Sustainable Development of Road Transport Infrastructure by Including Elements of Reverse Traffic in the "Smart City" Program

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Abstract. Recently, the use of various information data has significantly increased the growth of cities. Previously, the development of projects for the sustainable development of urban road transport infrastructure lasted for many years, but today most urban road transport problems are solved in a short time, due to intelligent transport systems (ITS). ITS is a “smart” innovative system, the main goal of which is to optimize the safe movement of transport. In this article, the authors present the analytical review and propose effective directions for solving the road transport problem by including an element of reverse traffic in the “Smart City” program to improve the efficiency of the road network and sustainable development of the road transport infrastructure of the city of Volgograd.

1. Introduction
Intelligent transport system (ITS) is a well-coordinated mechanism that includes what is directly related to the urban non-stop mode of movement [1; 3]. It is a smart system that uses innovation to regulate traffic, unload roads, and keep roads and communities safe. Smart public transport, solar panels and the unified security system for some cities are no longer fiction, but reality (Fig. 1).

The National Project "Safe and High-Quality Roads" envisages halving the number of dangerous accident road sections by 2024 and reducing deaths from road accidents by at least 3.5 times compared to 2017. The project aims to improve traffic safety based on the digital transformation of highways. Also, "smart" solutions will significantly increase the throughput of highways - by integrating digital technologies with the transport infrastructure [1; 4].

The project was developed by the Ministry of Transport of Russia in pursuance of the Decree of the President of the Russian Federation dated May 7, 2018 No. 204 "On national goals and strategic objectives of the development of the Russian Federation for the period up to 2024" and includes four federal projects: "Road network", "General system measures for development of road facilities ", "Traffic safety "and" Highways of the Ministry of Defense of Russia ". Implementation period of the national project: from December 2018 to 2024 [2; 7].
Figure 1. Smart public transport, solar panels and unified security system [2].

In Moscow, the implemented ITS (unites about 40 thousand traffic lights, about 4 thousand traffic detectors, about 48 meteorological stations and more than 170 information boards) has already made it possible to reduce the length of traffic congestion, to optimize public transport routes, and to notify drivers and passengers promptly about the situation on the road. According to the information of Moscow Traffic Management Center, there are more than 3 thousand different sensors on Moscow roads today that collect information about cars and traffic congestion, as well as about 2 thousand photo and video recording complexes in places with high accident rates [1; 8].

2. Materials and methods
The highways of the Volgograd and Volzhsky agglomerations are being combined into ITS. It was spent 297,800,000 rubles for its construction, start-up was from December 2020 [4; 8]. As part of the first stage of work to create the intelligent transport system of the Volgograd and Volzhsky agglomerations, subsystems and modules were put into operation that provide [9-20]:

- priority passage (organization of priority passage for public transport);
- meteorological monitoring;
- ecological monitoring;
- video surveillance, detection of road accidents and emergencies;
- monitoring of compliance with Traffic Rules and transport control;
- monitoring of traffic flow parameters;
- technical accounting of road transport infrastructure facilities;
- control of the movement of vehicles at the entrance to the territory of the Volgograd and Volzhsky agglomerations;
- transport forecasting and modeling;
- configuration of scenario plans for traffic control [4; 9].

The Volgograd Region currently has the infrastructure that will provide: an increase in the average speed of vehicles; a reduction in the number of accidents; a reduction in the time of delays on the way; a reduction in the area of increased deterioration of road surfaces; a reduction in the mass of emissions of harmful substances [4; 7].

What is the difference between a “smart city” and an ordinary one, except, as we have already said, it can regulate traffic, unload roads and secure roads and the population as a whole? For several years the Ministry of Transport of the Russian Federation has been actively working on the development and
implementation of innovative technologies in the transport infrastructure of Russia. For example, only in the field of navigation activities from 2013 to 2016, two federal laws, eleven decrees, six orders of the Government of the Russian Federation and other important documents regulating the use of GLONASS satellite navigation technologies in transport were adopted [3; 4; 9; 10].

Smart road solutions allow not only to improve road safety. They make it possible to intelligently manage traffic flows, improve the quality of driver service and collect the necessary data for the further development of road transport infrastructure. The “smart” roads concept includes the following components [20-30]:

- sensors of movement of cars and pedestrians;
- photo and video cameras;
- modules for controlling traffic lights and street lighting;
- meteorological sensors;
- electronic road signs and information boards at stops;
- monitoring;
- sensors that monitor traffic intensity and vehicle speed;
- parking meters;
- GPS/GLONASS navigation [3; 4].

Approaches to the "smart city" concept differ, but they always mean a project of a settlement in which there are too many unnecessary things equipped with Internet technologies. But the essence of the Internet of things is in the convenience of contact between oneself and the outside world without participation and for the comfort to human. The simplest example is street lighting, which turns on when there is a lack of natural light.

The purpose of smart cities is to make life comfortable and safe for a human, as well as to conserve public funds and space. For example, it is as safe at night on city roads with reverse traffic as it is during normal times of the day (Fig. 2). In the ideal smart city in the future, technology will have to look after residents constantly, in order to help them on time if it will be necessary, forming a single techno-system. "Smart cities" are not only Internet systems, they are also security, and directly what we are talking about in this article - a change in traffic [9-30].

![Image](Figure%202%20Reverse%20traffic%20on%20the%20city%20roads.jpg)

**Figure 2.** Reverse traffic on the city roads.

Using the example of Moscow, one of the main points of innovative technologies, we took one of the first countries which develop ITS - this is Japan. Since 1995, the Vehicle Information and
Communication System (VICS) has been developing in Tokyo, which help drivers to receive information about traffic congestion and possible bypass routes with GPS. Another of the countries which develop ITS is Singapore. There are traffic detectors which are installed on the roads every 500 meters, video cameras are installed on the highways every kilometer, and all traffic lights and buses are equipped with video surveillance. All information is transmitted to a single traffic control center. In terms of roads, since we are talking about them, it is necessary to briefly talk about the reverse traffic network on the roads, what it is and its both advantages and disadvantages. We will consider this process visually and on the example of Moscow, because this system is most established and necessary there.

Reverse traffic is the traffic in certain lanes, changing from one direction to the opposite, depending on different times of the day. This measure is forced and serves to normalize the situation on the roads in terms of congestion when there are too many vehicles [5]. Such traffic regulation increases the speed of traffic in general by 10 km / h, while the number of vehicles in both directions does not increase, the trip becomes comfortable, without negativity and nerves. Using the example of table 1, we can talk about the rules of reverse traffic and find out about some of its features [1-8].

### Table 1. Rules and features of reverse traffic [6, 7].

| The regulator and situation of the reverse traffic | Rules and features |
|-------------------------------------------------|--------------------|
| 1. Road markings                                 | The lines differ from the usual ones - they are double dashed, the distance between them is three times shorter than the colored part. You can enter the lane with markings, but if there are other identification signs or a reverse traffic light. You can drive off at any time, going to the right edge, and it is necessary if you see a red traffic light. Important! In the absence of a signaling device and signs, it is forbidden to enter the "through passage" lane |
| 2. Traffic light (traffic light signals)         | According to the conditions of the reverse traffic light, there are two-color signals: red, green and three-color: red, green, yellow. They do not regulate the flow of all cars, but only the section of road on which they are installed. |
|                                                 | • green - entry and use of the reverse road are allowed; |
|                                                 | • red - the use of the reversing lane is not allowed, a collision with oncoming traffic moving in the opposite lane is possible; |
|                                                 | • yellow - get ready, the movement in the opposite direction will start soon, leave the lane urgently. It has already become the obligatory condition for the use of such traffic lights in tunnels and in road repairs. |
|                                                 | Signs of the signaling device have the following designations: green is presented in the form of a passing arrow; red - in the form of a red cross; yellow - an arrow indicating which lane you need to urgently move to. |
|                                                 | ![The signs of signaling device](image)
| 3. Special signs                                 | 5.8 It indicates the start of a “through passage”. |
|                                                 | 5.9 It is opposite to the previous one, it is placed at the end of the way and means necessity of rebuilding to other lanes of the same |
5.10 Li is installed in front of the crossroad, which intersects the reversing lane.

4. Parapets
Accidents on the roads are largely related not only to congestion, but also to the fact that there are not enough traffic lights and markings to ensure correct reverse traffic. Therefore, in addition, parapet-type blocks which are made of concrete structures, can be used. They protect free lanes on the opposite side of the road, which makes it possible to increase the speed of vehicles at peak loads. Parapets are installed on the road and secured with rubber linings. Fences can be of constant or variable length. The parapets with variable length are made of steel and have welding structure. The use of such movable blocks ensures the division of the road marking into sections for reverse traffic.

5. Rules for driving with reverse traffic
1. You can enter the reverse lane from any crossroad, and leave only from the right lane.
2. If you are on the "through passage" you should to drive into the lane on the right.
3. Leading is possible only if the maneuver does not interfere with others.
4. Getting ahead is possible only on condition that the maneuver does not interfere with others.
5. It is forbidden to go beyond the marking lines on the left.
6. It is forbidden to stop at such section, if it is necessary you should go to the right.
7. If the yellow signal lights up or a red signal is soon, you should drive into another lane in the same direction immediately.

6. Passage on the bridge
Reversing traffic on a bridge does not differ from using the same section of a regular road. One or several lines can be highlighted here, where the directions can be changed. Moving on the bridge with a reverse, you need to pay attention to the markings, traffic signals and signs.

7. At the crossroads
When the reverse traffic at the crossroad causes difficulties, it is often a question of how to turn in this section:
- When entering a road cross where there is a lane with a changing direction, you must first take the far right position. And only by turning from it, you can change to reverse.
- If the car is already moving in this lane and you have to go straight at the intersection, the rules are the same as for normal traffic in this area. That is, you need to take into account the usual light. And if it is not there, give way to a car approaching from the right (provided that the roads are equivalent) or driving along the main road. If the car follows the reverse and you need to turn
off at an intersection, it is done from the far right lane. And it doesn't matter which way the car intends to move.

8. Other features

In addition to those already mentioned signs of the reverse traffic, the rule dictate the following:

- overtaking on the multifunctional lane is not prohibited, but must be carried out in compliance with paragraph 11 of the Traffic Rules.
- entrance to the reverse, limited on both sides by marking 1.9, when the traffic light is off or at the red signal, is equated to moving to the “opposite lane”; the U-turn from it can be performed if the marking line 1.9 does not divide the lanes intended for driving in opposite directions.

3. Results and discussion

As a rule, roads with reverse traffic have 1-2 reverse lanes, which are located in the center of the carriageway. Reversing traffic lanes are a quick and inexpensive way to improve the traffic situation in Moscow. At present, in Moscow, the reverse traffic regime is also in effect on the section of Volgogradsky Avenue - from Lyublinskaya Street to the Third Transport Ring in morning and evening rush hours, which is regulated by reverse traffic lights, road signs and special markings at the carriageway. Table 1 and Figure 3 clearly show signs, traffic lights, markings, and, a traffic controller which are necessary for reverse traffic. We only know the basis and theory of the reverse traffic of the city of Moscow [1-8].

![Figure 3. Reversing lane signs: a – traffic light; b – signs; c - marking (tabl.1).](image)

And in this article we will link this knowledge to the "smart city" project. But first, we would like to talk about the pros and the cons of the reverse traffic (Table 2).

In this table 2, we can see that in terms of importance, the disadvantages are much less than the advantages, so we can conclude that the reverse traffic is necessary. Among drivers, the introduction of reverse traffic causes a lot of controversy. However, despite some difficulties in the organization, reverse traffic really makes it possible to increase the speed of traffic in the general flow. Simultaneously with it, the number of cars in different directions does not increase.
Table 2. The pros and the cons of the reverse traffic.

| The pros                                                                 | The cons                                                                 |
|------------------------------------------------------------------------|------------------------------------------------------------------------|
| Improving transport coordination on roads with insufficient number of  | It does not help to unload roads that are loaded on both sides during   |
| lanes                                                                  | the highest load                                                        |
| Rational flow loading, variable use of the road in forward and         | Accidents in such areas occur more often than in normal ones during the |
| backward directions is possible                                         | highest load.                                                           |
| The use of signs, markings and traffic lights (previously, when         | The number of road traffic accidents on the reverse lanes does not      |
| eliminating congestion, the intervention of inspectors of the State    | change over time, which indicates that this issue is not fully         |
| Inspectorate for Road Safety was required, which entailed additional   | developed.                                                              |
| costs)                                                                  |                                                                        |
| Lack of negative pendulum migration (daily trips of the population from | It is forbidden to cross all road if you only need to go in one        |
| one settlement to another, to work, to study and back)                 | direction, for example, to the left                                     |
| Saving time spent on the road by the driver is 20–40%                  | The driver may get confused and not understand how to behave better     |

To increase the number of reverse lanes in the Russian Federation, a number of measures are required to improve discipline among drivers. The main requirement in this case is to reduce the accident rate at the reverse sections. The maximum concentration of attention is required from drivers. The car owner must understand his degree of responsibility and follow the existing rules. It makes it possible to minimize the number of accidents on a specific part of the road. It is necessary to be attentive when turning right and changing lanes at an intersection. It is possible to drive to another lane with a reverse only in the visibility zone of the traffic light [3-8].

The introduction of reverse traffic is advisable only on those sections of the road where the intensity of traffic flows in different directions is uneven. It can happen during rush hour, when performing road repairs or in the event of a traffic accident on a separate section of the road. Reversing lanes can be often found at the exits of large settlements, where the main flow of cars is directed outside the city before the weekends.

4. Conclusions

By 2022, all state construction in Russia will be carried out using digital modeling technologies, and the share of objects built on the basis of BIM will reach 80% (at the moment 20%). Until recently, according to the McKinsey consulting company, the construction industry was in one of the last places in terms of digitalization, and globally. The use of digital technologies makes it possible to reduce the design time by at least two times, as well as significantly reduce the construction time and increase the output per unit of equipment from 17 to 30% [3; 4].

Self-driving cars from Google, as well as cars with an autopilot from Tesla, Daimler-Benz and other manufacturers are popular. Cars that can process data from their own sensors can be classified as smart ones now. The next step will be the appearance of cars that will exchange information with each other in order to quickly respond to changes in the traffic situation, avoid accidents, and look for ways to bypass congestion.

The most advanced option will be to connect cars to the information and communication infrastructure of a smart city: road sensors and video cameras, counters of free parking spaces, as well as weather sensors along the route. Cars will be able to move safely at a much shorter distance from each other than they are now. They will respond flexibly to weather conditions and traffic jams, and more efficiently use the existing road network. For example, depending on the traffic intensity, it will be possible to virtually redefine traffic lanes without physically delimiting them. Most traffic accidents
caused by drivers’ errors will be a thing of the past. The congestion caused by drivers looking for a free parking space will disappear. It will help save billions in transportation costs, make road traffic safe, and improve the environmental situation [7; 8].

Meanwhile, the prospects that smart cities will bring with them sharply raise the question of how to manage the exchange of information when cars with different levels of intelligence are moving along the roads at the same time. Governments should take over this part of smart city planning.

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