We are IntechOpen, the world's leading publisher of Open Access books
Built by scientists, for scientists

4,800
Open access books available

122,000
International authors and editors

135M
Downloads

154
Countries delivered to

Our authors are among the

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Chapter 7

Influence of the Motor Transport on Sustainable Development of Smart Cities

Irina Makarova, Ksenia Shubenkova,
Vadim Mavrin and Eduard Mukhametdinov

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.71045

Abstract

The transport system is one of the fundamental intelligent systems in the Smart City, and one of the main directions to ensure sustainability and safety of the city transport system is the concept of smart vehicles. Herewith, all processes at all stages of the life cycle should be intellectualized. Since the production stage of the life cycle is one of the most important, the introduction of smart technologies (Industry 4.0) in automotive industry will allow not only to optimize the processes and improve product quality but also to establish favorable conditions for the subsequent intellectualization of the automotive service. The benefits of using smart transport in all fields of activities as well as intellectualization of the decision-making process by the example of the automotive industry enterprises are presented in this chapter.

Keywords: intellectualization, Smart City, industry 4.0, life cycle, automotive industry

1. Introduction

Automotive industry belongs to those sectors of economy, which largely determine the development of other industries where automotive equipment is used, because automotive vehicles can help to solve the problem of population mobility and carry out door-to-door cargo deliveries. High level of motorization and market globalization makes manufacturers to look for new solutions and constantly to improve both the car's design and production technology. Because it is possible to sustain significant competition in the markets only by the continuous development and application of innovative solutions.

The large companies should pay close attention to realization of two main tendencies. The first is a global tendency of a sustainable development, which includes stability of economy,

IntechOpen

© 2017 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

environment and the social sphere. The second is transition to "green economy," which is defined as low carbon, resource efficient and socially inclusive. These two tendencies can be realized by means of rational regulation of the physical, natural and human capital. Therefore, when developing new projects and technologies, it is necessary to consider social consequences of their realization. Potential economic effects of new machinery, and even entire production lines, can only materialize in the case of social efficiency and optimal interaction between man and technology. Moreover, with increasing complication of technical systems, which are becoming more intellectual, the probabilities of failure in such systems are increasingly dependent on erroneous human action. Therefore, the social responsibility of people, who design, create, operate and maintain complex intelligent engineering systems, increases. Thus, it is important to understand the interconnection between all stages of the life cycle of a complex engineering system and to develop management considering this.

2. Smart city as the main direction of urban lands development

2.1. Intellectualization of the complex organizational and technical systems' management

Intellectualization is currently the main trend of the economic and social development. This concept involves a reasonable and rational management and development of all fields of activities. Modern human civilization entered the third millennium and faced with global challenges. The need to solve these problems is formulated in "Millennium Development Goals."

Urbanization is one of the causes of most problems of our millennium. Today, there are 7.3 billion people all over the world, 54% of them live in urban areas. The world has experienced unprecedented urban growth in recent decades. As the population increases, more people will live in large cities. Many people will live in the growing number of cities with over 10 million inhabitants, known as megacities. Different organizations predict [1, 2] that the world population will reach 8.5 billion by 2030 and 27 megacities will exist that time. Analysts also say that there will be 9.7 billion people, and 66% of them will live in urban areas by 2050, with rapid urbanization of the less developed countries.

In information note, Achim Steiner (Executive Director, United Nations Environment Programme) [3] summarized and presented the key findings and policy messages stemming from the Global Environment Outlook (GEO-6) assessments conducted for the six United Nations Environment Programme regions. Each of these regional assessments includes: (1) a review of regional priorities, (2) the state of the environment in the region and the main trends that can affect it in the future and (3) an analysis of the actions so region could become more sustainable. Poor air quality, climate change, unhealthy lifestyles and the disconnection between society and natural environments increasingly affect human health and give rise to new risks. Living within planetary boundaries will require fundamental transitions in energy, food, mobility and urban systems. Transition to an inclusive green economy should be based on viable ecosystems, cleaner production and healthy consumer preferences. There

http://dx.doi.org/10.5772/intechopen.71045

is no doubt that achieving a healthy planet and healthy people requires urgent transformation of the current systems of production and consumption that most contribute to environmental degradation and inequalities in human health and well-being.

At the same time, the development of technique and technologies provided the opportunity of quality transition not only in industry and economy but also in other spheres, including social. Innovation is not only about technology and new ways to deliver services but also about new ways of thinking and finding new opportunities for development. In this case, an important thing is the transition of the control to a qualitatively new level, which enables harmonization of all activity areas within the city and getting the synergies of such interaction.

According to John Wilmoth Director of UN DESA's Population Division [4], "Managing urban areas has become one of the most important development challenges of the 21st century. Our success or failure in building sustainable cities will be a major factor in the success of the post-2015 UN development agenda."

Since ancient times, cities are centers of ideas, culture and science. However, there are many urban problems (including congestion, pollution, noise, diseases, straining land and resources), which should be solved in such a way that allow people to develop socially and economically. This can be achieved in the case of rational urban planning because the high density of cities can increase efficiency and bring technological innovation while reducing resource and energy consumption.

Mobility is a key dynamic of urbanization, and the associated infrastructure invariably shapes the urban environment: the roads, transport systems, spaces and architectural solutions. By 2005, approximately 7.5 billion trips were made in cities worldwide each day. In 2050, there may be three to four times as many passenger-kilometers traveled as in the year 2000. At the same time, the freight turnover may also increase by more than three times.

Nowadays, due to urban sprawl, the distances between points, which generate and attract the passenger flows, have become longer, which leads to the greater dependence of citizens on individual motorized transport. Thus, traffic jams, congestion, pollution, noise stress and traffic accidents are reality of today's megalopolises.

2.2. Smart City and smart mobility

Innovation in transportation today is a very relevant topic [5–10]. More than ever before, we understand that transportation has a key influence on how societies form and develop over time. This is reflected in the concept of Smart City. Herewith, smart mobility is one of the major issues, because it ensures accessibility of workplaces and recreations. Moreover, smart mobility is also a part of production and other subsystems of the city economy.

If we consider Smart Cities from the point of view of economic branches, then it is possible to allocate smart energy, smart transport, smart construction, smart industry and so on. On the other hand, Smart Cities can be considered from the point of view of different city subsystems' objects: smart infrastructure, smart buildings, smart vehicles, etc. And, finally, technologies that improve people's lives (education, medicine, service) can also be "smart"

(**Figure 1**). Whatever way of smart technologies' classification is used, it is impossible to organize processes of any area of economics without transport. It largely relates to the motor transport, because only it can organize door-to-door transportation of cargos and passengers. Therefore, smart technologies that provide design, creation and operation of smart transport in an optimal way and with minimal negative impact on environment and human are very important in transport sphere.

2.3. Smart transport as one of Smart City's development drivers

There is a need for substantial changes in Europe's transport systems, as well as in the mobility behavior of people and businesses in urban areas. Addressing the mobility challenge calls for a paradigm shift in urban planning, encouraging compact cities as a way to increase accessibility and to reduce the need for transportation altogether.

To ensure population mobility means to provide access to all functional destinations, services, places of work, etc. At the same time, city residents should be able to address their needs using as little travel as possible. It can be completed in two ways: (1) reducing the needs to travel by implementing modern information and communications technologies (Internet of Things, Industry 4.0 and other concepts) and (2) reducing distances between places of residence and functional endpoints (the reasons for travel), so that the population could use more sustainable modes of transport, such as walking, cycling, etc.

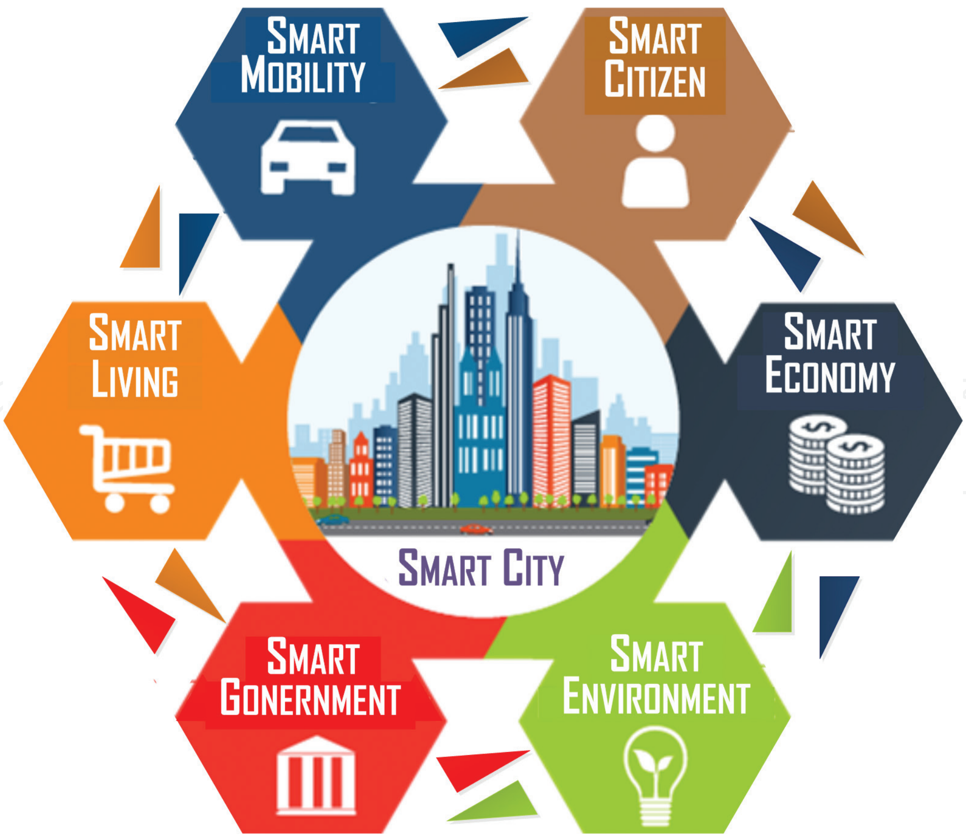

Figure 1. Directions of intellectualization in Smart City.

http://dx.doi.org/10.5772/intechopen.71045

To make people use more sustainable mobility concepts, it is necessary to ensure possibility to reach any point of passengers' attraction by public transport. However, sometimes it is rather difficult to allow residents easy access to the public transport system; it is the so-called Last Mile Problem. To solve this problem, cities need to provide multi-modal transport systems. For example, bicycle sharing systems can serve as a good way to connect users to public transit networks.

Transport system is one of the major intellectual systems in the Smart City. To ensure its sustainability and safety, the work is being done in three ways: smart infrastructure, smart vehicles and smart users (**Figure 2**). Solutions concern the creation of an efficient and integrated mobility system that allows for organizing and monitoring seamless transport across different modes, increasing the use of environmentally friendly alternative fuels and creating new opportunities for collective mobility.

One of the main areas of ITS, which is actively promoted over the past 15 years, is the implementation of intellectual vehicle. International program "Increased safety vehicle" is implemented. The first experiments of usage of onboard intelligent systems have shown that they are able to reduce the number of traffic accidents by 40% and to reduce

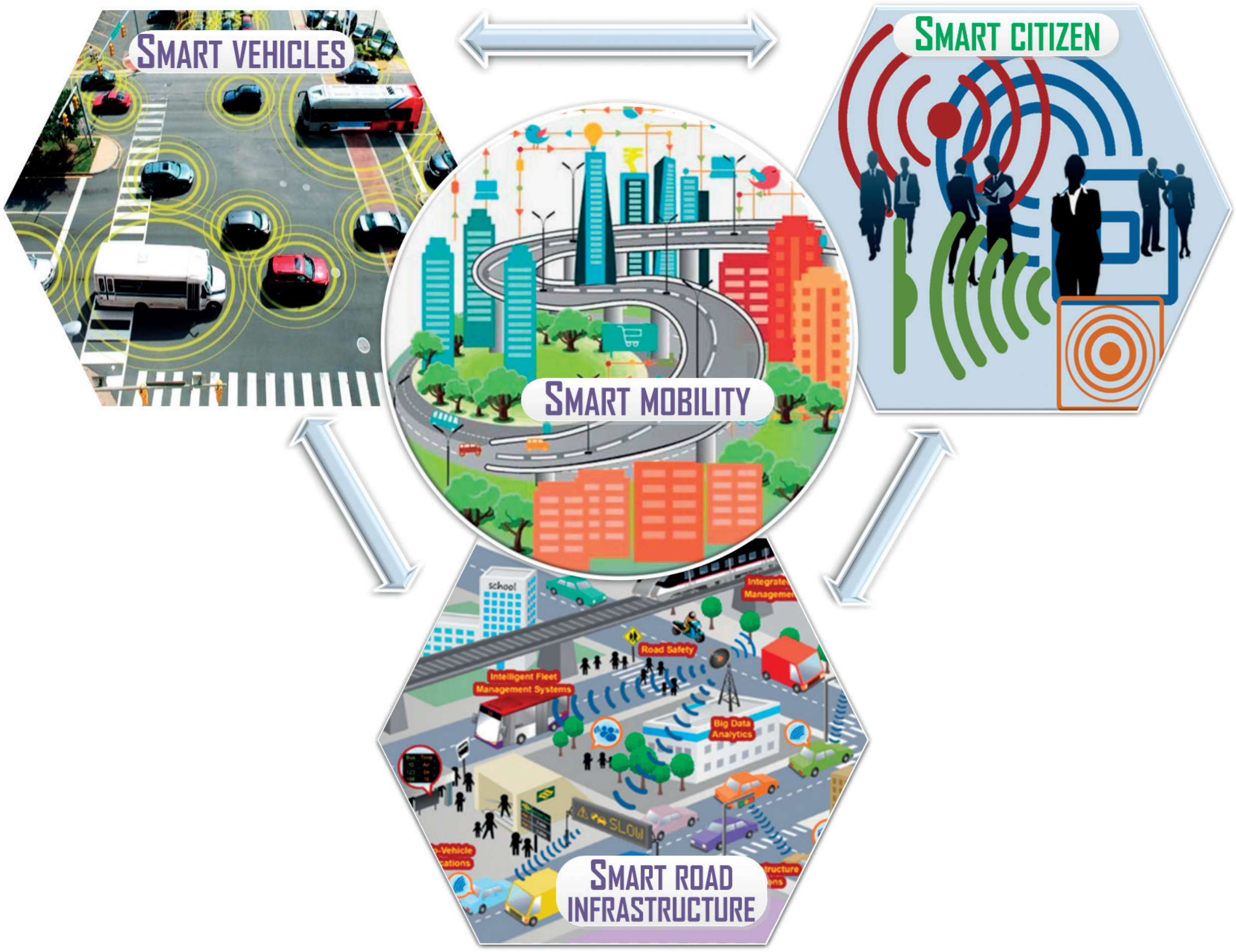

Figure 2. Directions of transport system's development in Smart City.

the number of fatal accidents by 50%. The transition from the creation of driver assistance systems to the development of semi-autonomous unmanned vehicles is a global trend, and it is explained by the desire of developers to ensure the sustainability and the safety of the transport system [11].

However, it should be understood that the emergence of new types of vehicles with fundamentally new control systems could cause problems of security and interaction with other road users. It is especially true in connection with the development of the "livable cities" concept that is aimed at encouraging the use of non-motorized transport, such as walking or cycling. On the one hand, streets need to be adapted, with safe walkways, crossings and cycling lanes, as well as transport junctions need to be established to create safe connection points between different transport modes. On the other hand, it is necessary to identify potential risks of the use of autonomous vehicles, to predict the likelihood of the traffic conflicts (between autonomous vehicles and pedestrians and cyclists, first of all) and to determine the possible consequences. In addition, the ways to prevent risk situations and to reduce the severity of the consequences in case of risk situations should be developed.

Automobile mode of transport is the main one in urban lands, and in the case of unreasonable transport management, it can cause significant problems for other road users. In addition, road transport is the main source of negative influence on the environment, so it needs qualitative management.

The main idea of Smart City is that the city can be "smart" only if the management of all its subsystems is built according to the same rules. If we talk about road transport, then it actually means the management of the vehicle's life cycle as a separate component of the vehicle fleet (**Figure 3**), and at a higher level—the management of the vehicle fleet as a whole. Along with it, all processes at all stages of the life cycle should be intellectualized. At the same time, the orientation to customer needs should be one of the main factors that should be taken into account when planning and implementing these processes. The main directions are creation of the elemental base of intelligent systems and software development.

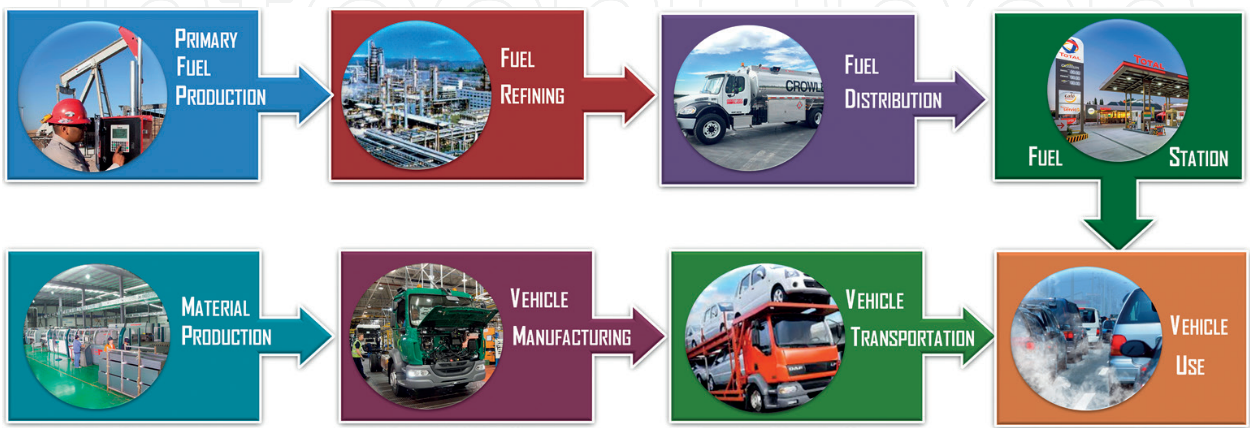

Figure 3. Negative impact on the environment throughout the life cycle of the vehicle.

3. Industry 4.0 and its role in implementation of the Smart City concept

3.1. Industry 4.0 as the fourth industrial revolution and the prospect for sustainable development of automobile industry

The current state of technics and technologies allows us to create tools and methods not only for managing technical and organizational and technical systems but also devices for analyzing the state of human functional systems and affecting them. This makes it possible to correct and optimize human activity both indirectly, using the recommended loads and parameters, and in real time, which allows creating a comfortable working environment, as well as increasing the safety and efficiency of labor, increasing the efficiency of production systems and product quality.

Real and virtual worlds are now beginning to merge in production that is why we are talking about "Industry 4.0"—the Siemens term for fourth Industrial Revolution. Increasing digitalization and networking is changing the entire industrial production chain, and the volume of data worldwide is exploding. Before analyzing and using the huge amount of data, systems that enable us to understand their content have to be developed. The first step is to get knowledge on what kinds of sensor and measurement technology can be used to collect necessary data and to understand operational principles of systems and devices.

The implementation of the concept Industry 4.0 (**Figure 4**) provides for the formation of cyber-physical systems (CPS), where all elements of the system are active objects that are involved in the exchange of information and make appropriate decisions. Continuous interchange of information in such cyber-physical systems is realized between its elements through the Internet of Things.

The Road Map developed by the group "TechNet" [12] provides creation of new generation of the modern digital productions—"Factory of the future" (**Figure 5**) that is a completely new production environment that is formed by the network of people, things and machines connected to each other. The proposed strategy is based on assumption that replication and scaling of advanced production technologies will determine further development.

Implementation of the "Factory of the future" concept will provide a significant reduction of the time placing on the market of the highly intelligent products by using digital design technologies throughout their life cycle.

Industry 4.0 is aimed at the process optimization, because it covers the entire life cycle, that is, each manufacturer is responsible for his product from the beginning of design and development to disposal.

Classical methods of production organization mean that the flow method can be used only for large quantities of goods. Thanks to the new principles of production processes organization, it becomes possible to manufacture also single products in an industrial way. Industry 4.0, thanks to its flexibility and adaptability provided by cyber-physical systems, can help to realize the mass production of individual orders, which will reduce the price of the product.

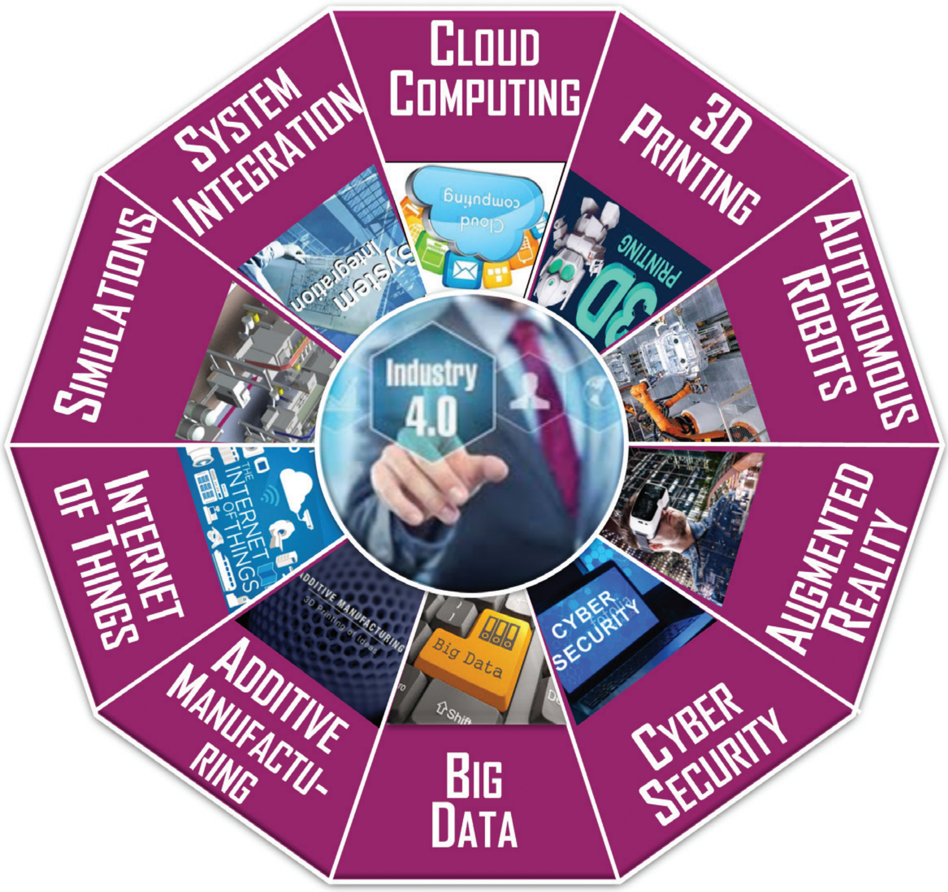

Figure 4. The technologies to implement the concept Industry 4.0.

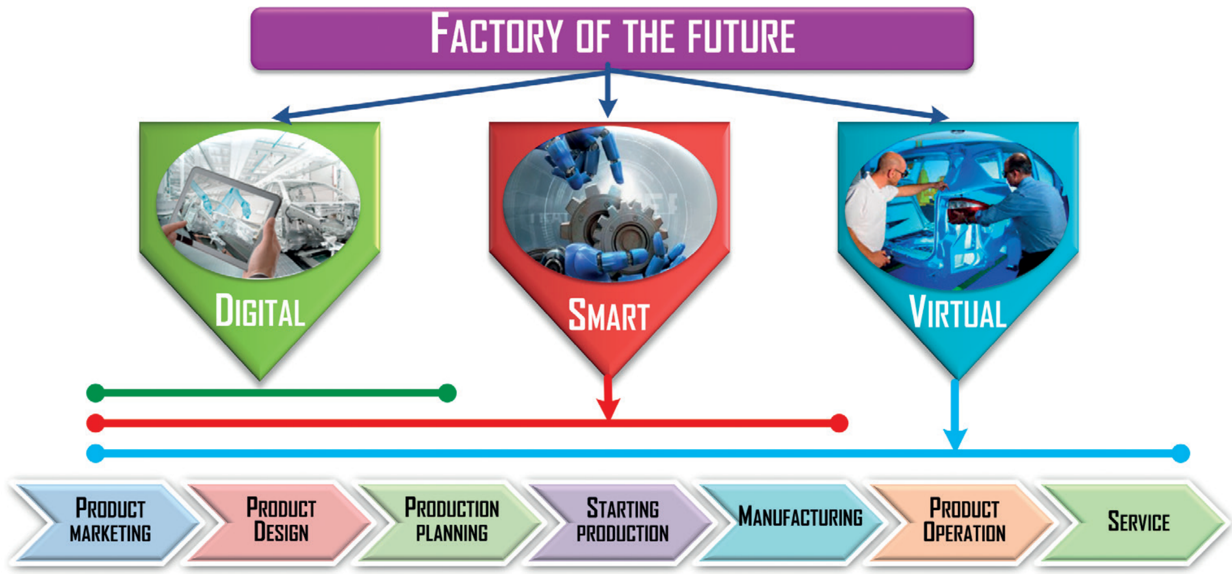

Figure 5. Factory of the future and the product's life cycle.

For production, the ability of various components to communicate through the network opens incredible prospects. In "smart factories," machines will understand their environment and will be able to communicate on a single network protocol among themselves, as well as with the logistics and business systems of suppliers and consumers. The production equipment, receiving information about the changed requirements, will be able to make adjustments to the technological process. As a result, production systems will become capable of self-optimization and self-configuration, the equipment will perform self-diagnostics and further flexibility and individualization of products will occur.

Chrysler's plant in Toledo is an example of the application of cyber-physical systems in manufacturing. Every day it produces more than 700 Jeep Wrangler's bodies. This involves 259 German robots KUKA, which "communicate" with 60,000 other devices and machines. Data interchange and its storage are organized with the use of cloud computing. Modern solutions have significantly increased productivity and flexibility of the factory.

This will also cause the change of the service concept, because the manufacturer will be interested in creating a branded service network that will provide him with implementation of the principle of responsibility for his product throughout the life cycle—from design to disposal (**Figure 6**). This is especially true for modern trucks, which, in contrast to cars, are almost impossible to service in small auto repair workshops. In addition, thanks to the availability of its own service system, the manufacturer will have all information on the features of operation, maintenance and repair of a particular car and the whole park.

3.2. The scope and means of implementing the smart industry concept

The production stage of the life cycle is one of the most important, because exactly at this stage ideas and projects turn into finished products. Besides, the quality of the product depends on the quality of manufacturing. It means that at this stage, it is determined if the targeted audience is large enough, if the product is competitive in the market and how effective and safe are the stages of operation and service.

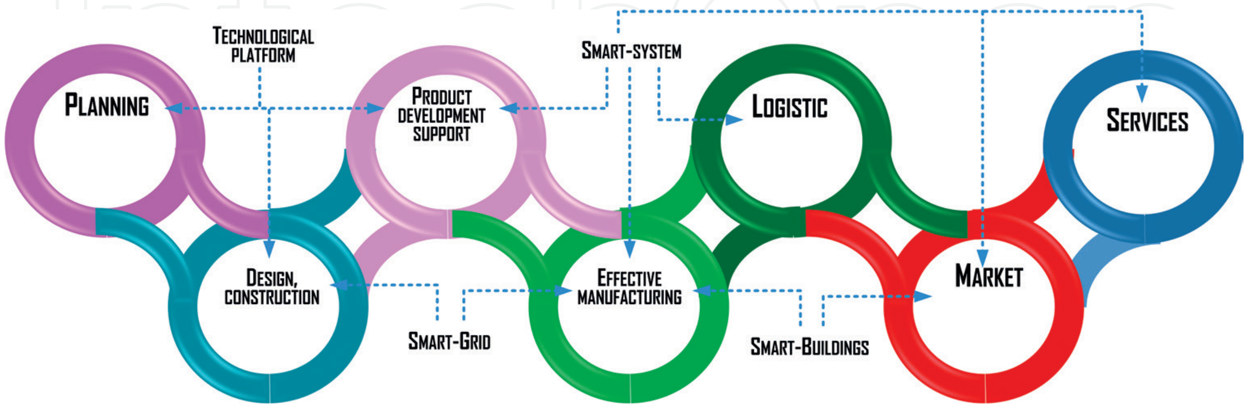

Figure 6. The use of smart technologies at the life-cycle stages.

The terms “Smart Factory,” “Smart Manufacturing,” “Intelligent Factory” and “Factory of the Future” all describe a vision of what industrial production will look like in the future. Digital technologies will make factories more efficient, intelligent, flexible and dynamic. In connected Industry, everything from design to manufacturing is done through interaction between products and machines and collaborative effort between machines themselves.

Manufacturing in a Smart Factory will be more intelligent, flexible and dynamic in comparison with today’s industries. It is so because all production processes and functions (product development; resource planning; logistics; factory and production planning and executing; monitoring, control and management functions, etc.) will be closely interconnected. At the same time, machinery and equipment will have the ability to improve processes through self-optimization and autonomous decision-making.

3.3. Examples of the processes control intellectualization in production systems

3.3.1. Methods and models to improve the assembly line production

In the production process of products with the great amount of components, several problems may occur: stock storage limit, limits of functional zoning, creation of a balanced flow, minimizing the component delivery time to the assembly line positions, etc. Nowadays, in an open and competitive market, companies cannot afford to waste time and resources for work that can be done in a better and faster way with advanced solutions. In Ref. [13], implementing production monitoring systems (PMS) in order to support product lifecycle management (PLM) system with historic knowledge regarding the state of machinery, correctness of assembly operations, etc. is suggested. A module to analyze collected information and predict the future performance of the monitored component is thus needed. In numerous studies, the use of models for this purpose and simultaneous reduction of costs that arise at different stages of production and technological process are suggested. Hence, one of the most important tasks of the organization of the assembly line production is line balancing problem. To balance unilateral and bilateral flow lines, in Ref. [14], a model that takes into account zoning and priority limits, synchronous and positional constraints, buffer time have been developed. The objective function of the model maximizes line efficiency and minimizes index of smoothness and total cost per unit of product. As an example, bilateral assembly line of chassis production of motor vehicles lowering the cost per unit by 42% has been provided.

In the market of automotive components, competitiveness is ensured by high-quality products and low cost. This requires manufacturers to search for methods to minimize costs at all stages of production. To meet the challenges of balancing assembly lines with considering costs exact methods, heuristic and metaheuristic approaches can be applied [15–17]. The developed approaches combine heuristic models and exact algorithms based on “taboo” search in order to minimize short-term operating costs, capital investments, costs of labor and work in progress.

Inefficient production and suboptimal in-plant logistics contribute significantly to environmental degradation. Hence, large number of studies aiming at optimizing the planning of technological transport in view of its negative impact on the environment. Thus, a concept to optimize component deliveries to the plant for the production of motor vehicles has been developed [18]. Reducing CO_2 emissions by 3% was simply achieved by lowering the number of lorries used for transportation and by increasing the lot sizes and the speed of the transportation and loading process. The impact of the type of forklift engine (diesel, gas, electric) on the nature of the impact on the environment was also assessed [19]. It was concluded that electric forklifts are more effective from an environmental point of view; however, the research did not take into account economic and technological factors (cost of forklifts, downtime for battery charging of forklift, etc.).

Analysis of the studies shows that a systemic approach to the solution of the problem is needed. This is especially true because once all of the complex subsystems of the production process and their interactions are taken into account, positive synergistic effect can be achieved.

3.3.2. Optimization of technological processes on the assembly line

Simulation models are used to determine the optimal parameters of technological processes when changing internal or external parameters of production. Input data for the development of the simulation model of technological process are typical manufacturing processes and Teamcenter database (data on assemblies, products, equipment, tools and environment).

The structure of individual technological process is adjusted in accordance with the composition and structure of the unified technological process by analyzing the need for each operation and the technological transition with the consistent refinement of all solutions. Technological design consists in the development of standard technological processes, from which in the future it is possible to assemble various methods of assembling cars. This makes it possible to significantly reduce labor input and the time required for their introduction into production.

Mass conveyor production is based on the principle of the flow organization of technological assembly processes, providing:

- the division of the assembly process into a series of assembly operations, sequentially arranged in time and space, performed by the operators-assemblers;
- the use of special transport devices to move the assembled units between assembly devices and to ensure a given assembly rate;
- the use of special transport devices for supplying parts and assemblies to the main assembly conveyor;
- the use of special and unified tools and devices for mechanization and automation of the technological process;
- mechanical machining of parts and assembly of units in machine-assembly shops.

When the production is organized in such way, assembly of the entire vehicle on the main assembly conveyor is carried out from the finished assembled units and aggregates, connected together by fasteners. The open architecture of the Teamcenter system allows you to connect to the PLM environment systems such as Matlab/Simulink and Rhapsody. In order to work with data in the usual formats, we can use the capabilities of dynamic integration with Microsoft Office software package. The obtained solutions are stored in the knowledge base and can be used in similar production situations.

The use of simulation models allows you to isolate operations that need optimization, determine the required number of employees and optimize the working load. Obtained solutions can allow reduction of the assembly time at the conveyor positions, and, accordingly, the cycle time by 6%, while the optimal loading of personnel decreases the number of errors.

Implementation of the proposed method was carried out during the development of the Decision Support System (DSS) for automotive company KAMAZ (of Naberezhnye Chelny, Russia) [20]. To optimize production processes, special documentation was developed. The documentation is integrated in production system for shared use [21].

Since the interdependent processes are modeled in parallel, program modules share the information for operational adjustment processes. Optimization of the conveyor in order to reduce delays is performed in two directions: alignment of operations on the assembly line positions and the operational management of the supply of components to the position. Optimization of technological transport includes providing the conveyor positions by necessary components with minimum cost (the number of forklifts and work time).

3.3.3. Monitoring and managing equipment efficiency

3.3.3.1. Literature review

One of the most important conditions of the successful operation for any industrial plant is to ensure uninterrupted operation of the equipment. That is why the indicators that characterize the quality of the equipment's use can be used as the objective function when modeling of technological processes [22]. In so doing, it should be taken into account not only the actual time of the equipment use and its performance but also the share of goods without any defects in the overall product output.

In the case of robotic production, the equipment efficiency depends significantly on the quality of its service, which affects indicators of availability, performance and quality of the final product. As a rule, a system to support the workability of equipment (maintenance and repair) is developed to ensure its efficient use. Frequency of service is determined depending on the equipment characteristics and is assigned by the manufacturer. To exclude catastrophic failure, the methods to predict and improve reliability exist.

Since there are different categories of losses, for monitoring the equipment condition, it is necessary to foresee methods for their control. The adjustment of the equipment maintenance system must be performed in accordance with the criteria of its efficiency. Furthermore, the method of complex multidimensional assessment of the performance indicators allows to raise the efficiency of production system management and, at the same time, to increase its stability as well as to reduce unplanned downtime.

The specificity of robotic production is that mistakes and failures in the technological processes are not attributable to mistakes of operators. Quality control of the equipment in this case can be carried out by comparison with the model of production system (i.e., system of virtual production). It is possible to identify the causes of errors by using imitation of the real system processes. In addition, simulation models allow to test new production concepts and agree with each other that all the subsystems on the design phase of production. It is also possible to optimize and to modernize virtually the existing complex of production with the aim, for example, to test the transition to the new product. Such systems allow to optimize the process of equipment maintenance, taking into account condition and features of the real system.

It is shown in the research paper [23] that maintenance scheduling, quality control and production scheduling influence one another and, therefore, need to be considered jointly for improving the system performance. A model has been created to integrate maintenance scheduling and process to develop a policy of decision management. It provided optimal parameters of preventive maintenance as well as a chart of control intervals, which minimize expected cost per time unit. Subsequently, the optimal interval of preventive maintenance is integrated with the production schedule in order to determine the optimal batch sequence, which allows to minimize penalty costs due to schedule delay.

The authors of the article [24] offer the method of multi-criterial classification of critical equipment (MCCE), which allows to classify equipment objectively according to its importance. They assume that according to such service approach the most critical equipment will not fail or, at least, all appearing failures will be rapidly detected and corrected in a minimum possible amount of time. To provide this information, the consequences of any failure in the appropriate equipment are analyzed for a particular company.

The article [25] is devoted to analyze mistakes and false operations, which require to carry out service operations. The authors designed two models to describe an ideal situation: the first one, in which a false-positive alarm implies the renewal of protection system and the second one: not. In the first situation, imperfect inspection is manifested in the scenario, where a false alarm implies an additional cost for the system owner; in the second situation, a false alarm does not imply renewal of the protection system. In both cases, a false-negative inspection can appear, in which the system is considered to be in a good condition, when it does not work in fact.

A condition-based preventive maintenance approach that is developed as a software service located in a "cloud" is presented in the paper [26]. It acquires and processes data from the shop-floor of machine tools using the technique of information fusion. The authors consider that benefits from the combination of monitoring and maintenance techniques under the umbrella of Cloud and mobile communication have not been still exploited sufficiently. At the same time, advanced maintenance methods, which cover and process the shop-floor information, can reduce costs and increase the sustainability of the enterprise. An operator reports through mobile devices the following data: status of machine tool (for example, available, busy, etc.), current running task, cutting-tool availability and appearance of failures. Combining inputs from the machine tool operator and the sensory system, an actual machining time of machine tools and cutting tools is calculated. The controlling data are processed through the technique of information fusion to identify the status of machine tool and, consequently, its actual machining time. On the basis of this information, the maintenance department is able to schedule the maintenance of machine tool according to its actual wear, not in fixed intervals.

As it is seen from the above review, the authors believe that to improve the efficiency and sustainability of the production system it is necessary to improve service. For these purposes, we offer different methods, but the general is the simulation of systems. A model is suggested to be constructed using statistics of failures and malfunctions of equipment. Reliable operation of the equipment is based on information about its failures, unplanned stops and failures recorded in the complaint acts and stored in databases. The analysis of such information allows us to identify the causes of emergencies and warn them. For the operational management and adjustment of a service system, intelligent control systems, including cloud technology, are offered.

3.3.3.2. Challenges in transition to a smart factory

In our opinion, the existing platforms to create a unified information space are the most effective way of both strategic and operational management stages of the life cycle of the product. The concentration of heterogeneous data, semantic linking and providing access to them through search interfaces is a topic which today is engaged in many companies. Many long-term benefits of implementing management systems and product lifecycle (PLM) cannot be achieved without having a comprehensive digital manufacturing strategy, which allows the simulation of production processes aimed at reuse of existing knowledge and optimizes processes before products are manufactured. In addition, digital production allows you to get feedback from actual manufacturing operations and to incorporate it into the design process of the product, so businesses already can solve production and technological problems at the design stage. Among the initiatives for the development of systems to support digital manufacturing is improving user interaction by providing information in the context of the problem being solved, thanks to which engineers can make the right decisions faster. Measures are taken to ensure direct communication with technological equipment, such as programmable logic controllers (PLCs), machine controllers, numerical control (CNC), etc. Single platforms are created to manage the information stored in the PLM system and manufacturing execution systems (Manufacturing Execution systems, MES).

The creation of DSS is especially important when creating flexible production systems, which are based on robotic systems. However, it is necessary to consider that the flexible automated manufacturing (FAM) operates on the basis of a solitary technology, so the work of all production components is coordinated as a whole multi-level control system which ensure the change in program, fast tuning technologies when changing production facilities.

The decision on the design and optimization of manufacturing from Tecnomatix is parametric 3D smart objects that can be used for quick and efficient planning of the enterprise. The use of 3D smart objects for planning of the enterprise also enables to detect design errors not on the factory floor but even in the planning stage. The flow of materials, transportation, logistics and auxiliary operation can be optimized using material flow analysis and modeling events.

Along with it, it should be borne in mind that while the transition to a smart factory, there will be a number of problems that need to be solved.

The product/process design is the first of these challenges. It covers all the tools and engineering services supporting the design of parts, finished products, processes, production lines and factories. This category is evolving from a separate design towards one that is largely modeled and simulated, and most importantly, joint between product and process.

The virtual factory means simulating the production lines from start to end and enabling you to anticipate potential sources of additional costs or poor quality and preset the machinery and equipment and control of the productive facilities. This integrates the control system (digital control, interconnection with the factory's upstream and downstream, planning and centralized control of the production line), traceability (sensors of production conditions, monitoring of individual parts being manufactured) and the management of physical flows (automation of internal logistics and interconnection of external logistics).

Manufacturing operations (at the heart of processing) were identified as the third challenge, with two performance criteria: precision (the optimization of existing technologies, such as high-speed machining and laser cutting, and smart self-correcting machines) and flexibility (multi-device multimedia additive manufacturing machines).

The fourth challenge covers services related to the productive facilities. It includes the integration services of the various components of the production line and the installation and maintenance of production machinery.

The fifth challenge is the newcomer; it includes the digital technologies behind the upheaval. Hard to imagine the factory of tomorrow without the contribution of cloud computing, whether to store data, work with remote desktops or use SaaS software; without Big Data Analytics, which will improve production through predictive remote maintenance or will increase energy efficiency and without the Manufacturing Internet of Things, these autonomous cyber-objects capable of making local decisions.

Finally, work organization is the last challenge. Examples include the establishment of organizations that empower operators or can learn.

3.3.3.3. Examples of existing cyber-physical systems

When developing a strategy for transition to a smart factory, it should be borne in mind that modern industrial automation systems are composed of several clearly separated levels:

- Data collection level (sensors and actuators)
- Level of control (operator terminals and control devices)
- Level of business processes management (computers for data processing, MES systems)
- Manufacturing level (server, where MRP I, II, III, ERP systems, etc. are located).

Each of these levels is relatively well structured and individual devices can be clearly mapped to one of the levels.

In Industry 4.0, the system structure changes. The data collection level remains a separate dedicated level, as it is now, but the devices will be more intelligent and they will also significantly increase in numbers. All other functions will move to the high speed real-time network consisting of data processing center and cloud computing. The benefits of such a structure are as follows: (1) reduction of diversity of devices and processing hardware that are the most modern in the world; (2) separation of specific functions and (3) the use of augmented and virtual reality. All of it contribute to simplification of the management process, more efficient use of resources and, consequently, cost savings. This approach has not been implemented yet due to the low efficiency, reliability and throughput of communication channels between servers and data collecting devices. However, all these problems will be solved in new and future systems.

Industry 4.0 will be built in cyber-physical systems, which involves the integration of computation, networking and physical processes. Embedded computers and networks monitor and control the physical processes, with feedback loops where physical processes affect computations and vice versa.

An example of such a system today is the CarTel project at MIT [27] where a fleet of taxis collects real-time traffic information in the Boston area. This information is combined with historical data to calculate the fastest routes for particular times of the day. Another example that you may be familiar with is the Smart Grid. One of its definitions, based on [28], is: “A modernized electrical grid that uses information and communications technology to gather and act on information in an automated fashion … to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity.”

Finally, an example for a factory [29] is changing systems so that the energy consumption in a vehicle assembly line is reduced when the line does not operate. Today, many production lines continue running during breaks and weekends. Consider laser welding technology that remains powered up over weekends, so it can resume quickly on Monday. This practice consumes up to 12% of total energy consumption of the assembly line. With Industry 4.0 and cyber-physical systems, robots will go into standby mode as a matter of course during short production breaks and power down during longer breaks. Speed-controlled motors that reduce the energy required to run machines will be widespread. Such changes will significantly reduce energy consumption and will be taken into account up front as part of Smart Factory design practices.

4. Conclusions

Introduction of the concept Industry 4.0 can reduce losses and improve efficiency of the processes, because only comprehensive solutions can lead to real improvements. Developers of smart vehicles optimistically believe that autonomous vehicles on roads will improve the safety of the transport system, reducing the number of accidents due to the exclusion of the human factor.

At the same time, despite the existing positive experience of introducing intelligent technologies, there are still can appear situations when alleged improvements can lead to losses while vehicles production. There are also a lot of issues identified by analysts that could lead to critical situations while such vehicles operation.

First, it should be noted that operation of any complicated system is always closely connected to the risks. It is especially actual for transport systems. The complexity of transportation systems' risk analysis is due to the fact that an accident potentially may happen in any part of the route and the same events may lead to absolutely different consequences. That is why every decision for the existing transportation system's optimization should also be considered from the perspectives of risk management.

The most possible risks with the most drastic consequences can be grouped by types:

1. Technical:
   a. Reduction of operational reliability because of increased complexity of the vehicles' design.
   b. Increased infrastructure requirements.
   c. Increased requirements to communication systems.
2. Ecological:
   a. The risk of technological disasters if there are cyberattacks or failures in the control system.
   b. The risk of increasing negative impact on environment because of expansion of the vehicles' fleet.
3. Organizational:
   a. Complexity of the movement algorithms for rough terrain.
   b. The absence of a panoramic view of the streets, impeding the routing.
   c. Increased requirements to information processing speed.
   d. Complexity of decision-making in unusual situations.
4. Economic:
   a. The high cost of infrastructure changes.
   b. The high price of the vehicles.
5. Legal and ethical:
   a. Ambiguity of legal responsibility for causing damage and when organizing transportation.
   b. Loss of privacy.

6. Social:

  a. The loss of jobs by people whose work is related to driving vehicles.

  b. Lack of driving experience of drivers in critical situations.

  c. Loss of self-driving capability.

All problems described above have to be solved now, before the widespread of intelligent vehicles. The main but not the only trends in solving these problems are as follows:

- Development of new communication systems, information security systems and improving the reliability of control systems.
- The use of resource-saving technologies, improving the efficiency of transportation management.
- Accidents' statistics collection and analysis, development of expert systems and knowledge bases in the field of traffic management and improving the movement algorithms and the vehicles' design and position control systems.
- Service system improvement, the use of highly reliable components and redundancy of elements that ensure safety.
- Improvement of gesture recognition and speech-understanding technologies.

In this regard, the processes of the vehicles' intellectualization should be considered from the point of view of each stage of the life cycle and the most dangerous situations should be highlighted for the subsequent countermeasures development.

Author details

Irina Makarova, Ksenia Shubenkova*, Vadim Mavrin and Eduard Mukhametdinov

*Address all correspondence to: ksenia.shubenkova@gmail.com

Kazan Federal University, Naberezhnye Chelny, Russia

References

[1] Department of Economic and Social Affairs. World Population Prospects the 2015 Revision: Key Findings and Advance Tables. New York: United Nations; 2015 66 p

[2] City Population. Major Agglomerations of the World [Internet]. 01-01-2017. Available from: https://www.citypopulation.de/world/Agglomerations.html [Accessed: 24-07-2017]

[3] UNEP. Summary of the Sixth Global Environment Outlook GEO-6. Regional Assessments: Key Findings and Policy Messages [Internet]. 2016. Available from: http://www.unep.org/geo/assessments/regional [Accessed: 24-07-2017]

[4] UNEP. More than Half of World's Population Now Living in Urban Areas, UN Survey Finds [Internet]. 2014. Available from: http://www.un.org/apps/news/story.asp?NewsID=48240#.WXbkYRXyjMw [Accessed: 24-07-2017]

[5] Makarova I, Pashkevich A, Shubenkova K. Ensuring sustainability of public transport system through rational management. Procedia Engineering. 2016;**178**:137-146

[6] Makarova I, Khabibullin R, Pashkevich A, et al. Modeling as a method to improve road safety during mass events. Transportation Research Procedia. 2016;**20**:430-435

[7] Makarova I, Shubenkova K, Mavrin V, et al. Ways to increase sustainability of the transportation system. Journal of Applied Engineering Science. 2017;**15**:89-98

[8] Makarova I, Shubenkova K, Gabsalikhova L. Analysis of the city transport system's development strategy design principles with account of risks and specific features of spatial development. Transport Problems. 2017;**12**(1):125-138

[9] Makarova I, Khabibullin R, Shubenkova K, et al. Ensuring sustainability of the city transportation system: Problems and solutions (ICSC). E3S Web of Conferences. 2016;**6**:02004

[10] Makarova I, Khabibullin R, Belyaev E, et al. Increase of City transport system management efficiency with application of modeling methods and data intellectual analysis. In: Sladkowski A, Pamula W, editors. Intelligent Transportation Systems—Problems and Perspectives. Switzerland: Springer; 2016. p. 37-80

[11] Richardson N et al. Assessing truck drivers' and fleet managers' opinions towards highly automated driving. Advances in Human Aspects of Transportation. 2016;**484**:473-484

[12] TechNet. Explanatory Note to the Road Map of the National Technological Initiative [Internet]. 2015. Available from: http://assets.fea.ru/uploads/fea/nti/docs/2015_1225_Zapiska_technet.pdf [Accessed: 24-07-2017]

[13] Paavel M, Snatkin A, Karjust K. PLM optimization with cooperation of PMS in production stage. Archives of Materials Science and Engineering. 2013;**60**(1):38-45

[14] Li D, Zhang C, Shao X, Lin W. A multi-objective TLBO algorithm for balancing two-sided assembly line with multiple constraints. Journal of Intelligent Manufacturing. 2016;**27**(4):725-739

[15] Amen M. Heuristic methods for cost-oriented assembly line balancing: A comparison on solution quality and computing time. International Journal of Production Economics. 2001;**69**(3):255-264

[16] Padrón M, Irizarry M, Resto P, Mejía H. A methodology for cost-oriented assembly line balancing problems. Journal of Manufacturing Technology Management. 2009;**20**(8):1147-1165

[17] Erel E, Sabuncuoglu I, Sekerci H. Stochastic assembly line balancing using beam search. International Journal of Production Research. 2005;**43**(7):1411-1426

[18] Florian M, Kemper J, Sihn W, Hellingrath B. Concept of transport-oriented scheduling for reduction of inbound logistics traffic in the automotive industries. CIRP Journal of Manufacturing Science and Technology. 2011;**4**(3):252-257

[19] Fuc P, Kurczewski P, Lewandowska A, et al. An environmental life cycle assessment of forklift operation: A well-to-wheel analysis. The International Journal of Life Cycle Assessment. 2016;**21**(4):1-14

[20] Kamaz PTC. Official Website [Internet]. 1997-2017. Available from: https://kamaz.ru/en/ [Accessed: 24-07-2017]

[21] Khabibullin R, Makarova I, Pashkevich A, et al. Application of simulation modeling to improve management of technological processes during production of automotive components. In: Maga D, Stefek A, Brezina T, editors. Proceedings of the 2016 17th International Conference on Mechatronics Mechatronika (ME); Dec 07-09, 2016; Prague, Czech Republic. 2016. p. 43-49

[22] Makarova I, Khabibullin R, Mukhametdinov E, et al. Efficiency management of robotic production processes at automotive industry. In: Maga D, Stefek A, Brezina T, editors. Proceedings of the 2016 17th International Conference on Mechatronics Mechatronika (ME); Dec 07-09, 2016; Prague, Czech Republic. 2016. p. 35-42

[23] Pandey D, Kulkarni M, Vrat P. A methodology for joint optimization for maintenance planning, process quality and production scheduling. Computers & Industrial Engineering. 2011;**61**(4):1098-1106

[24] de Leon FG, Cartagena J. Maintenance strategy based on a multicriterion classification of equipments. Reliability Engineering & System Safety. 2006;**91**(4):444-451

[25] Berrade M, Cavalcante C, Scarf P. Maintenance scheduling of a protection system subject to imperfect inspection and replacement. European Journal of Operational Research. 2012;**218**(3):716-725

[26] Mourtzis D, Vlachou E, et al. A cloud-based approach for maintenance of machine tools and equipment based on shop-floor monitoring. Procedia CIRP. 2016;**41**:655-660

[27] MIT Cartel. CarTel [Internet]. [Updated: 2014]. Available from: http://cartel.csail.mit.edu/doku.php [Accessed: 24-07-2017]

[28] Department of Energy. Smart Grid [Internet]. Available from: https://energy.gov/science-innovation/electric-power/smart-grid [Accessed: 24-07-2017]

[29] KennisBank. Best Practices [Internet]. Available from: http://www.3if.be/nl/kennisbank