The role of cooperative intelligent transport systems in road traffic safety

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Abstract. Traffic management, with increasing levels of motorization, is a serious and relevant issue for all major cities and agglomerations in the world. The creation of cooperative intelligent transportation system (C-ITS) is an effective solution to all the problems connected to road management. The current state of development of information systems in the world shows the high level of state interest in creating their own intelligent transport and road systems, as well as the formation of conditions for implementing such technologies on every level of road operation. For fulfilling this purpose, standardization systems of various levels and architectures have been created and developed, but still haven’t been implemented in local traffic safety schemes. The purpose of this article is to review, present, and describe positive outcomes of C-ITS implementation in modern road traffic management. Studies on this matter have shown that the implementation of C-ITS will reduce the number of accidents by 76% and, subsequently, completely eliminate the number of fatal accidents.

Keywords: Cooperative Intelligent Transport Systems, Road traffic safety, Road management, V2X, Vulnerable road users

1 Introduction

Cooperative Intelligent Transportation Systems (C-ITS) is a set of modern electronic information technologies and telecommunications aimed to ensure the safety and efficiency of road traffic and road capacity, as well as the modification and management of transportation systems of all kinds. This synthesis of such high information and communication technologies is designed to contribute to the important development of the transportation system in many aspects, including the reduction of traffic accidents, control of traffic demand and reorganization of traffic flow. One of the main major results, ITS creates a more convenient and profitable transportation system, especially in the areas of traffic efficiency and utility, while reducing the difficulties and costs of road regulation, and solving transportation problems through the synchronous management of both the operation of transportation and the behavior of road users.

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Cooperative ITS are based on vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I, I2V), infrastructure-to-infrastructure (I2I) and vehicle-to-pedestrian (V2P) communication systems [12]. Together, V2V and V2I technologies are usually referred to as V2X to generalize perspectives of communication in a road setting. While the modern automobile remains a high-risk agent on a road, manually operated means of transportation are also considered to be at a high risk. However, this is gradually changing, because a whole new innovative trend has already emerged – implementation of ITS and C-ITS. To create a safe space for vulnerable road users in the future, each vehicle will need to serve as a kind of traffic monitoring unit that delivers data anonymously and in real time to a traffic control center that further distributes it to every road user on their mobility device. The center will generate the forecast very quickly and use V2X technology to send it only to the vehicles that can be affected in this particular situation. Vehicles will only get the information they really need, because the system can monitor and process the information by itself.

2 Materials and Methods

Development of ITS and C-ITS in Russia. In Russia, ITS began to be developed later than in many other advanced countries. The first such systems began to be created in the early 2000s. This situation was largely influenced by objective reasons. In Soviet times, the emphasis was placed on public transport and public traffic, and as a result, the general level of motorization of the population remained rather low. Nevertheless, many systems, including traffic control systems, were developed, and implemented during the Soviet era. The first such projects were implemented back in the 1960s, and in the 1980s, such systems were functioning in all cities with a population of more than 1 million people [4]. One of the main functional systems – ATMs (automated traffic control systems) was used for decades and is still used in some cities, is still used despite the fact that Russian government is actively investing in the deployment of ITS. An important step in the development of domestic ITS was the appearance of conceptual methodological documents, the first of which was published in 2009 with the creation of Russian International ITS Congress.

Despite the actions of the Russian International ITS Congress, no results have been achieved in building ITS architecture across the country, even though, this is where the successful implementation of any intelligent system for traffic management lies. In Moscow, which is the busiest town in Russia, there are lots of effective ways of ITS implementation that help to maintain traffic congestion level and transport demand. If it’s possible to recreate similar scheme throughout Russia, it will lead to a drastic improvement in the transport and traffic situation.

The concept of ITS implementation is a vision of user services, system building ideology, task setting and development of plans for the system promotion of ITS in Russia. At the moment, the fourth generation of ITS is being developed, but only the most developed cities (such as Seoul, Tokyo and Singapore) are operationally using the third generation. Despite the active interest of the government, in Russia it is still quite rare to find effective use of intelligent systems for traffic and accident level regulation. The only cities where elements of the second generation are used are Moscow and Saint-Petersburg, which indicates the lack of ITS, therefore the lack of C-ITS development in the country.
3 Results

3.1 Strategic plan of C-ITS implementation and integration

The strategy to reduce traffic accidents is key to the creation and implementation of new generations of ITS and C-ITS. In recent years, lots of automotive companies have been very active in creating unmanned and electric cars and improving the road infrastructure for their movement. In order to test all elements of the infrastructure and its interaction with the car, experimental sites are actively being created and used. Research showcases that these cars are the possible future for modern society. And one of the fundamental functions of their work is based on C-ITS implementation.

To always stay in control of your own vehicle, it's important to know where your neighbor's vehicle is and where he or she is going. The purpose of cooperative ITS is to help drivers maintain a safe speed and distance, to be able to change lanes without danger, to avoid overtaking in critical situations, to ensure the safety of vulnerable road users and to create a unified protocol for safe road crossings passing. In addition, DSRC-based technology can be used to determine the optimal parking location, transmit parking space availability data to an information resource, deliver that information to the appropriate vehicle via the network, and create a route to help the driver get to their destination faster. Every DSRC communication line consists of two main parts: the OBU (On-Board Unit) and the RSE (Road Side Equipment), which communicate with each other and transmit information.

The main idea behind implementation of C-ITS is to develop an efficient client-oriented approach, meaning that ITS technologies are created in the direction of working with an individual driver (or a vehicle), rather than with the traffic flow and transport demand, as it is carried out today. The developers of C-ITS have defined the key points of transport demand generation: the territories of traffic flows to and from (to and from what place does the transport go), the timing of trips and the expected continuation of such trips (certain periods of time). To link them to each other by means of transport and traffic lines and to create the transportation framework are the most important elements of modern traffic management. So, one of the main tasks comes down to improvement of the transport efficiency and road complex management in order to meet modern criteria for the quality of transport services and road safety and achieving the required level of public mobility.

3.2 Advantages of C-ITS

The advantages of cooperative ITS come from the more comprehensive and broader vast of information that is available from the vehicle itself and its environment. The same set of information can also be used to extend the functionality of the safety systems in the vehicle and mobile devices for pedestrians. The monitoring method is used to collect data such as vehicle detection and vehicle speed, while video and photo detectors help to assign the group of pedestrians to every road user.

One of the most essential functions of C-ITS is based on functional and informational integration of transport processes and road complexes to eliminate departmental, technological, institutional barriers for transport process management in real time. If system is able to achieve that, it can also contribute to the realization of bigger plan: to compensate for the negative effects of sharply increasing traffic volumes on the living conditions of the population and the functioning of the economy.
Vehicles communicate with the infrastructure by sending messages to the service center. The infrastructure is only an intermediary that does not apply any data processing methods. For example, through pedestrian-to-vehicle (P2V) communications, drivers will have an early warning on the numbers of pedestrians inhabiting in the local environment. In addition, both types of wireless node (wearable and vehicular) may act as relay nodes for one another and in the process provide multihop access to wireless networks outside their communicating range [2].

Table 1. Benefits of implementing a highway management system (part of C-ITS)

<table>
<thead>
<tr>
<th>Key indicators</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel time</td>
<td>20-48% decrease</td>
</tr>
<tr>
<td>Speed of traffic flow</td>
<td>16-62% increase</td>
</tr>
<tr>
<td>Road capacity</td>
<td>17-25% increase</td>
</tr>
<tr>
<td>Traffic collisions</td>
<td>15-50% decrease</td>
</tr>
<tr>
<td>Pollutant emissions</td>
<td>Reduction of CO emissions by 122 thousand tons per year</td>
</tr>
<tr>
<td></td>
<td>Reduction of HC emissions by 1,400 tons per year</td>
</tr>
<tr>
<td></td>
<td>Reduction of NOx emissions by 1,200 tons per year</td>
</tr>
<tr>
<td>Average fuel consumption</td>
<td>4.1% decrease</td>
</tr>
</tbody>
</table>

According to the research that took place in 2022 and later was provided by Don State Technical University’s Organization of Transportation and Road Traffic Department, further implementation of C-ITS can greatly improve overall state of road traffic safety and be beneficial to every road user. It is important to emphasize the positive impact on the environmental condition of road traffic that leads to reduction of pollutant emissions. It successfully copes with the basic problems of road management (such as control of traffic flow and road capacity), while implementing more functionality and opening up new possibilities for further transport systems and traffic managers [11].

Intelligent systems provide us information about vehicles and their location on the road, information about traffic conditions, and also allow us to optimize and secure traffic on the road network, and overall speed up response to traffic incidents and accidents. The intelligent road network adapts to actual changes in the situation in real time. Traffic flow, incidents and accidents are made available to the entire network.

ITS is being developed along the following key parameters, that can also be implemented for C-ITS:
1. Creation of a safe and reliable transportation system.
2. Increasing the level of autonomy of vehicles and pedestrians outside of traffic flow and traffic management.
3. Improvement of environmental condition of road traffic.
4. Development of information and communication technologies that maintain traffic infrastructure.
5. Implementation and development of an integrated regional ITS and C-ITS in order to create a broad transportation network.
6. Management of the transport system in abnormal mode (collisions and accidents) and in case of emergencies.
3.3. Disadvantages of C-ITS

Even though overall creation of such systems has a great impact on road infrastructure, it still has some complications and disadvantages to it. One of the serious problems is the imperfection of mechanisms for the creation and operation of C-ITS. C-ITS are systems that are meant to ensure the effective functioning of the territory (and its life cycle support), the creation of which is possible only by combining the efforts of a large number of participants representing both government agencies and local businesses. The creation of such systems within the framework of the current legislation on public procurement is extremely problematic. It is necessary to widely use legal mechanisms when creating and operating any ITS, which will solve the problem of operating as a unified system based on complex long-term contracts. However, the problem here is the insufficient development of business in the field of ITS and the lack of government policy for its development. The success of any industry is determined by the level of development of the industry business, because it is business that creates this or that product, and without business to the advanced level of quality and modern products is impossible [9].

4 Discussion

As it is seen from the figure above, situation with traffic collisions in Russia is far from being normalized. The number of fatalities in collisions doesn’t change much throughout the year. In order to prevent fatalities and reduce the number of collisions, it is necessary to introduce new transportation technologies that would allow road users to be informed about the possibility of accidents in a timely manner.

By providing advance warning, V2V and V2P technology can help drivers avoid more than half of the collisions that could occur. If deployed widely, V2V technology could warn not only the pedestrians, but also the drivers in order for them to manually affect vehicle behavior. The successful realization of the objectives set for cooperative ITS is based on two main components.
The first component is a reliable multiservice link between vehicle and vehicle, as well as between the vehicle and the infrastructure. Such a channel must at least meet the following requirements:

- Be standard and provide the instant information transaction principle;
- Have sufficient bandwidth, low latency and high speed to establish a connection to the moving object at the particular limit of its speed in order to solve the whole range of assignment tasks;
- Be secure;
- Be able to function in any weather.

The second component is various mathematical models, oriented on the solution of given tasks.

The common property of all these models is the need to represent a reflection of some specific real road network or represent a limited section of such a network. C-ITS involve the integration of existing transportation and traffic control systems and the solution on their basis of new tasks in dynamic route management, the organization of priority traffic of public transport, the cognition prevention, detection of traffic accidents and elimination of their consequences, while also providing information support for all participants of the transport process.

There are currently four processes associated with the development of C-ITS systems in Russia:

- Development by various enterprises of ITS-systems using their own models (this is mostly done by manufacturing firms);
- Adaptation of foreign and domestic radio electronic equipment for the creation of C-ITS systems (C-ITS integrators or providers);
- Provision of various services (mainly monitoring and remote protection of vehicles) on the basis of C-ITS systems of foreign companies (C-ITS operators);
- Wide sale of on-board land navigation complexes of components for C-ITS systems (C-ITS dealers) [6].

One of the main complications to occur when designing the concept of developing C-ITS, it is the necessity to use and design such systems, that will be compatible with its foreign counterparts based on a typical structure, which includes: a set of target data acquisition tools, including monitoring tools; a hardware and software complex for analysis and decision making (situational, dispatch and operations centers); means of implementing control decisions (information and technical means of peripheral devices); technological environment of telecommunication interaction between C-ITS objects: communication channels between different C-ITS objects; means of information protection.

Russia must be ready for the arrival of vehicles equipped with cooperative ITS elements in the very near future. Not only that, but state must already create the infrastructure for cooperative ITS. The task of developing a strategic development plan for the cooperative ITS in Russia is urgent, which will define a number of tasks to be carried out in at least the following areas: policy requirements, international and national promotion efforts, technical requirements, platform deployment requirements, testing and demonstrations, service marketing and communication of different agents.

Like any other complex system, integrated C-ITS applications require a strategic infrastructure as the basis for decision-making and execution. The implementation of the decisions made is the most important part in the formation of any system, because it is able to control and affect possible consequences of accidents, and one must be able to predict
not only the actions of the system itself, but also the response of road users. That is why it is essential to create a governmental state that would be responsible for creating a C-ITS infrastructure in Russia.

5 Conclusion

In a rapidly changing world, the problem of organizing a well-managed road transportation system is extremely important. The development and deployment of C-ITS is a potentially effective competitive innovative business and a stimulus for the development of a new high-tech industry sector. One of the tasks of coordinated transport policy is the integration of Russia's transport systems into the world transport system, improving the quality of transport services and ensuring transport safety, reducing the harmful effects of transport on the environment and human health. Various studies on this matter have shown that the implementation of C-ITS technologies and schemes will reduce the number of accidents by 76% and, subsequently, completely eliminate the number of fatal accidents [7].

The components development of intelligent transport systems in Russia so far has been implemented by the principle of coordinating individual unrelated projects with a lag in their modernization and reassignment of already existing components to meet the increasing requirements for hardware and software complexes, where it can contribute to traffic management.

References

7. Evstigneev I.A (In Rus.) Using Collective ITS to Reduce Accidents, XXI Century Roads of Russia. 05 (2016). (In Rus.)

12. Topilin, I.V., Zyryanov V.V. and M Volodina M.V. Special aspects of the use of "floating" cars information to estimate the quality of road traffic in real time, IOP Conf. Series: Materials Science and Engineering 698 (2019)

