Improving Transport Infrastructure in the Context of the Transition to the Smart City Concept in Small Towns

Regina Nikolaeva and Rustem Sakhapov

April 1, 2020

Improving transport infrastructure in the context of the transition to the Smart City concept in small towns

R.V. Nikolaeva [1 [0000-0002-5324-432X]], **R.L. Sakhapov** [1 [0000-0001-9665-1251]]
[1] Kazan State University of Architecture and Engineering, 420043, Kazan, Zelenaya str., 1, Russia
E-mail: nikolaeva1@bk.ru

Abstract. Cities are faced with such tasks as providing residents with a quality infrastructure for life support, public transport, and social infrastructure. In order to solve the problems, cities increasingly turn to digital technologies, which has led to the formation of a full-fledged and well-established name for this area of activity - “Smart City”. Using the example of the small town of Zelenodolsk in the Republic of Tatarstan, we carried out the studies to improve transport infrastructure in the context of the transition to the Smart City concept in small towns. To increase the stability of the transport infrastructure, it is necessary to introduce intelligent transport systems. The influence of intelligent transport systems on the transport process in Zelenodolsk was evaluated using the AIMSUN simulation package, which allows simulating traffic. Studies have shown that all indicators characterizing traffic flow have changed for the better. Consequently, the transition to the concept of "Smart City" is applicable not only for large, but also for small cities.
Keywords: Intelligent transport systems, "Smart City", Transport systems, AIMSUN, Traffic, Model.

1. Introduction

The majority of the world's population lives in cities, increasing the burden on energy, transport, water supply, construction and public places. There is a growing need for smart urban solutions that are effective and sustainable, on the one hand, and can generate economic prosperity and social well-being, on the other hand.

Today, most cities are moving to the Smart City concept. A smart city is characterized and determined by a number of factors, including sustainability, economic development and high quality of life. These factors can be achieved through infrastructure (physical capital), human capital, social capital, and information and communication technology infrastructure.

There are six indicators of the Smart City, namely: smart economy, smart management, smart citizen, smart life, smart environment and smart mobility. Mobility or transport occupy the most important position due to its influence on all other indicators.

Transport system is one of the fundamental intelligent systems in the Smart City. One of the main directions of ensuring the stability and security of the urban transport system is the concept of introducing intelligent transport systems (ITS). Moreover, all processes at every stage of the life cycle should be intellectualized. Since the stage of production of the life cycle is one of the most important, the introduction of ITS will optimize processes and improve the quality of transport services to the population. It is also worth noting that a well-designed and efficient transportation system contributes to economic growth and helps to improve the quality of life, thereby becoming one of the most important sectors of urban development.

Until recently, the concept of "Smart City" was applied mainly to large cities, which is clearly demonstrated by its name (“city” instead of “town”). Studies show that the development of a small town today is very limited if this town does not become smart. This study discusses the improvement of transport infrastructure in the context of the transition to the Smart City concept in small towns of the Republic of Tatarstan, using the example of Zelenodolsk.

2. Materials and methods

2.1. Transport problems and their solutions.

Difficulties in the traffic movement are often associated with the low throughput of the street-road network, which does not correspond to the existing traffic intensity, and the load level exceeds its permissible value [1]. At the same time, the development of road infrastructure is lagging behind the daily growing number of cars [2, 3].

One of the biggest problems in the field of the road transport complex of Zelenodolsk is the current state of the roads, which is holding back the development of the main sectors of the city’s economy.

The transport problem in Zelenodolsk is compounded by the fact that 50 to 90% of the population and about 45% of the car fleet are concentrated in a relatively limited area.

The configuration of the town’s street-road network has such a structure that the choice of an alternative route is not sufficient. This leads to re-runs of vehicles and overloading of the road-street network. It is necessary to solve this problem with the help of changes in the organization of traffic.

The main reasons for the difficulties experienced by ground transportation in Zelenodolsk are the very rapid increase in motorization, the insufficient capacity of the road network, surface drainage, and the lack of urban storm sewers, all of which adversely affect the organization and safety of traffic. An effective way to increase the throughput capacity of the Zelenodolsk street road network is to improve controlled traffic lines to the level of continuous or high-speed traffic.

To solve the problem of developing transport infrastructure, increasing the capacity of the road network and traffic safety, it is necessary to take comprehensive, interconnected measures aimed primarily at improving traffic management systems, solving the problem of car parking, and creating safe conditions for pedestrian traffic.

The works of modern experts in the field of transport describe various methods of traffic regulation on complex road junctions and highways, as well as methods for designing economical transport systems with high throughput [4]. Methods of machine simulation of traffic flow are given in the books of R. Kartabaev [5], V. Silyanov [6], F. Haight [7]. The works of these authors undoubtedly deserve attention, but their studies were carried out until 1983 [8].

Today, science in the field of traffic management has taken a big step forward, which also affected the way of management. First of all, this is connected with the modeling of traffic flows, which allow us to design the existing traffic situation and conduct an experiment with changed conditions. Thus, modeling of traffic flows will allow a more realistic presentation of the various situations that may arise in practice.

2.2 Intelligent transport systems as a method of increasing the stability of the city's transport network

ITS unites the motor transport industry and the information technology and is based on the modeling of transport systems and the regulation of traffic flows.

Improving the transport infrastructure of Zelenodolsk during the transition to the Smart City concept is possible through the introduction of ITS for regulation and traffic management. The introduction of ITS will enable the transition from separate management of the elements of the city's transport system to centralized management of the road network. Objects of intelligent transport systems can significantly improve the quality of transport services.

Considering the road network of Zelenodolsk, we can say that the current problem situation is associated with a limited number of connections between the central part of the town and peripheral areas and the orientation of drivers on the same traffic routes.

The essence of ITS is the ability to make the most efficient use of existing and prospective resources, to provide the maximum possible throughput of the road network and to distribute traffic flows without exceeding this throughput.

The structure of ITS in the context of the introduction of the Smart City concept for Zelenodolsk is shown in Figure 1.

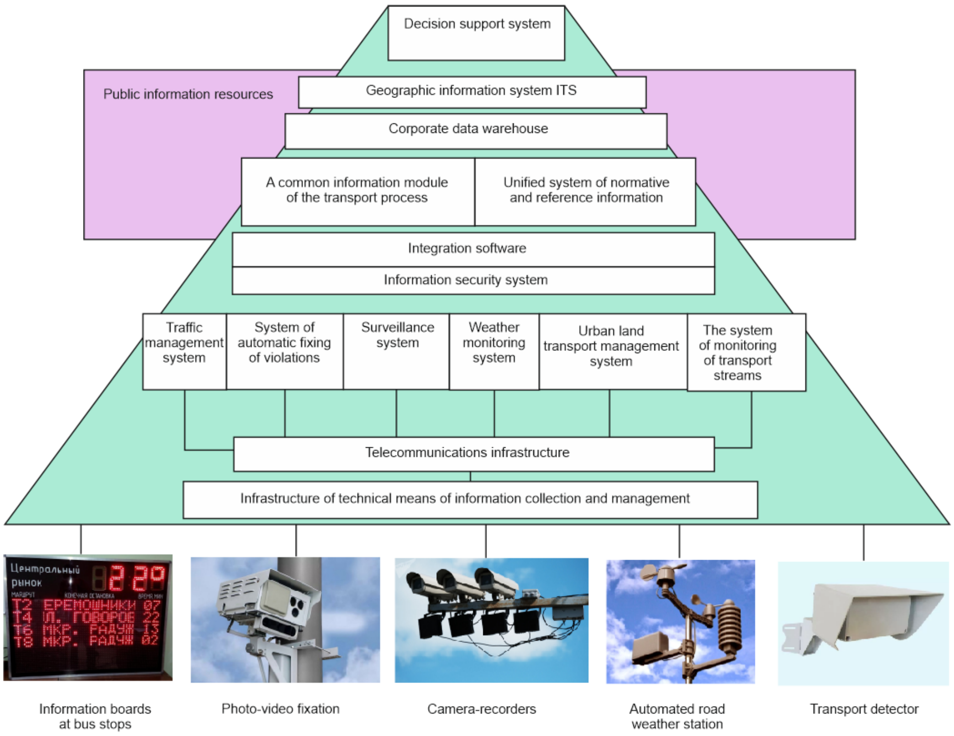

Fig. 1. ITS structure in the context of the introduction of the Smart City concept in Zelenodolsk.

2.3 Study of the road network model in AIMSUN

Measures to increase the stability of the transport system are expensive, including new road construction and multi-level interchanges, reconstruction, and improvement of traffic management schemes. Modeling of transport networks allows you to find out how the parameters of the traffic flow change when appropriate measures are taken. This is necessary for a feasibility study, confirmation of the validity of the proposed measures, evaluation of the results of their implementation and analysis of the costs and benefits. This is especially relevant when exploring the deployment of modern information technologies presented by intelligent transport systems.

Simulations are classified depending on the level of detailisation on the micro-mesoscale and macrolevel models [9-11].

The main purpose of transport models is to conduct experiments. Using modeling, we can check how certain changes in the organization of movement affect the behavior of the traffic flow [12, 13]. In the models, we can consider events such as the construction of new roads, the expansion of the street, the prohibition or permit of turns, the organization of one-way traffic, etc. At the city level, transport modeling will make it possible to decide on the consequences for the transport situation of the construction of the next shopping center or new neighborhood. In the modeling process, we can create several hundred control scenarios [14].

In recent years there have been developed successful mathematical and computational methods to formulate a model of a dynamic transport system. Among the software products for dynamic transport systems that have been tried and tested in developed countries of the world there are: CORSIM (development began more than 30 years ago by the Federal Highway Administration), Paramics Modeller (Quadstone Paramics, UK), AIMSUN (TSS - Transport Simulation Systems, Spain, Barcelona), SimTraffic (Trafficware Corporation, USA), PTV Vision (PTV Group, Germany; the main components of PTV Vision are VISUM and VISSIM software), SUMO (Germany; the package is designed for modeling broadband highways) [15].

AIMSUN is one of the world's best micro-simulators, allowing us to simulate an extensive array of traffic management components, strategies and techniques. The product is a full-featured set of tools for analyzing traffic flows and transportation, which can be used for planning, detailed modeling and research of requirements and conditions of activity in the field of transport. The product implements an integrated platform suitable for performing both static and dynamic modeling [16, 17].

A package can deal with various transport networks: city networks, freeways, highways, ring roads, arteries, and any combination of them [18, 19]. It was developed and implemented as a tool for analyzing traffic flow to help engineers design and evaluate the performance of transport systems. This package turned out to be very useful for testing new traffic control systems and control policies based either on traditional technologies or on the implementation of intelligent transport systems. The result is clearly reproduced in the form of animated two-dimensional and three-dimensional objects [20].

In this work, to assess the impact of ITS components on the organization of traffic in Zelenodolsk, we used the AIMSUN program.

Typically, when modeling, the impact of ITS components is assessed either on individual network elements or on the whole modeling zone. However, since the task is more specific in this case, we detailed the entire road network of Zelenodolsk. For this, all sections of the road network were divided into groups according to the influence of the applied components of ITS on them.

The modeling conditions provided two possible scenarios, the first - the organization of movement without ITS components, the second - the distribution of traffic flows with ITS elements.

The configuration of the simulation zone is shown in Figure 2.

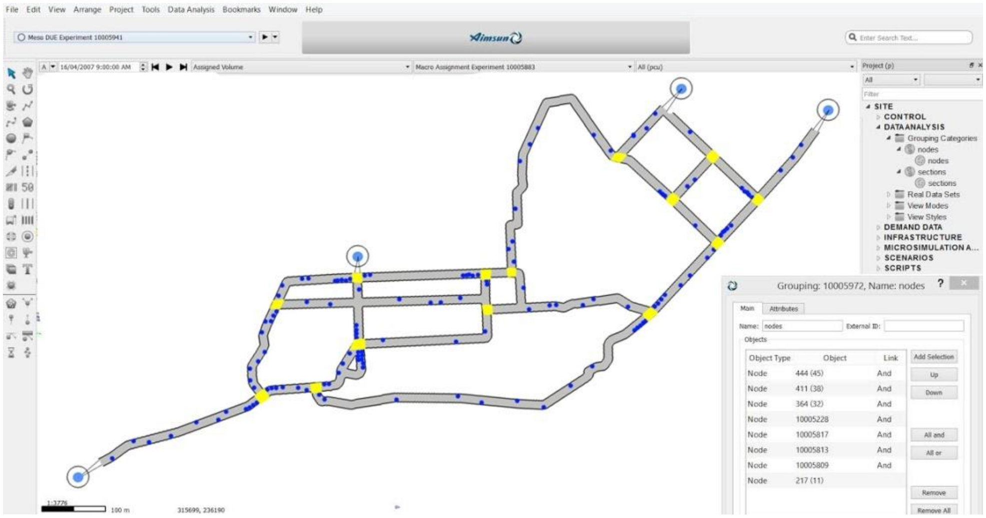

Fig. 2. Modeling zone in AIMSUN.

3. Results and Discussion

During the experiments in the transport model of Zelenodolsk, the parameters were changed in such a way that the intensity and structure of traffic flows corresponded to the existing ones. Thus, the model was validated. It was assumed that the proposed measures for the implementation of ITS will have a positive impact on the organization of traffic and increase the throughput of the road network.

As a result of experiments with the model before and after the introduction of ITS on the road network, we obtained the main empirical characteristics of traffic flow parameters. The results are summarized in table 1. The main simulation results at the network level are shown in Figures 3 - 5.

Table 1. Assessment of the empirical characteristics of the parameters of the road network in Zelenodolsk.

Analyzed Indicators	Indicator values	
	Before ITS	After ITS
Travel time, sec / km	155,19	127,74
Delay time, sec / km	81,45	73,59
Stop time, sec / km	90,23	76,97
Number of stops, vehicle./h	8,36	6,45
Density of a stream, vehicle/km	12,33	10,32
Average speed, km / h	29,01	35,03
Traffic jam size, vehicles	112,21	65,71

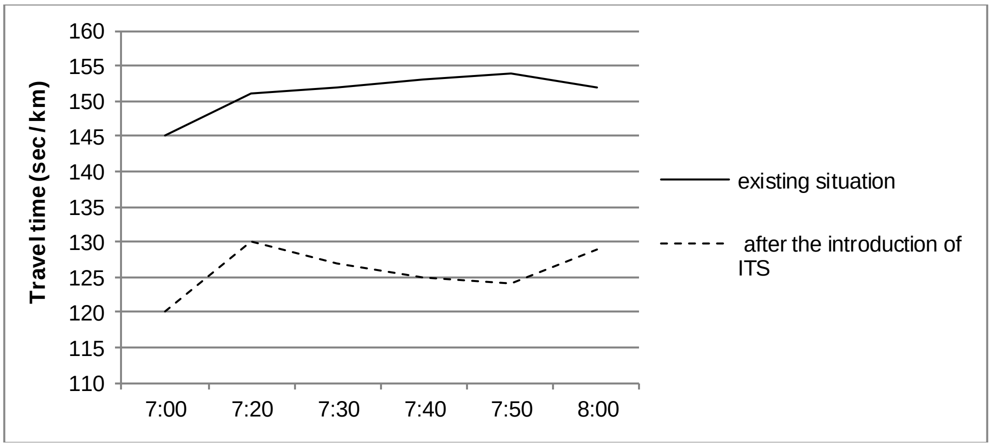

Fig. 3. Change in the travel time at the studied area.

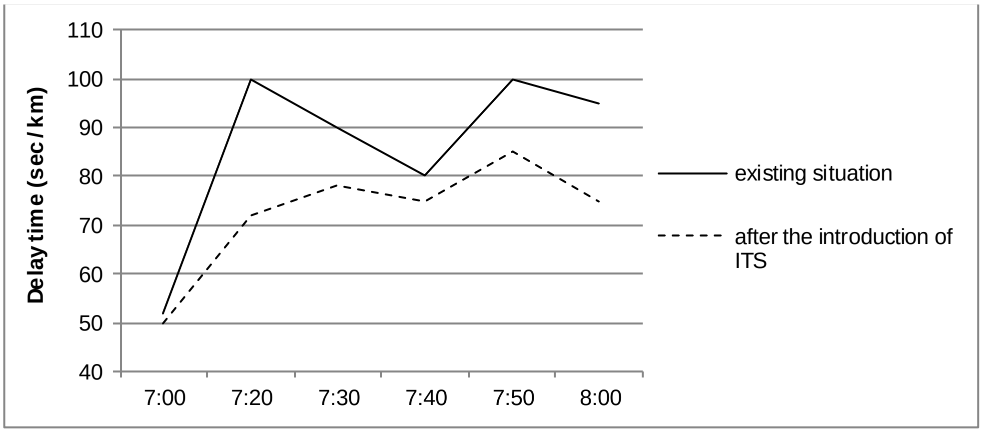

Fig. 4. Change in the delay time in the studied area.

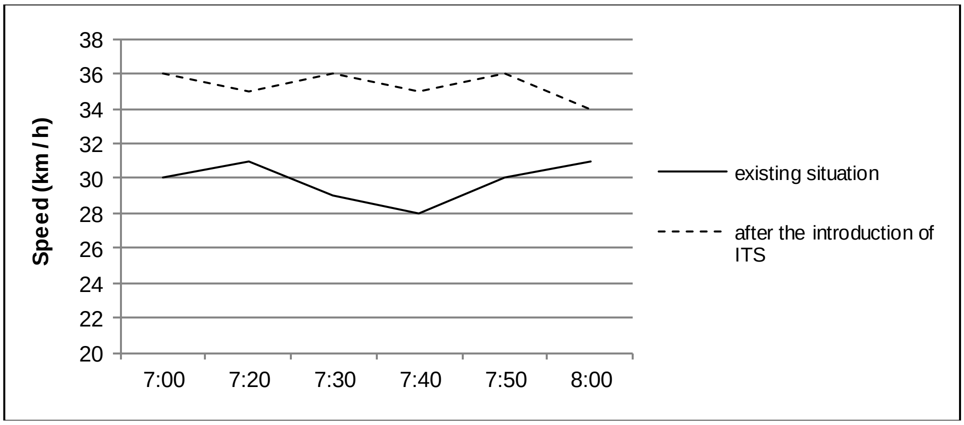

Fig. 5. Change in the speed of movement in the studied area.

Conclusion

The basis for improving the living standards of modern people is the transition to the concept of "Smart City". Smart City uses a complex of advanced digital and engineering solutions and organizational measures aimed at achieving the highest possible efficiency of resource management and the provision of services, in order to create sustainable favorable living and stay conditions, business activities of current and future generations on its territory. One of the fundamental components of a smart city is the transportation system.

Studies have shown that increasing the stability of the city's transport network is possible through the use of ITS. The impact of ITS was assessed using special mathematical and computational methods to create a model of a dynamic transport system. The constructed comprehensive model of traffic flows based on existing traffic rules allowed testing both individual sections and the entire road network of Zelenodolsk to assess traffic capacity and predict possible traffic situations.

The results of the study showed that the proposed solutions for the implementation of ITS are effective, reasonable, systematic and can be recommended for practical use not only in Zelenodolsk, but also in other cities of the Republic of Tatarstan.

The development of smart cities requires considerable costs and the use of modern equipment, and the storage of big data requires the latest servers. However, progress will inevitably lead to smart cities becoming a familiar trend.

References

1. Serova, E.Y.: Vozmozhnye puti povysheniya propusknoy sposobnosti ulichno-dorozhnoy seti. Inzhenenrnyy Vestnik Dona 1, 38-45 (2017).
2. Zhankaziev, S.V.: Intellektualnye transportnye sistemy. MADI, Moskva (2016).
3. Zhivoglyadov, V.G., Bahtina, O.N.: Teoreticheskie printsipy vozniknoveniya i uprezhdeniya zatorovyh sostoyaniy na avtodorogah. Izvestiya vuzov. Severo-Kavkazskiy region 3, 52-54 (2004).
4. Inose, H., Hamada, T.: Road traffic control system. Transport, Moskva (1983).
5. Kartabaev, R.S., Eremin, V.A.: Mashinnaya imitatsiya dvizheniya transportnyh potokov dlya proektirovaniya avtomobilnyh dorog v gornoy mestnosti. Ilim, Frunze (1983).
6. Silyanov, V.V.: Teoriya transportnyh potokov v proektirovanii dorog i organizatsii dorozhnogo dvizheniya. Transport, Moskva (1983).
7. Haight, F.A.: Mathematical theories of road traffic. Institute of Transportation and Traffic Engineering, University of California (1960).

8. Zaharov, Y.I., Karnauh, E.S.: Osnovnye sovremennye instrumenty imitatsionnogo modelirovaniya transportnyh potokov. Vesnik PDABA 1, 46-51 (2014).

9. Knose, W., Santen, L., Schadschneider A., Schreckenberg, M.: Towards a realistic microscopic description of highway traffic. J. Phys. A. Gen, 477-485 (2000).

10. Hoogendoorn, S.P.: State-of-the-art of vehicular traffic flow modeling. Delft University of Technology, 283–303 (2001).

11. Immers, L., Logghe, S.: Traffic floow theory. Curricular Material. Katholieke Universiteit Leuven, Belgium (2002).

12. Balakrishna, R.W., Ben-Akiva, Y.M., Antoniou, C.: Simulation-based framework for transportation network management for emergencies. Transportation Research Record: Journal of the Transportation Research Board 2041, 80–88 (2008).

13. Kunde, K.K., Calibration of Mesoscopic Traffic Simulation Models for Dynamic Traffic Assignment. Master's Thesis, Massachusetts Institute of Technology, Cambridge (2002).

14. Florian, M., Mahut, M., Tremblay, N.: A hybrid optimization-mesoscopic simulation dynamic traffic assignment model. Proceeding of the International IEEE Conference on Intelligent Transportation Systems 118–121. Oakland, CA, Aug., 25-29 (2001).

15. Zadorozhnyy, V.N., Yudin, E.B.: Obzor programm modelirovaniya transportnyh potokov. OmGTU 1 , 254-257 (2012).

16. Zhankaziev, S.V.: Imitatsionnoe modelirovanie v proektah ITS. MADT, Moskva (2016).

17. Barcelo, J.: Dynamic Network Simulation with AIMSUN 10.1007/0-387-24109-4_3 URL: https://www.researchgate.net/publication/225945073_Dynamic_network_simulation_with_AIMSUN, last accessed 2019/05/11.

18. Kolmakova, N., Yurshevich, E., Yatskiv, I.: Modelling as a means of solving the problem of city traffic optimization. Transport and Telecommunication l.7 (2006).

19. Pyshnyy, V.A.: Modelirovanie zagruzki transportnoy seti. Izvestiya TulGU 2, 55-68 (2012).

20. Barceló, J., Casas, J.: Dynamic network simulation with AIMSUN Simulation. Approaches in Transportation Analysis, 57-98 (2013).