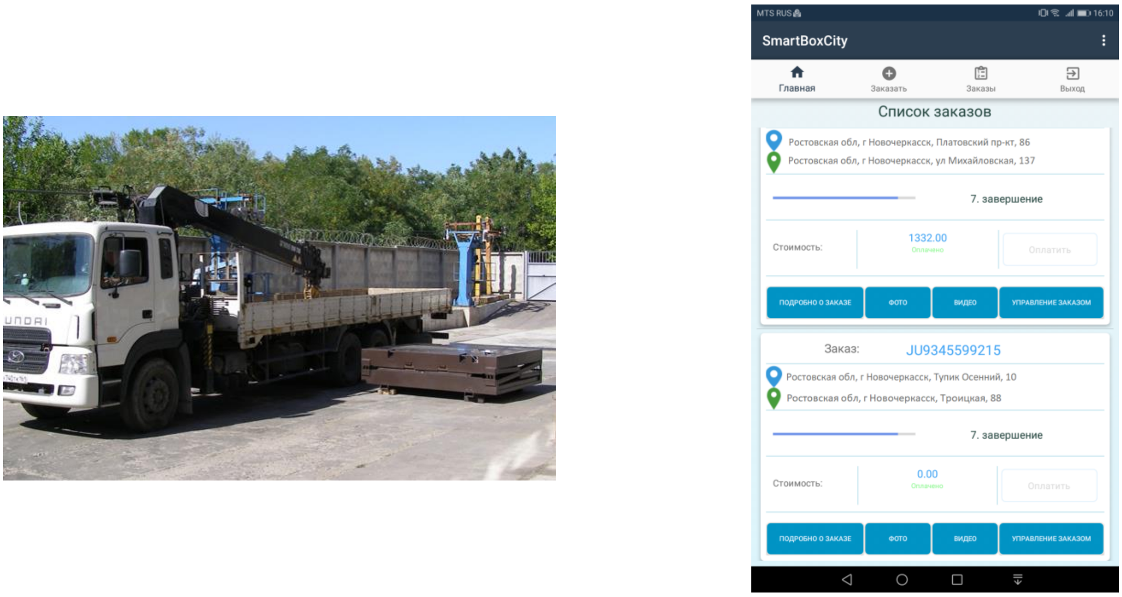

Fig. 3. Departure point

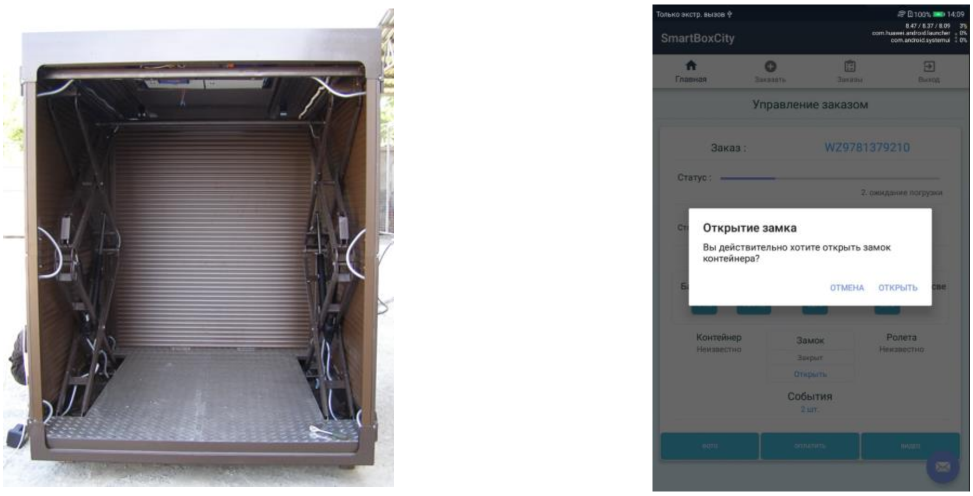

Fig. 4. Loading stage

— "Waiting for cargo" stage — the container is unloaded on the site and the container is assembled.

— "Loading" stage (Fig. 4-6) — the door is opened (roller door). The cargo is placed in the container; the container door is closed; the readiness of the container for transportation is confirmed.

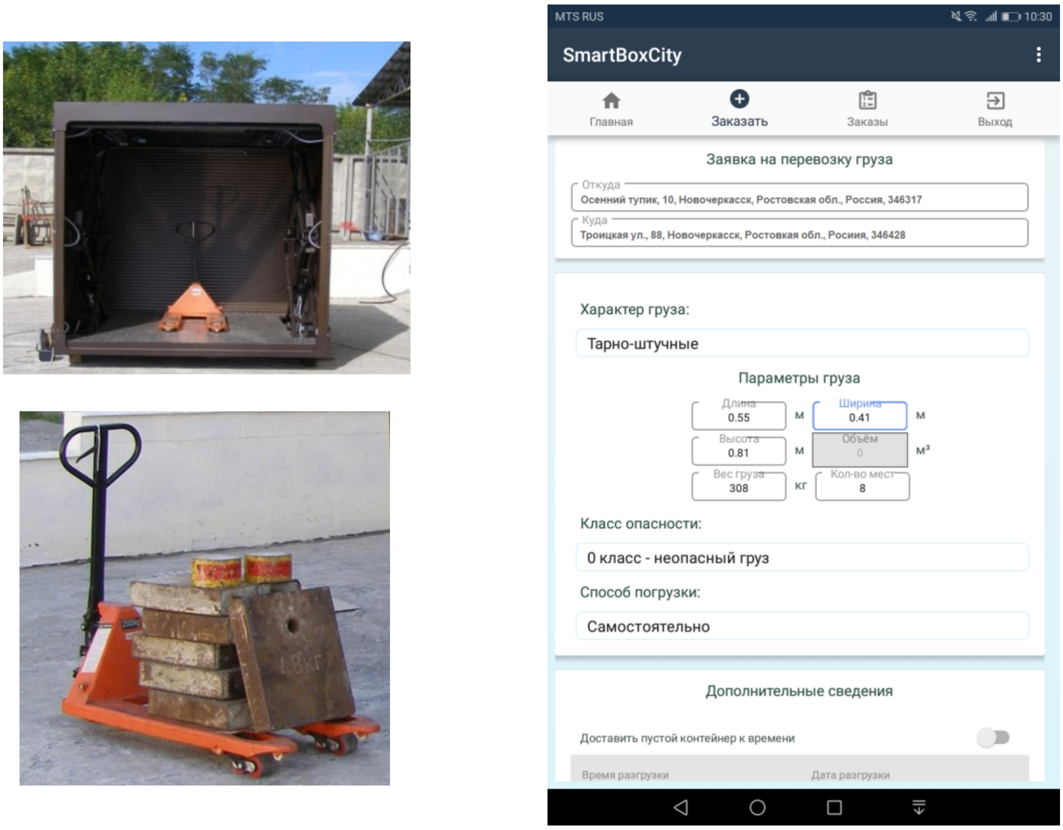

Fig. 5. Loading stage

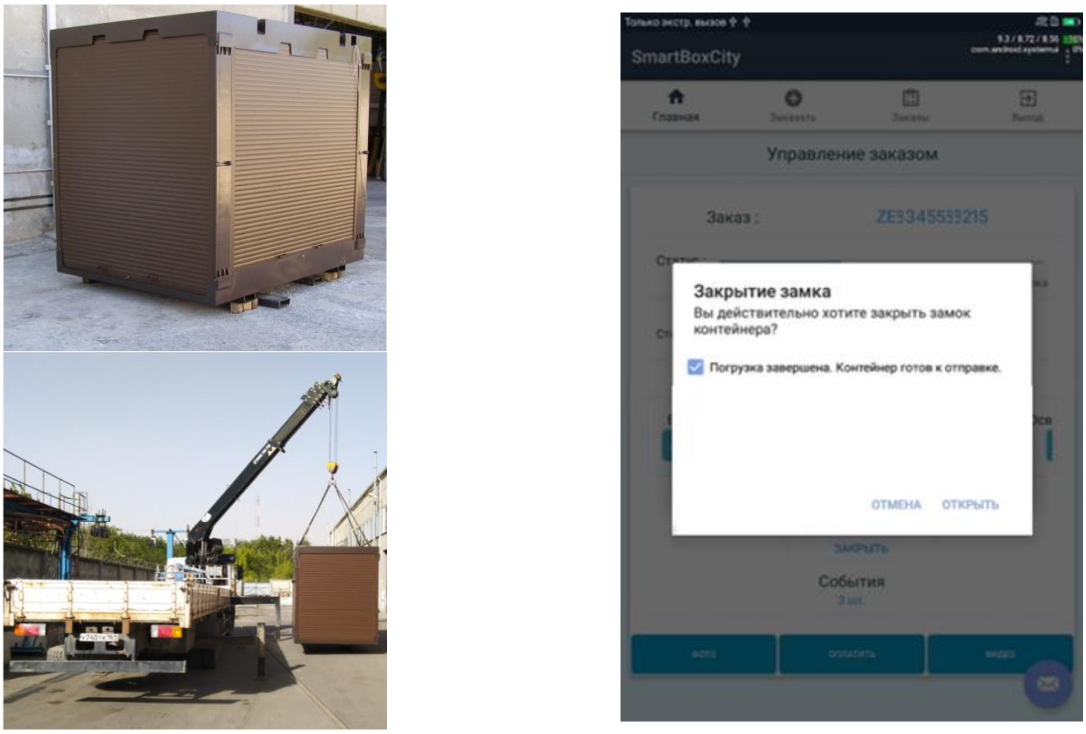

Fig. 6. Loading stage

— "Transportation" stage — all cargo parameters are checked; the container is placed on the vehicle; the container is delivered to the destination (Fig. 7-8);

— "Waiting for unloading" stage — confirmation of payment for the container transportation.

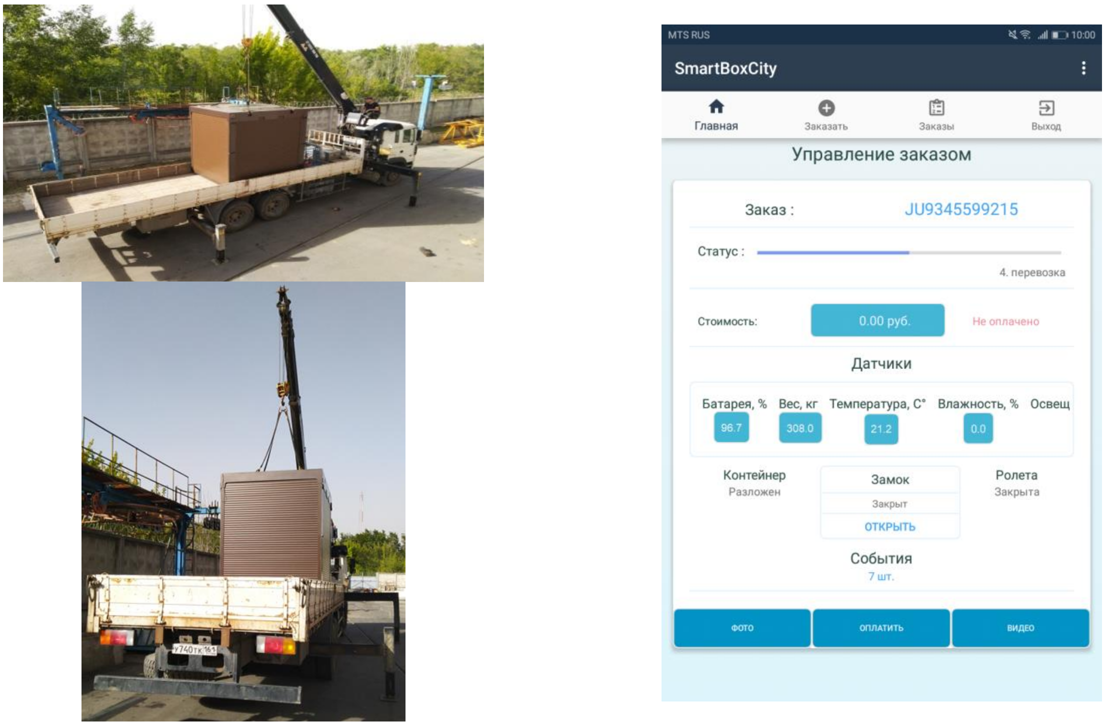

Fig. 7. Transportation stage

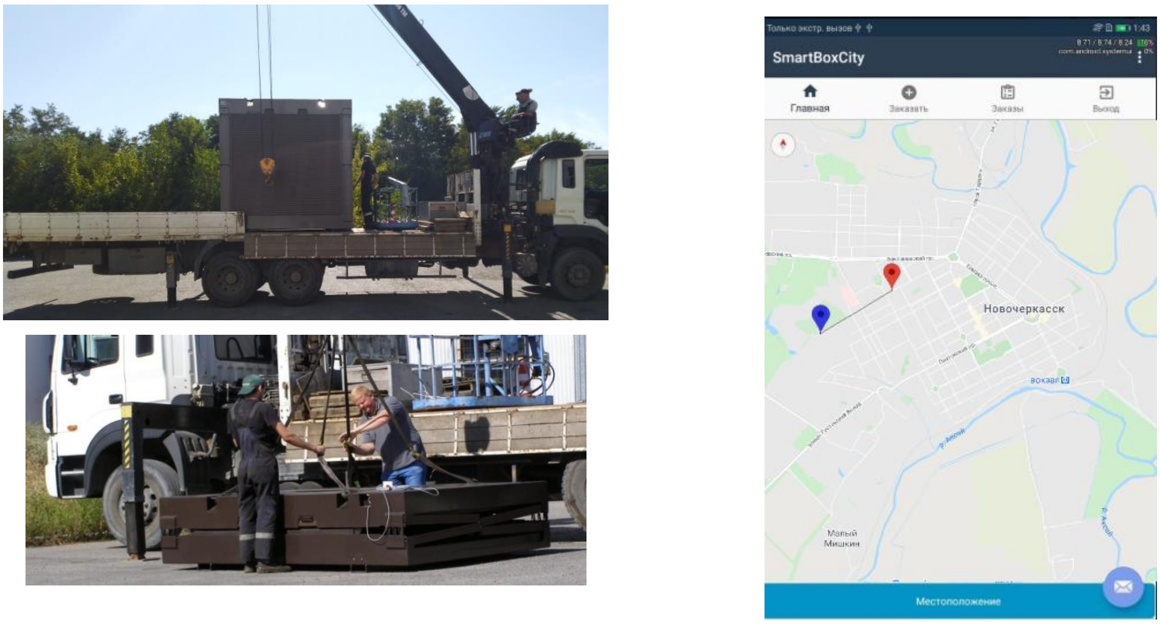

Fig. 8. Transportation stage

— "Unloading" stage — the container is removed from the vehicle. All cargo parameters are checked, the door is opened; the cargo is removed from the container; the unloading is confirmed and the container door is closed.

— "End of use" stage — the container is stored in the transport state; the container is placed on the vehicle; the button is pressed to switch the container to the "free to order" mode; the container is returned to the stand for simulation of movement, testing and calibration.

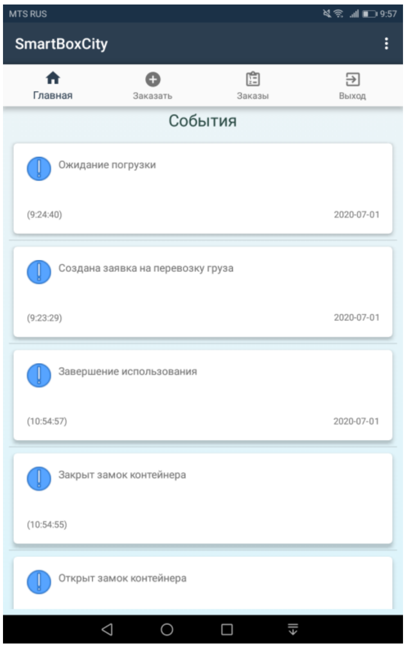

Fig. 9. Control over the parameters and functionality via the app

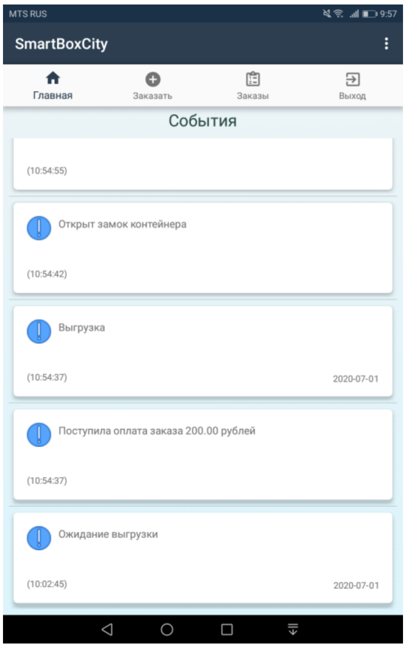

Fig. 10. Control over the parameters and functionality via the app

All the stages are performed using the SmartBoxCity mobile app and by pressing the appropriate buttons. The prototype has passed full-scale tests on transport and is suitable for further operation.

Conclusion. Simulation of the transportation process using simulators showed a decrease in the share of empty runs of cargo vehicles by more than 3 times due to the use of platooning and a vehicle with a body for two loading places.

The interruptions in work related to the human factor are reduced by more than 2 times, due to the combination of the profession of slinger, driver and freight forwarder, remote online payment and lack of waiting. Travel time is reduced by 50 % thanks to route optimization. Logistics of the platooning of the vehicle with a body for two loading places is organized in cooperation with the Yandex.Routing program.

The containers are equipped with the information system for remote administration, scenario management, and mobile applications. The use of platooning in an urbanized environment is a system-forming interaction of all the components of the technological process of cargo delivery in urban conditions.

The approach based on the Internet of Things technology provides a high level of technological reliability of the logistics chain with a low level of costs. The method of implementing platooning is aimed at improving the efficiency of three main aspects of road traffic: environmental protection, safety and reducing traffic congestion on routes, providing more comfortable working conditions for drivers. The movement of vehicles is on "closed" optimal routes, taking into account the parameters that are constantly adjusted depending on the statistics of incoming orders and traffic congestion.

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A. A. Korotkiy — formulation of the main concept, goals and objectives of the study; N. N. Nikolaev — development of the process flow diagram; G. A. Galchenko — analysis of the research results, revision of the text, correction of conclusions; I. V. Yurgin — description of the principles of platooning functioning.