The smart city transport and logistics system: Theory, methodology and practice

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Abstract. Forming the systems of flow processes management in the context of limited resources and a sharing economy is among the most pressing problems of digitalization. The scientific review analyses the theoretical and methodological foundations and special features of forming the smart city transport and logistics systems in practice, as well as the promising trends in their development aimed at increasing the level of mobility. Methodologically, the study rests on institutional and evolutionary economics theories, sustainable development theory, as well as the provisions of the quantitative school of management. The methods of systemic, comparative and cluster analysis were applied. Using VOSviewer software, the author analyses research publications indexed in the Russian and global citation databases and selects the articles dedicated to the latest trends in the field of mobility, transport and logistics. The research outlines the dominant trends and specific features of the smart mobility services development in real time for businesses and individuals, as well as intelligent transportation systems and highly autonomous vehicles in smart cities worldwide. The findings prove that the development of the Internet of Things underlies all trends, and a tendency to the formation of a multimodal environment, in particular. The study substantiates the necessity to develop the concept of urban logistics as a tool that expands the opportunities for forming sustainable systems of flow processes management in an urban area. The research results can complement the research trends in the development of the smart city transport and logistics system, formulate the norms and rules for cooperation of economic agents, and also serve as a theoretical and methodological framework for further research.

Keywords: municipal administration; smart city; intelligent transportation system; highly autonomous vehicles; bibliometric analysis.

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INTRODUCTION
Currently, relationships between economic agents are moving to a new level, which is characterized by new forms and principles of interaction, as well as by an increase in transaction costs associated with the search for information, negotiations, maintenance of contractual obligations, and opportunistic behaviour. Relationships are being transformed into a digital area of the information space of autonomous algorithms for business, population and government authorities, while ensuring the integration of intra-industrial, business and other processes.

In this context, the traditional transport and logistics system (TLS) of any city slows down the turnover of economic resources, which results in the growth of people’s personal consumer spending, economic losses of businesses and budgets of different levels.

There is a persisting trend towards the development of points of growth in the global economy. The smart city transport and logistics system serves as the basis for organization and effective functioning of the socio-economic system, as well as a crucial infrastructure project in the field of management that lays the foundation for other spheres (economy, environment, management, standards of living, etc.). The transformation of this system under digitalization requires significant administrative changes to be made in order to achieve high interorganizational logistic coordination of flow processes.

The relevance of the present scientific overview is due to the trends of digitalization, which forms new models and realities of human functioning, as well as their economic activity. At the same time, current relationships are characterized by the growing number of services in comparison with material production, as well as by new forms and principles of interaction, and an increase in transaction costs.

Within the paradigm of sustainable development, smart cities are formed, in which digital technologies are introduced into the economy, healthcare, waste disposal, housing and utilities infrastructure, transport and other spheres. This allows one to plan, execute and control flow processes and resources, including service and information, in the most efficient way. The mentioned trends are focused primarily on the growth in the quality of human life, which is impossible without the development of innovative and science-intensive technologies, industries, and modern management systems.

It is worth highlighting that amid the cyclical nature of economic development and the crisis of the world economy, there is a growing need for assessing the total logistics costs. In addition, the role of the planned effective use of limited resources is increasing to accumulate intelligent assets that enhance the competitiveness of national economy, enterprises, and firms in a city, in particular.

The global processes of the smart city transport and logistics system formation are reduced to building intelligent transport systems (ITSs), which are designed to deal with economic and social problems, ensure safety control, increase mobility and reduce harmful emissions into the environment. At that, cooperative intelligent transport systems are being established all over the world, as well as technologies and projects of highly autonomous vehicles (HAVs) are being developed.

The purpose of the research is to systematize the theoretical and methodological approaches to studying the smart city transport and logistics system and the practical foundations of its development in order to attain a higher level of inter-organizational interaction between economic agents and reduce transaction costs.

To fulfil the stated purpose, the following objectives have to be accomplished:
• to generalize the Russian and global experience of digital transformation and perform a theoretical cross-section of scientific branches in the field of the smart city transport and logistics system formation, as well as to determine semantic analogues of the concept and the main approaches to its examination;
• to identify promising research clusters that act as the major competitive knowledge domains and allow devising new avenues for reducing transaction costs, as well as ensuring the transport and logistics system of a new type to be formed;
• to carry out comparative analysis and systematize the main performance indicators of TLSs in smart cities all over the world in the context of ongoing and completed infrastructure projects; to compile a list of cities leading in the successful implementation of special practices for achieving a higher level of inter-organizational interaction between economic agents, and to identify the threshold levels of digitalization in the field of traffic management.

The purpose and objectives of the research serve as a rationale for forming its information base. The article presents an analytical overview of research publications indexed in the citation databases Scopus, Web of Science and eLibrary, as well as institutions characterizing the given research area and its practical implementation, and offer the primary directions of scientific studies, development of technologies and infrastructure in the field of forming the TLS of a smart city.

The research results make a contribution to the scientific theoretical and methodological framework for developing a new type of the flow processes management system.

RESEARCH METHODOLOGY
The object of the research is the smart city transport and logistics system, and the subject of the research is digitalization processes in the development of this system.

To address the mentioned issues covering several scientific research areas, the logic of analysis is based on the
fact that, from the standpoint of its practical implementation, the transport and logistics system is an infrastructure project encouraging the most efficient movement of economic resources.

At the first stage of the study, through system analysis, we identified semantic analogues of the concept of the smart city transport and logistics system in the Russian and international citation databases. At the second stage, we analysed the major articles on the topic under consideration using the VOSviewer bibliometric tool and formed research clusters in the field of mobility, transport and logistics that contained the relevant research avenues and characterized the strength of the connection between them. Next, having performed a comparative analysis of the cities leading in each of the identified clusters, we systematized their current performance indicators (traffic, time, CO₂ emissions, congestion), which made it possible to draw conclusions about the level of inter-organizational interaction under digitalization and propose the author’s vision of the TLS development in a smart city in the future.

The studies on intelligent transport systems and networks prevail among the foreign publications we have analysed. The scientific interest is also ignited by the discourse about the establishment of urban distribution logistics centres and consolidation centres and about the provision of active, inclusive mobility, etc. Moreover, the problem of sustainable urban planning in the context of the growing population is associated with urban logistics designed to ensure the most efficient transportation of people and goods, and the attempts to suggest possible variations of urban logistics policy in view of creating a sustainable transport system are analysed.

Another aspect of the research valuation is digital initiatives on developing services that enhance the competitiveness of cities due to the fact that they provide living in a relatively stable and safe society while using clean and renewable energy sources and maintaining high rates of economic efficiency in the context of a balanced and sustainable use of economic resources. From this perspective, there are currently no generally accepted rules and norms for the interaction of economic agents.

It is worth emphasizing that the topic under review prompts us to analyse a wider range of scientific publications addressing the problem of insufficient elaboration of the term “transport and logistics system”, as well as to intertwine it with intelligent transport systems, logistics centres and, naturally, with initiatives for the formation and development of a smart city. In addition, a 78 % increase in demand and a 21 % rise in congestion projected by 2030, coupled with the predominance of digital technologies and solutions implemented in the world today, indicate that there are made attempts to create intelligent control systems and do intensive search for solutions to optimize the last mile in urban areas using green logistics.

Thus, in the absence of a unified approach, we aim to suggest own interpretation of the concept of the smart city transport and logistics system. To do so, we perform a bibliometric analysis in Scopus, Web of Science and eLibrary citation databases that highlight the semantic load of this category (Fig. 1, 2).

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**Fig. 1. Number of scientific publications on transport, logistics and mobility in a smart city indexed in Scopus and Web of Science databases, 2000–2020**

**Рис. 1. Количество публикаций по вопросам изучения транспорта, логистики и мобильности в умном городе в базах данных Scopus и Web of Science, 2000–2020**

**Fig. 2. Number of scientific publications on transport and logistics system and intelligent transport system in a smart city in the eLibrary database, 2000–2020**

**Рис. 2. Количество публикаций по вопросам изучения транспортно-логистической и интеллектуальной транспортной систем умного города в базе данных eLibrary, 2000–2020**
The bibliographic cross-section includes more than 75,000 articles on various improvements in smart cities. The use of VOSviewer enabled us to get the most accurate and complete results to detail the research topic.

The foreign citation databases widely operate the definition of smart city. The year of 1974 witnessed the first attempts to examine this topic; however, the most intense debate in the academic community started in 2000 after a progressive increase in the number of scientific articles on the given subject. Analysis of research activity shows that the semantic meaning of the term “smart” implies the associated development of society, infrastructure, urban planning, digital technologies, etc. Infrastructure development is associated with energy, networks, and transport.

In the context of the studied subject, a number of researchers [Kramers et al., 2014; Bibri, Krogtie, 2017; Valcarcel-Aguilar, Murias, Rodriguez-Gonzalez, 2019; Zhang et al., 2020; Sharifi, 2020] investigate economic, social and environmental aspects of sustainability, and effective resource management, in particular [Schneider et al., 2019]. At that, studies on smart mobility take the lead [Paiva et al., 2021], and the following initiatives are highlighted: the development of consolidation centres, autonomous and green transport (no more than 120 g of CO2 emissions per 1 km), ensuring effective calibration of access time, introducing a progressive scale of road toll schemes, and the use of alternative delivery modes.

Researchers pay special attention to the necessity to ensure sustainability and environmental friendliness of supplies amid the rapid development of e-commerce, as well as to the transport and logistics system and the development of mobility, which are promising targets for technological improvements.

In the international citation databases, there are three basic aspects for exploring smart cities, these are mobility (1,956 articles in 2020, and 989 for the first half of 2021), transport (2,044 and 1,037 articles, respectively), and logistics (611 and 376 articles, respectively).

However, in the Russian scientific community, the situation is different: the pivotal role belongs to the studies on the optimization of logistic processes in the implementation of information and communication technologies (ICT) in enterprises and supply chains and on the use of digital services in cities and regions. The number of Russian-language articles in this field of research is significantly less than foreign ones, but it is growing steadily (334 articles in 2020, and 124 articles in the first half of 2021).

Hence, a smart city transport and logistics system refers to a unified system of flow processes management, which is focused on achieving sustainable use of resources and ensuring zero losses for all categories of economic agents in the field of traffic management [Savin, 2020a].

There emerges a question as to how the traditional transport and logistics system of a city differs from its smart category. The answer is obvious: they differ in the application of new principles of organization and management of flow processes when using ICT, that, in particular, ensure the reliability, accuracy and security of the transmitted digital information in real time. At the same time, environmental friendliness when applying the principles of urban logistics is of special importance.

The tardy analysis of the semantic categories of the smart city transport and logistics systems, which is typical of the Russian research segment, allows us to highlight the main trends of a theoretical, methodological and practical nature observed in foreign citation databases. In addition, we can correlate the concept with selective domestic developments and get a general idea of the formation of transport and logistics systems in the future.

In conclusion, it is worth stressing that, along with digital solutions in the field of intelligent transport systems development and the introduction of highly autonomous vehicles, it is logistics that will drive the implementation of smart mobility as a smart city component in the coming years.

**THEORETICAL AND METHODOLOGICAL APPROACHES TO STUDYING THE SMART CITY TRANSPORT AND LOGISTICS SYSTEM: CURRENT AND PROSPECTIVE SCIENTIFIC RESEARCH**

Currently, a system-based approach in the field of urban policy and planning founded on digital technologies, as well as social, environmental and economic innovations has been formed.

Multidimensional and conceptual problems in defining smart cities support the view that the introduction of digital solutions, the knowledge economy, citizen engagement, social and institutional innovation, and information management are essential elements of smart cities’ development [Cocchia, 2014; Talari et al., 2017; Mora, Bolici, Deakin, 2017; Pereira et al., 2018; Ruhlandt, 2018; Guo Y.-M. et al., 2019; Zhao, Tang, Zou, 2019; Wamba, Queiroz, 2019; Echebarria, Barrutia, Aguado-Moralejo, 2021; Janik, Ryszko, Szafraniec, 2020; Moradi, 2020; Pérez et al., 2020; Sharifi, 2020; Zheng et al., 2020].

Moreover, in the context of the sustainable development paradigm while forming a smart city, which enjoys all the advantages of the spatial concentration of mass consumption, high savings from wholesale and retail trade operations, reduced delivery times, and increased convenience for buyers and customers, there are significant transformations in the transport and logistics system and introduced social and environmental innovations.

Among the promising avenues for the formation of a smart city are the development of mobility [Bonnefon, Shariff, Rahwan, 2016; Rafael et al., 2020; Paiva et al., 2021] and the introduction of the 15-minute city concept [Moreno et al., 2021], which decentralizes the urban infrastructure and implies that all necessary amenities should be located within a short distance.
It should be noted that the concept of smart mobility is in line with the scientific paradigm of sustainable development in the field of people and goods transportation, and is also linked with modern digital technologies within the Internet of Things (IoT), big data, blockchain, and artificial intelligence. However, a number of researchers claim that smart mobility requires no digital technologies to be involved, which only complement this concept [Docherty, Marsden, Anable, 2018; Buchiarone, 2019].

A bibliometric analysis of the smart city TLSs from the standpoint of mobility (Fig. 3) allows identifying the distinguishing features of their formation: the development of public transport [Docherty, Marsden, Anable, 2018; Jin, Kong, Sui, 2019; Ceder, 2021], intelligent transport systems [Balasubramaniam et al., 2021; Bryazgina, Kurguzov, Belov, 2020], and information processing and analysis centres focused on the introduction of services for improving consumers’ quality of life [Mirri et al., 2016; Belbachir et al., 2019; Lopez, Farooq, 2020].

At that, the initiatives aimed at improving mobility indicators make it possible to slightly increase the quality of life in the smart city transport and logistics system [Savin, 2020b].

Some researchers note that mobility is focused on meeting human needs and implies a consumer choice, as well as takes into account the minimum level of emissions and low transportation costs. Mobility embraces sensors for gathering information in real time (including mobile phones) and intelligent video surveillance, autonomous decision-making algorithms, an information system, etc. [Amoretti, Belli, Zanichelli, 2017; Aleta, Alonso, Ruiz, 2017; Yigitcanlar, Kamruzzaman, 2019; Paiva et al., 2021].

Currently, there is an obvious trend towards the formation of a multimodal environment in the field of smart mobility [Groth, 2019; Mukhtar-Landgren, Paulsson, 2021] in the development of the sharing economy [Rong, Xiao, Wang, 2019; Schneider et al., 2019].

We agree that smart mobility may not cover all consumer groups, but its development depends on investments in digital and intelligent systems infrastructure, as well as 4/5G networks, including highly autonomous vehicles [Bonnefon, Shariff, Rahwan, 2016; Cugurullo et al., 2021; Guo H. et al., 2020; Rafael et al., 2020; Mourad, Puchinger, van Woensel, 2021]. In addition, in today’s situation, among the central elements that slow down the development of the concept of smart mobility are the provision of legal regulation, interoperability, personal data protection and cybersecurity [Elisa et al., 2018; Naz et al., 2019; Behrendt, 2020], ethical and legal issues in the context of artificial intelligence [Martinho et al., 2021; Naniev, 2020], and allocation of responsibilities.

Another aspect associated with smart mobility is the development of an intelligent transport system, which is oriented towards using modern ICT to solve the issues of choosing flow processes management system amid limited human rationality. Such systems reduce transportation time (by 10–15 %), the number of transport stops (by 20–40 %), fuel consumption (by 5–15 %), logistics costs (by 5–25 %), as well as increase inventory turnover (by 15–45 %), safety (up to 60 % in certain road sections), and

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Fig. 3. Key terms in the field of smart city mobility and their relationships: analysis of publications indexed in Scopus, Web of Science and eLibrary databases, 2000–2021
Рис. 3. Ключевые термины в области изучения мобильности в умном городе и их взаимосвязи: результаты анализа публикаций 2000–2021 гг. в базах данных Scopus, Web of Science и eLibrary
environmental friendliness (a 5–15 % decline in harmful emissions into the atmosphere).

In the field of transport, the analysis of terms allows us to form the following main research clusters (Fig. 4): 1) assessment of the workload and development of intelligent transport systems; 2) Internet of Things, data analysis, and security; 3) processes of transportation and traffic management; 4) sustainable development; 5) energy efficiency and electric transport.

The clusters highlighted in purple and yellow concentrate on modern approaches to deploying intelligent transport systems in the world and planning the functioning of urban transport [Gohar, Muzammal, Ur Rahman, 2018; Pan et al., 2021], including parking systems, congestion reduction, traffic forecasting, security systems, emergency management, payment management, organization of freight transportation and information services on public transport using technologies for spatial positioning, as well as receiving, processing, exchanging and distributing information.

The introduction of ICT and the development of intelligent transport systems are expected to serve as the basis for the management and optimization of traffic flows [Schwerdfeger, Boysen, 2020]. These systems are regarded as an optimal opportunity to use investment, planning and resources¹. Today, within the framework of the ISO Technical Committee 204, there is implemented the cross-country research cooperation in the field of architecture, autonomous identification of vehicles and equipment, and freight transport management, as well as there are tested the standards for cooperative intelligent transport systems and adaptive traffic control systems (Sydney Coordinated Adaptive Traffic System SCRAM, GLIDE, Vehicle Information and Communication Systems, etc.).

In terms of studying smart cities, the Internet of Things is the most comprehensive research subject in the field of security [Hammi et al., 2018; Elisa et al., 2018; Naz et al., 2019], intelligent infrastructure development [Barns et al., 2017; Minoli, Sohraby, Occhiogrosso, 2017; Kosimkhuzhav, Skoryupina, 2020], and in-depth examination of digital technologies for information analysis and processing. Within the smart city concept, special attention is paid to the introduction of V2V technologies in the field of IEEE 802.bd and NR-V2X, DSRC according to IEEE 802.11p that ensure the interaction of transport vehicles, as well as to convolutional and recurrent neural networks, deep learning systems, machine learning, computer vision improvement, and analysis of distributed data ledger application [Balasubramaniam et al., 2021; Savin, 2021].

The given research on transport and logistics systems from the perspective of logistics focuses not only informatization of the main flow processes for all economic agents, but also takes into account congestion, traffic and optimization (Fig. 5).

Nowadays, the development of urban logistics [Savin, 2020c] acts as a powerful tool for forming sustainability and mobility, and the emergence of effective transport systems, in particular [Hu et al., 2019; Dolati Neghabadi, Evrard Samuel, Espinouse, 2019]. At the same time, there

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appear studies on locating and operating urban consolidation centres [Aljohani, Thompson, 2016] and pick-up points, the use of drones [Shavaran et al., 2019; Macrina et al., 2020] and alternative transport; some attempts are made to optimize the last mile [Oliveira et al., 2017; Lim, Jin, Srai, 2018; Melacini et al., 2018; Ranieri et al., 2018; Olsson, Hellström, Pålsson, 2019; Simoni et al., 2020] and crowdshipping [Szmelter-Jarosz, Rześni-Cieplińska, 2020; Devari, Nikolaev, He, 2017; Binetti et al., 2019; Dai, Jia, Liu, 2020; Gatta et al., 2019]; much attention is devoted to reducing emissions, developing green logistics [Perboli, Rosano, 2019; Ren et al., 2020; Mello Bandeira et al., 2019; Zhang et al., 2020; Asghari, Mirzapur Al-e-hashem, 2021; Moghdani et al., 2021; Patella et al., 2021], routing, delivery time windows [Cortés-Murcia, Prodhon, Murat Afsar, 2019; Galkin, Sysoev, 2020], and organizing stakeholder participation [Tompson, 2017; Szmelter-Jarosz, Rześni-Cieplińska, 2020].

It is worth emphasizing that the existing penetration of digital technologies accelerates the flow processes of economic activity and human functioning and creates risks of resource management, which requires a new development paradigm to be found within the framework of institutional and evolutionary economics theory [Popov, 2020]. In this context, the new paradigm “mobility as a service” [Amoretti, Belli, Zanichelli, 2017; Müller, Wirtz, Schmidt, 2020; Pahwa, Starly, 2021; Ho et al., 2021] and the use of the full toolkit of urban logistics can contribute to implementing and complementing the systems approach. It will provide the effective flow processes management in the smart city transport and logistics system and offer a complete range of services in real time upon the request of both business and citizens.

Currently, in order to assess smart city, a ranking approach (IESE Cities in Motion Index, Global Power City Index, The Global Cities Index, EasyPark Smart City Index, etc.) is applied, which examines mobility and transport: time in traffic jams, average commute time, taxi fares, availability of parking apps, number of parking spaces, number of electric charging points, as well as smart transport initiatives (smart traffic lights, strategies to reduce vehicle use and increase public transport use, interagency collaboration, road safety, open transport data), etc.

Present TLS research studies concentrate on building mobility development simulation models [Del Vecchio et al., 2019; Beaver et al., 2020; Kronsell, Mukhtar-Landgren, 2020]; infrastructure design [Barns et al., 2017; Fu, Zhu, 2021; Fontaine et al., 2021], public transport efficiency [Johansson et al., 2017; Gatta, Marcucci, Site et al., 2019; Jin, Kong, Sui, 2019; Mathirajan, Devadas, Ramanathan, 2021; Ceder, 2021], routing [Beaver et al., 2020; Paiva et al., 2020], traffic [Dong et al., 2020; Wang, Quan, Ochieng, 2020], traffic flow modelling [Anda, Erath, Fourie, 2017], etc.

All of the mentioned models are insufficient to attain the main goal — that is, to ensure the logistic coordination of flow processes, — and the scrutiny of the socio-economic system is centred around methodological holism, which employs a holistic approach to this system. Numerous economic agents, namely firms and households, create friction in the field of flow processes organization [Wang, Quan, Ochieng, 2020]. As a result,
representative analysis is only possible with a general evaluation of the movement of passengers and goods within certain boundaries. This outcome can be achieved through the combined design of the smart city TLS [Savin, Bronnikov, 2018; Caird, Hallett, 2019] in terms of the creation of a single ecosystem [Lagorio, Pinto, Golini, 2017; Longo, Zappatore, Navathe, 2019; Komninou et al., 2021] and the transport-logistic, digital and smart infrastructure, as well as the development of norms and regulations for the interaction between economic agents.

With the arithmetic growth of population and urbanization, needs grow geometrically, which poses the question of organizing flow processes in the development of the “mobility as a service” global platform. Within the framework of sustainable development, the formation of a unified technological system is a significant milestone in the integration of transport and logistics. At that, a change in the management system, an increase in automation and robot application, and a rise in the number of services will add new essential elements to the transport and logistics system of a smart city.

The growing number of economic agents prompts the search for new approaches that would allow adapting to the new economic paradigm while promoting cooperation and simultaneously passing on selective research mutations in terms of the succession of current research approaches and ideas initiated by firms, as well as in the context of social innovation in the formation of smart cities.

Amid the direct structural relationships of transport-logistics and socio-economic systems, consumer-initiated innovations exert an overwhelming impact on flow processes. At that, logistics can contribute to the economic development when selecting the best of them from the position of not only rational choice, but also improving the quality of human life.

Thus, various theoretical and methodological approaches are being currently implemented; they are associated with sustainable development and a better quality of life in the field of the growing indicators of mobility, transport and logistics. However, there is considerable confusion in interpreting the transport and logistics system and filling this definition with a more specific meaningful non-digital idea. In addition, no unified norms and rules for economic agents to interact while introducing ICT are shaped, and the maximum levels of possible and necessary digitalization are not considered.

SPECIAL FEATURES OF IMPLEMENTING THE SMART CITY TRANSPORT AND LOGISTICS SYSTEMS IN PRACTICE

At the moment, there are active discussions about the concept of sustainable development and urban logistics policy in view of creating the smart city transport and logistics system [Hu et al., 2019; Rodrigues, Vale, Costa, 2020; Reda et al., 2020; Viu-Roig, Alvarez-Palau, 2020; Patella et al., 2021] that is designed to reduce congestion and emissions and ensure a higher level of mobility. Its current state is attributed to the introduction of digital services, autonomous vehicles on public roads, the formation of intelligent transport systems, but these initiatives are limited by financial, technological, legal, institutional and other barriers.

The successful formation of the transport and logistics system is founded on the proper functioning of the Internet, “regulatory sandboxes” and legislation, as well as the introduction of ICT (Table 1), preparation of the appropriate infrastructure, and work with the population. It is noteworthy that the average stable Internet speed serves as the basis for the development of modern digital technologies, and countries with stable data transmission networks are more active in developing ICT.

Table 1 – Autonomous vehicles and ICT development country rankings, 2020

<table>
<thead>
<tr>
<th>Country’s position in the overall ranking</th>
<th>Autonomous Vehicles Readiness Index(^1)</th>
<th>Position in the ICT development ranking(^2)</th>
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<td>Policy and legislation</td>
<td>Technology and innovation</td>
<td>Infrastructure</td>
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<td>11. Japan</td>
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Many leading economies are characterized by a high level of ontogeny of the broadband and mobile Internet. They concentrate their efforts and initiatives on building secure Internet servers, translate information systems to Web 2.0 (3.0), invest in next-generation software, popularize IoT analytics and analytic scalability, and initiate cybersecurity education. Moreover, they actively develop ITC business models, direct careful attention to employee training, patent work and R&D, invest in the development of 4G/5G, fibre optic networks, and invest in cloud infrastructure, the Internet of Things and artificial intelligence.

Amid the global trend towards digitalization, there stand out two ways of developing intelligent transport systems and introducing autonomous vehicles:

- vehicle machine learning in decision-making in the context of interaction with pedestrians and stationary objects;
- enhancing the infrastructure with accounting and information systems when integrating with the ITS, the development of which in many cities lags behind due to high costs of both bringing the current infrastructure in line with established standards and creating a new world-class digital and intelligent infrastructure.

The formation of road traffic control centres (RTCCs) is underway amid the improvement processes in the framework architecture (FRAME, U.S. DoT ITS et al.) in order to protect the environment ensuring safety and a high level of mobility.

There are a substantial number of system aggregators globally that provide transportation services of both people and goods. The booming and well-known mobility development services are the following:

- selecting private car drivers (Blablacar, Uber, Yandex, Kiwitaxi, taxi.eu, Gett, YouDrive, etc.);
- carsharing (Addumacar, Cambio Car2go, Enjoy, Enterprise, Flinkster, Sharengo, Zipcar, etc.);
- bicycle rental (Velib, Yellow Bike, Black Bikes, Deutsche Bahn, Lidl, Nextbike, Mattia 46 Bikes, Bycyklen, Velobyke, etc.);
- scooter sharing (YouDrive Lite, Revel, Skoda Auto Digila, Hoop, Whosh, Bounce, etc.).

Among the most advanced companies that develop highly autonomous vehicles are Tesla, Nissan, Volvo, Audi, Google, Apple, Yandex and others. The projects and initiatives undertaken are given in Table 2.

The formation of the smart city transport and logistics system involves numerous technologies and solutions, which are embodied in ready-made projects, however, cooperative (autonomous) systems are only at the early stage of their development.

Firstly, it is required to strengthen the relationships between economic agents in the field of cooperation and

<table>
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<th>Country’s position in the overall ranking</th>
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<td>22. Spain</td>
<td>23</td>
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<td>23. Czech Republic</td>
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<td>24. Italy</td>
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<td>25. Hungary</td>
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<td>26. Russia</td>
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<td>27. Chile</td>
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<tr>
<td>28. Mexico</td>
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<tr>
<td>29. India</td>
<td>28</td>
<td>28</td>
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<tr>
<td>30. Brazil</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 2 – Main projects in the field of highly autonomous vehicles, 2020

<table>
<thead>
<tr>
<th>Country</th>
<th>Projects and outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>Technical Reference for Autonomous Vehicles (TR 68), model framework for voluntary implementation of AI-based systems (Model AI Governance Framework)</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>Tests of self-driving trucks convoys, share of electric vehicles (hybrids) is 15%</td>
</tr>
<tr>
<td>Norway</td>
<td>Driverless buses with a speed limit of 20–25 km/h. Unmanned snow clearing machines. Share of electric vehicles (hybrids) is 56%</td>
</tr>
<tr>
<td>United States</td>
<td>Uber tests in San Francisco, self-driving vehicles (Origin, Apple, Tesla, etc.)</td>
</tr>
<tr>
<td>Finland</td>
<td>Regulatory sandboxes for any autonomous vehicle challenge. Unmanned bus on public roads</td>
</tr>
<tr>
<td>Sweden</td>
<td>Self-driving electric truck Einride Pod</td>
</tr>
<tr>
<td>South Korea</td>
<td>Future Car Industry National Vision aimed at promoting electric and hydrogen vehicles</td>
</tr>
<tr>
<td>United Arab Emirates</td>
<td>Strategy stipulating that 25% of all transport in the country will be smart and driverless by 2030</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>The Automated and Electric Vehicle Act. Testing an unmanned bus on public roads</td>
</tr>
<tr>
<td>Denmark</td>
<td>The Danish Road Traffic Act with amendments on self-driving cars. Test drives of an automated bus SmartBus</td>
</tr>
<tr>
<td>Japan</td>
<td>The Road Transport Vehicle Act and the Road Traffic Act with amendments on self-driving vehicles. Launching Honda with level 3–4 autonomous driving technology</td>
</tr>
<tr>
<td>Canada</td>
<td>Autonomous Vehicle Innovation Network. Partial municipal subsidies for ride-hailing trips instead of using a public bus system</td>
</tr>
<tr>
<td>Taiwan</td>
<td>Pure-electric, self-driving minibus The WinBus</td>
</tr>
<tr>
<td>Australia</td>
<td>Automated passenger vehicles BusBot, Intellibus on public roads. Autonomous haul trucks in mining operations</td>
</tr>
<tr>
<td>Germany</td>
<td>Freightliner Cascadia truck and bus with autonomous control system. Testing autonomous vehicles on public roads. Cars with level 4 autonomous driving technology are allowed</td>
</tr>
<tr>
<td>Israel</td>
<td>Own fleet of self-driving vehicles</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Automated bus on public roads. Unmanned aircraft system (drones)</td>
</tr>
<tr>
<td>Austria</td>
<td>Testing autonomous mini-buses, flying taxi project</td>
</tr>
<tr>
<td>France</td>
<td>A legal framework to launch self-driving transport by 2021. Opening of a proving ground. 16 projects in the field of unmanned vehicles</td>
</tr>
<tr>
<td>China</td>
<td>100 robot taxis with a speed limit of up to 80 km/h. Testing Pony.ai on public roads</td>
</tr>
<tr>
<td>Belgium</td>
<td>Test drive of an autonomous shuttle bus</td>
</tr>
<tr>
<td>Spain</td>
<td>Test drive of self-driving buses. Legal framework on the popularization of electric vehicles</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>Testing autonomous vehicles. BMW proving ground</td>
</tr>
<tr>
<td>Italy</td>
<td>Developing a smart road network. Test drives of autonomous Next buses and Olli cars. Developing V2V technologies</td>
</tr>
<tr>
<td>Hungary</td>
<td>ZalaZone proving ground. Developing an autonomous parking system to use in garage complexes</td>
</tr>
<tr>
<td>Russia</td>
<td>Lurching a self-driving taxi. Autonomous delivery robots. Test drives of unmanned trucks</td>
</tr>
<tr>
<td>Chile</td>
<td>Autonomous haul trucks in mining works. Testing self-driving buses on public roads. A plan to reach a 40% level in using electric vehicles</td>
</tr>
<tr>
<td>Mexico</td>
<td>Plans to learn from the USA experience</td>
</tr>
<tr>
<td>India</td>
<td>Plans to increase the share of electric vehicles</td>
</tr>
<tr>
<td>Brazil</td>
<td>Autonomous haul trucks in mining operations</td>
</tr>
</tbody>
</table>

Secondly, in order to improve the efficiency of using highly autonomous vehicles, the present infrastructure should be transformed and HAVs need to be tested on public roads.

Thirdly, the formation of the smart city transport and logistics system requires a new approach based on a digital road model, which can handle the problem of TLS congestion on a fast-track basis. Such an approach will ensure the turnover of resources and increase mobility within the theory of sustainable development, as well as improve the environmental situation.

Table 3 presents the rankings of the world’s smart cities implementing innovations in the field of mobility, transport and logistics.

Today’s development of the smart city transport and logistics systems allow us to draw the following conclusions.

1. There exist successful practices of TLS implementation in which the congestion level is quite low with regard to the city’s population (Tokyo, London, Vienna,
Berlin, Copenhagen, etc.); many of them create ultra-low emission zones (London, Amsterdam, Berlin, Stockholm, Oslo, etc.) and advance electric transport and related infrastructure. Their development models can be viewed as best practices.

2. Currently, adaptive ITS solutions are being implemented with Tokyo, Singapore and Seoul leading in this area. The systems of fixation, informing and intelligent information processing are established, which are focused on passenger and freight transport management.

3. Vehicle machine learning occupies the central place among autonomous transport systems technologies. Today, its legal framework is being formulated, new technologies (V2V, ADAS, CNN, RNN, DRL) and the specific infrastructure are being developed and implemented, as well as consumers are familiarized with these innovations. Singapore, the Netherlands, Norway, the USA, and Finland are the leaders in this area. Many countries are introducing highly autonomous vehicles on public roads.

4. Residents of the megacities use the metro (Tokyo – 58.75 %, New York – 44.12 %, London – 43.58 %, Paris – 40.71 %, Seoul – 39.60 %) and trams (Vienna – 11.96 %) as frequently as possible, while other municipalities promote cycling (Rotterdam – 42.86 %, Amsterdam – 40.74 %, Copenhagen – 38.98 %, Berlin – 26.52 %), introduce administrative bans, develop the concept of a multimodal

<table>
<thead>
<tr>
<th>City</th>
<th>IESE¹</th>
<th>GPCI²</th>
<th>GCI³</th>
<th>EPSCI⁴</th>
<th>Traffic⁵</th>
<th>Congestion⁶</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Index</td>
<td>Min</td>
<td>CO₂ emissions per capita, tonnes</td>
<td>%</td>
<td>Index</td>
<td>CO₂ emissions per capita, tonnes</td>
</tr>
<tr>
<td>1. London</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>155.42</td>
<td>43.85</td>
<td>0.45</td>
</tr>
<tr>
<td>2. New York</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>161.50</td>
<td>42.79</td>
<td>0.71</td>
</tr>
<tr>
<td>3. Amsterdam</td>
<td>3</td>
<td>6</td>
<td>23</td>
<td>97.90</td>
<td>29.47</td>
<td>0.51</td>
</tr>
<tr>
<td>4. Paris</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>152.02</td>
<td>41.56</td>
<td>0.66</td>
</tr>
<tr>
<td>5. Reykjavik</td>
<td>5</td>
<td>–</td>
<td>–</td>
<td>90.99</td>
<td>19.96</td>
<td>0.80</td>
</tr>
<tr>
<td>6. Tokyo</td>
<td>6</td>
<td>3</td>
<td>4</td>
<td>130.48</td>
<td>41.20</td>
<td>0.27</td>
</tr>
<tr>
<td>7. Singapore</td>
<td>7</td>
<td>5</td>
<td>9</td>
<td>147.60</td>
<td>41.23</td>
<td>0.59</td>
</tr>
<tr>
<td>8. Copenhagen</td>
<td>8</td>
<td>19</td>
<td>–</td>
<td>86.91</td>
<td>28.58</td>
<td>0.39</td>
</tr>
<tr>
<td>9. Berlin</td>
<td>9</td>
<td>7</td>
<td>15</td>
<td>100.57</td>
<td>33.88</td>
<td>0.31</td>
</tr>
<tr>
<td>10. Vienna</td>
<td>10</td>
<td>16</td>
<td>22</td>
<td>77.79</td>
<td>26.45</td>
<td>0.36</td>
</tr>
<tr>
<td>11. Hong Kong</td>
<td>11</td>
<td>9</td>
<td>6</td>
<td>145.69</td>
<td>42.72</td>
<td>0.39</td>
</tr>
<tr>
<td>12. Seoul</td>
<td>12</td>
<td>8</td>
<td>17</td>
<td>157.47</td>
<td>42.14</td>
<td>0.72</td>
</tr>
<tr>
<td>13. Stockholm</td>
<td>13</td>
<td>22</td>
<td>–</td>
<td>120.56</td>
<td>35.91</td>
<td>0.53</td>
</tr>
<tr>
<td>14. Oslo</td>
<td>14</td>
<td>–</td>
<td>42</td>
<td>109.14</td>
<td>31.34</td>
<td>0.66</td>
</tr>
<tr>
<td>15. Zurich</td>
<td>15</td>
<td>20</td>
<td>–</td>
<td>102.34</td>
<td>33.64</td>
<td>0.37</td>
</tr>
<tr>
<td>16. Los Angeles</td>
<td>16</td>
<td>12</td>
<td>7</td>
<td>340.31</td>
<td>60.35</td>
<td>3.63</td>
</tr>
<tr>
<td>17. Chicago</td>
<td>17</td>
<td>25</td>
<td>8</td>
<td>191.20</td>
<td>42.07</td>
<td>1.81</td>
</tr>
<tr>
<td>18. Toronto</td>
<td>18</td>
<td>18</td>
<td>19</td>
<td>203.02</td>
<td>45.15</td>
<td>1.62</td>
</tr>
<tr>
<td>19. Sydney</td>
<td>19</td>
<td>11</td>
<td>15</td>
<td>194.17</td>
<td>39.88</td>
<td>1.64</td>
</tr>
<tr>
<td>20. Melbourne</td>
<td>20</td>
<td>14</td>
<td>18</td>
<td>176.39</td>
<td>40.51</td>
<td>1.52</td>
</tr>
<tr>
<td>21. San Francisco</td>
<td>21</td>
<td>24</td>
<td>13</td>
<td>254.06</td>
<td>50.90</td>
<td>2.19</td>
</tr>
<tr>
<td>22. Helsinki</td>
<td>22</td>
<td>32</td>
<td>–</td>
<td>92.82</td>
<td>30.86</td>
<td>0.40</td>
</tr>
<tr>
<td>23. Washington</td>
<td>23</td>
<td>36</td>
<td>10</td>
<td>187.48</td>
<td>40.37</td>
<td>1.95</td>
</tr>
<tr>
<td>24. Madrid</td>
<td>24</td>
<td>13</td>
<td>16</td>
<td>137.67</td>
<td>35.03</td>
<td>1.08</td>
</tr>
<tr>
<td>25. Boston</td>
<td>25</td>
<td>27</td>
<td>21</td>
<td>213.08</td>
<td>45.42</td>
<td>2.0</td>
</tr>
<tr>
<td>26. Moscow</td>
<td>26</td>
<td>30</td>
<td>20</td>
<td>219.33</td>
<td>51.31</td>
<td>1.09</td>
</tr>
</tbody>
</table>

The analysis of research publications suggests that the scientific paradigm of sustainable development with the intensive introduction of ICT is only partially formed. From the perspective of the system approach, the formation stages and specifics of transport and logistics systems' evolution, as well as the transformation of the current forms of relationships under digitalization and the growing role of formal and informal institutions, are of great importance. It should be pointed out that the use of the theoretical and methodological toolkit for urban logistics makes it possible to provide additional economic benefits and reduce transaction costs when establishing sustainable regional transport and logistics systems.

The contribution of the scientists listed in the study is substantial and undeniable, and the practical implementation and adopted technological improvements are arousing intense interest among researchers. However, in the age of the digital economy, there is a need for new theoretical and methodological research in the formation and evolutionary development of the integrated smart city transport and logistics system.

It should be noted that, within the framework of the institutional-evolutionary approach, the systems with the minimum level of transaction costs play a dominant role. Achieving this indicator is only possible with the coordination of the functioning and development of all economic agents. We believe that in these conditions there is a need to provide modelling of the digital logistics institute, which formulates the basic principles and rules for organizing flow processes to attain a higher level of inter-organizational interaction between economic agents in the TLS of a smart city.

The presented analytical review allows drawing a general idea of the trends in the development of the concept of smart mobility in urban areas, as well as determining possible variations in the formation of the smart city transport and logistics systems that provide future savings for all categories of economic agents.

**References**


Источники


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