Analytical support for effective functioning of intelligent manufacturing and transport systems

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Abstract. The formation of the digital economy is one of the important priorities in the development of the information society. The article is devoted to the problem of improving the efficiency of the transport system, taking into account the development of industry based on implementation of digital technologies. The approach to the organization of the regional logistics center, assuming the division of space into clusters, has been presented. Two cases of the cluster model, depending on the size and number of clusters relative to the size of the city, have been examined. This forms the methodological basis for the construction of the functional architecture of the intelligent transport system.

1. Introduction

The change of technological orders causes the transformation of all spheres of society. Currently, the global trend of the digitalization of economy is associated with the use of highly intelligent cognitive technologies, industrial Internet, big data, virtual and augmented reality, robotics and sensors, distributed registry systems, which will lead in the nearest future to significant changes in the organization and architecture of production, transport systems, business models, principles of interaction of economic entities. In the Russian Federation, the formation of the digital economy is one of the important national priorities in the development of the information society, determining its competitiveness in the world market [1]. By the way, according to the European Commission, which estimates the international index of digital economy and society (I-DESI), Russia in the ranking of 17 countries outside the EU, took only 12th place, ahead of China, Turkey, Brazil and some other countries [2]. According to the program "Digital Economy of the Russian Federation" by 2024, the successful functioning of at least 10 industry (industrial) digital platforms for the main subject areas of the economy (including the "smart city") should be ensured; the share of industries whose digital platforms are integrated with domestic platforms that provide a single trusted environment for working with data should be 100 percent; the number of international competence centers that are partners of digital platforms for research and development – at least 30 units [3]. The ongoing changes also have affected...
such key sectors of the economy as industry, transport. The new stage of industry development – "Industry 4.0" – provides the mass implementation of cyberphysical systems in production, the use of artificial intelligence. When organizing traffic, geolocation equipment is used, incoming signals from vehicles, information from numerous IP cameras are recorded and analyzed, "deserted technologies" of vehicle management are introduced, "smart stations" are built, and delivery time is reduced. The distinctive features of digital systems are that they can function autonomously, have analytical and prognostic functions, independently solve human tasks. In Russia, the use of modern digital technologies for the organization of processes of production and delivery of goods to the final consumer, providing the full integration of intelligent communication technologies between the user, the vehicle, the traffic management system and infrastructure, is designed to ensure the sustainable competitiveness of domestic companies in the global market. It is the positive synergetic effect resulting from the joint effective realization of the industrial and transport and transit potential of the Russian regions on the innovation basis that is one of the main conditions for accelerated economic growth, increasing the investment attractiveness and competitiveness of the country.

2. Setting the task

The new approach requires flexibility and a high speed of response to changes. This is possible with the transition to a digital model. At the same time, according to experts, there is a significant lack of integration of business processes on a functional basis, a low degree of flexibility of management, a significant level of production errors, insufficient precise planning, which leads to a decrease in the efficiency and effectiveness of activities, a low degree of realization of economic potential, an increase in unrealized profits of enterprises [4]. In addition, the changes in the components, parameters, relations, proportions of the economic system, which cause its transition to a qualitatively new state, as a rule, is associated with a decrease in system stability, accompanied by crisis phenomena. In turn, the lack of elaboration of the risk management system leads to a decrease in the development potential of the economic system. (The digitalization of the economy is associated with increased risks, mainly due to the fact that this process occurs simultaneously with the formation of the environment necessary for the development of platforms and technologies, effective interaction of market players and sectors of the economy: regulatory, information infrastructure, training, information security). The problems of digitalization of the economy, including in industry, transport, are given enough attention in both domestic and foreign literature [5 -8, 10 -12]. However, the issues of high-tech development of the manufacturing and transport systems in conjunction, as well as their transformation, which involves the transformation of a significant part of the parameters of the system while maintaining its basic properties, in the context of the widespread introduction of digital technologies require further study. In connection with the above research, the results of which are presented in this article, is devoted to the problem of improving the efficiency of the transport system, taking into account the development of the manufacturing system based on the implementation of digital technologies, forecasts of socio-economic development and intellectualization of decision-making processes.

3. Conceptual Framework

The scientific research was based on the theory of economic zoning, an important methodological provision of which is the substantiation of the economic efficiency of the hierarchical principle of the territorial organization of production and servicing transport [9], as well as the concept of sustainable development, stakeholders, "Industry-4.0", "Smart-city", a systemic approach. We have used the methods of collecting information, analyzing documentation, generalization, grouping, the Voronoi diagram in order to solve this problem. It is important to note, in this article the intelligent transport system (ITS) is understood as a management system that integrates modern information and telematic technologies and is used for automated search and adoption to implementation the most effective scenarios for managing the region transport and road complex, a vehicle or group of vehicles in order to ensure the specified population mobility, maximizing the use of the road network, improving the safety and efficiency of transport processes, comfort for drivers and users of transport [10].
The construction of the intelligent transport system on the Crimean Peninsula will increase the speed of exchange of regional logistics processes, the quality of urban mobility management, the quality of transport services to the population, reduce mortality and improve road safety, increase the capacity of the transport network by optimizing the operation of the transport system elements (traffic lights, decision support systems for drivers and pedestrians, mobile applications for transport). The block diagram of the intelligent transport system is presented at figure 1.

The main element of the ITS is an intelligent subsystem of transport monitoring. For high-quality transport management, this subsystem should provide: collection of data on the position and condition of mobile and stationary transport facilities; transmission of these data through communication channels to information processing devices and control centers; comparison of data with existing information; and analysis and archiving of information from mobile and stationary facilities. The functions of the system include the collection and control of data on users, urban vehicles, urban infrastructure and cargo data; management of traffic lights, information boards, road signs of variable information, mobile information decision support systems for drivers, logistics operators, pedestrians, citizens and tourists. The presented architecture of the system will allow to make the transition to the personalized recommendation management of the urban transport system elements and to the control of urban transport and logistics processes. ITS can be a solution for limits to transport growth - it expands these limits, optimizes efficiency and increases the effectiveness of existing transport infrastructure [11].

The intelligent manufacturing system presents system which contains capability of adaptation to unexpected changes, i.e. assortment changes, market requirements, technology changes, social needs etc. It consists of the next components: intelligent design, intelligent operation, intelligent control, intelligent planning, intelligent maintenance [12].

4. Results
Digital transformation generates positive effects at both the macro and micro levels of the economy. For enterprises, the transition to a digital development model provides a number of undeniable competitive advantages. Among them: cost reduction by eliminating a variety of intermediaries, especially in the sphere of organizing the sale of finished products, reducing labor costs, transaction costs, speeding up
business processes; better understanding of consumer expectations and prompt response to them through the establishment of direct communications; accumulation of large amounts of data, the implementation of their automatic processing and analysis; activation of innovation. Digital production allows companies to efficiently use raw materials, as well as use RFID chips to store information about the product assembly, which materials are used for which components. Thus, it also simplifies disassembly and recycling, and reduces resource losses. This serves as the basis for the so-called "circular" economy, or a closed-cycle economy. In addition, the positive macroeconomic effects are manifested in increasing productivity, investment, industrial production, the intensification of economic growth. In order to ensure the maximum positive impact of digitalization on the development of the economic system, it is necessary to stimulate the activation of innovation processes, primarily in those industries, clusters, enterprises that provide the greatest contribution to the formation of gross domestic product. Consider the issue of ensuring the effective digital functioning of industrial and transport systems on the example of the city of Sevastopol.

The structure of the GRP of the city of Sevastopol is formed mainly due to the wholesale and retail trade and industries related to the provision of services, whose share is 50%. Industrial production, production and distribution of electricity, gas and water, construction and agriculture account for 21% of the GRP, 19% for state administration, military security and social insurance. The region's economy specializes, firstly, in shipbuilding and ship repair (industrial enterprises: the Sevastopol Marine Plant branch, CS Zvezdochka OJSC, Shipyard VALM-RUS LLC, Sorius Sudoverf LLC, Tekhflot LLC, CKB Coral JSC, SRC Persey LLC, Popilov LLC, Molot-Mechanics Plant LLC, NTP KIWI LLC, Sevmormash-2M LLC, Atla LLC, etc.) - second, in instrument making and radio electronics (LLC “DNPP Monsoon-Morsvyaz-Service”, LLC “NTTs Impuls-2 " , LLC “ Sevastopol Radio Plant " , LLC“ Uranis " , LLC“ Sevastopol Instrumentation “Parus” factory, “Sevlektomotazh-464” LLC, etc.), thirdly, in the production of building materials (Akvalit LLC, Balaklavskoe mine department JSC, Bayt LLC, Plant ZHBI No. 1 LLC, LLC 24 Reinforced Concrete Products Plant " , Inkerstrom JSC, Violet Color LLC, Yasaka LLC, Sevkomposite LLC, Oknaplast-Crimea LLC, Accent LLC, etc.).

Accordingly, it is assumed that digitalization 1) in shipbuilding will involve the use of intelligent information systems that control the movement of individual components for a vessel from their origin in the supply chain to installation on a vessel, and the complex hard work that makes up the bulk of the manufacturing process will be delegated robots; 2) in the ICT sector, electrical engineering and electronics, which can show significant growth (since it is a supplier of many information and communication technologies demanded by control systems of other industrial sectors) further improvements are possible in the field of robotics, assembly processes can be largely automated; 3) in the building materials industry the following changes will result: production processes will be fully automated at all stages (mining-> processing-> packaging-> transportation); Customers will be able to create their own “recipes” of specialized materials online with their own specifications based on the Internet support system, as well as collaborative platforms for web applications; application of technologies for servicing machines and equipment based on self-diagnosis (or augmented reality applications for staff). In this case, it is advisable to consider the digitization of industry from the point of view of not individual enterprises, but integrated value chains.

The distribution of productive forces and the resettlement of the population, the prospects for the development of key sectors of the economy, changes in effective demand largely determine the solution to the problem of the formation and effective functioning of an intelligent transport system. From the provisions of the theory of economic zoning, it follows that the structure of communications and technology of the transportation process at each level of organization of territorial production and transport complexes should be designed and developed in concert with the development of the serviced production and the needs of the population in transportation services. The organization of hierarchically coordinated production and transport complexes, according to expert estimates, makes it possible to reduce the need for a built-up area by 9-10%, reduce the length of railway lines by 18-20%, the length of roads by 9-11% and the length by 10-15% engineering communications. The construction time of production and transportation facilities is reduced by about 10%. Provides a significant reduction in
transport costs serviced enterprises. Capital costs and operating costs are reduced by 20-30% compared with separate accommodation and uncoordinated functioning of production and transport enterprises serving them.

It should be noted that in 2017 the turnover of transport of the city of Sevastopol increased by 12.9% compared with 2016 and amounted to 326.1 million ton-kilometers. The length of the network of public roads of regional and inter-municipal significance of the city of Sevastopol in 2017 increased by 170.1 km and reached 1,095.6 km by the end of the year, including 975.8 km of hard surface, of which 855 are asphalt-concrete, 6 kilometers. By the end of 2019, it is planned to carry out the reconstruction of the regional highway Sevastopol - the port of Kamyshovaya Bay with a length of 6.73 km (the volume of investments is 2.1 billion rubles). By the end of 2020, it is planned to complete the construction and reconstruction of the Sevastopol section of the Kerch-Feodosiya-Belogorsk-Simferopol-Bakhchisarai-Sevastopol highway, 13.25 km long (near the village of Verkhnesadovogo). By the end of 2030, an increase in the density of public roads with hard surface to 9358.0 km of roads by 10.0 thousand square meters is predicted. km of territory (according to the target version of the forecast) [13]. During 2018, the flow of freight transport on the highway through the Crimean Bridge amounted to about 900-1100 vehicles weighing over 3.5 tons per day. According to the estimates of the designers of the Crimean Bridge, a gradual increase in the flow of up to approximately 5,000 freight vehicles is predicted daily in 2024. Chairman of the State Duma Committee on the Financial Market Anatoly Aksakov believes that a large logistics center should be built on the peninsula in connection with the opening of traffic for heavy trucks on the Crimean bridge. According to Sergei Makeyev, Chairman of the Board of the Association for the Promotion of Trade in the Crimea, currently there is not a single logistics center in the region. S. Makeev added that such a logistics center is necessary for interaction with other logistics centers in the South of Russia, Moscow and other territories of the Russian Federation, but state support is necessary to implement this project [14]. The Consumer Market and Licensing Office of Sevastopol is looking for large investors to create a logistics center and increase distribution networks to reduce prices for consumer goods. The relevant order during the hardware meeting was given by the governor Dmitry Ovsyannikov to the head of the department Vadim Kirpichnikov [15].

The study of the actual picture of traffic shows that real traffic flows have a complex, changing organization, with certain patterns of change of its components in time and space. The systems approach to traffic flows is based on the following provisions: 1) passenger and cargo traffic are heterogeneous and dynamic in nature; 2) the change in the magnitude and structure of the flows proceeds quite naturally, although there is uncertainty and the presence of elements of randomness.

The method of joint study of cargo traffic, transportation conditions and clientele features can be used in organizing a regional logistics center in the city of Sevastopol [16]. One of the ways to solve the problem of improving the efficiency of the transport network with regard to capacity can be the provision of operational services for the movement of goods. The development of this direction will give additional impetus to optimize production, stimulate the rise of the real sector of the economy and lead to the development of new space. According to statistical data, logistic transport technologies are practically not used in the Russian market. The experience of other countries shows that it is necessary to use these technologies now, until the load on the districts has reached a critical level. These technologies include the widespread use of intelligent transport systems, and the process of modeling the transport network. Their implementation will allow to control the process of transportation of goods in real time, to increase the accuracy of planning and forecasting the speed of delivery, to simplify the procedure for finding the shortest distances [17].

To improve the efficiency of motor transport service of transport hubs and large cargo-generating facilities, it is necessary to recreate the operational management systems for vehicles, including those owned by various owners, as well as develop integrated freight forwarding services for enterprises in various sectors of the economy with the responsibility of the coordinating body to manage this work. For efficient operation of transport corridors, you need uninterrupted interaction with logistics centers. They must ensure the prompt arrival of goods in the required volume without creating congestion in the network. In addition, it is necessary to take into account economic factors, in particular a decrease in:
gasoline consumption, the average rolling mileage, the number of loading and unloading posts for servicing specified areas [17]. A solution to this problem is to build a Voronov diagram that divides the city into cells, each cell corresponds to a specific zone. The Voronov diagram is used to find the map of the shortest distances using geometric tools. The procedure involves the division of space into clusters.

The tools used are embedded in geographic information systems, where the result depends on the underlying landscape model. Many attempts have been made to model the real world with a simple mathematical model. The most famous is the weighted model, in which the plane is divided into areas with weights corresponding to the difficulty of crossing the terrain. There is no effective algorithm for finding the shortest distances in the general model without approximation of the solution. A special case is the shortest paths among polygonal obstacles in the plane in which the obstacles are infinite, and all free space has unit weight [18]. The cluster network consists of m groups of closely related points, each group is located far enough from the others so as not to affect the transport distance in it. Formally, let $k_i$ be the number of points of the $i$-th $T_i$ cluster where:

$$\sum_{i=1}^{m} k_i = k, k_{\text{max}} = \max_i \{ k_i \}$$

(1)

Let $d_{\text{max}}$ be the distance from the most remote enterprise of the supplier / consumer of goods to the point, and $sep = \min \{ d_x(t_i, t_j) \}_{t_i \in T_i, t_j \in T_j, i \neq j}$ - minimum distance between clusters. Suppose that $d_{\text{max}} < sep$, is the shortest distance between any two enterprises, suppliers / consumers of goods in different clusters. Each cluster is analyzed as independent. Splitting the clusters ensures that the maximum radius is within the cluster of the network. This condition is not necessary for the algorithm. In the case when each cluster is a chain, the sum of squares is less than the square of the sum, therefore:

$$\sum_{i} k_i^2 \leq \frac{k}{k_{\text{max}}} \sum_{i} k_{\text{max}}^2$$

(2)

and the total number of points within the problem is limited $O(k_{\text{max}})$. The overall complexity of the reduction becomes [19]:

$$O(k_{\text{max}} + k \ln k + (n + k) \ln n + e)$$

(3)

We now consider two cases of the cluster model, when the mathematical formulation changes depending on the size and number of clusters relative to the size of the city [19]:

1. The size and number of clusters is proportional to the size of the city, the larger the city, the larger and more numerous clusters. This means that the clusters have the average size $\sqrt{k}$ or $k_{\text{max}} = \Theta(\sqrt{k})$. This complicates the algorithm:

$$O(k 3/2 + (n + k) \ln n + e)$$

(4)

2. Clusters are relatively small and isolated, there is no need for domestic transportation. We model this case as $k_{\text{max}} = \Theta(1)$. This simplifies the algorithm:

$$O(k \ln k + (n + k) \ln n + e)$$

(5)

It should be noted that there are heuristic approaches used to reduce the range radius at each iteration. The difference between the maximum and minimum transport distance is the upper limit associated with the range of the location of the logistics center, which can be improved by applying the Euclidean distance. The work of logistics centers is affected by the proximity of cargo stations and facilities. In the future, this range is presented as a complex form consisting of straight line segments, circular arcs and hyperbolic segments. To improve efficiency, you can apply a heuristic algorithm that reduces the range, which will allow solving problems with a smaller area [20, 21]. In general, the effectiveness of the functioning of the ITS of the city of Sevastopol is proposed to be assessed on the basis of an assessment.
of the integral indicator for certain particular indicators that characterize the expectations of the main groups of stakeholders [22].

5. Conclusion
The realization of the main directions of Sevastopol city development, defined by the Strategy for socio-economic development of Sevastopol city till 2030, the Federal target program "Socio-economic development of the Crimea Republic and Sevastopol till 2020" on the basis of functioning of the intelligent manufacturing and transport systems will create a highly efficient economy focused on the production of products, goods and services with high added value, to develop the city as a business center, a center of tourism, education, culture. Since digitalization contributes to the proactive introduction of new technologies, producing of innovative products, focusing on customer needs, improvement of the quality of goods while ensuring resource savings, reducing time spent on production, transportation, improving the professional level of personnel, motivation, realization of the creative potential of staff through the effect of involvement in key decisions, improving the interaction between enterprises, customers, contractors, research centers, thereby increasing the competitiveness of organizations, sales volume and gross domestic (regional) product.

The proposed approach to determining the location of the logistics center forms the basis for the construction of the functional architecture of the intelligent transport system. Planning the functioning of the intellectual transport system of the Russian Federation on the basis of the above indicators allows to take into account the growth of tourist, industrial, scientific and technical potentials of the region, to develop forecasts of business activity, to stimulate innovation and investment activity of enterprises, economic and social growth of Sevastopol city, this, as a result, will contribute to the achievement of the established strategic goals.

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