Intelligent Transport Systems: Revolutionary Threats and Evolutionary Solutions

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Victor Osipkov
LaserArt Ltd.

Tatiana I. Ksenevich and Boris Belousov
Bauman Moscow State Tech Univ

Oleg Karasev
Lomonosov Moscow State Univ

Sergey Sokolov
Keldysh Inst for Applied Math RAS

Mykola Rudynets and Mykola Skalyga
Lutsk National Tech Univ

Sergei Naumov, Vitalii Stepnov, and Anna Klimachkova
Bauman Moscow State Tech Univ

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Abstract

In the coming half-century, the global transport industry is expected to be affected by two technological revolutions - the first will start upon admission of autonomous vehicles to public roads, while the second will finalize a complete removal of manned vehicles away from them. As a result of the above revolutionary shocks, several major changes are anticipated: the modification of whole paradigm of ground vehicles; introduction of new business models in the transport sector, as well as new vehicle ownership forms; transition to technologies of collective and cooperative management and synchronized parrying the dangerous traffic collisions.

The paper defines the major goals of intelligent transport systems development for the next decade, namely: creation of highly adaptable mechatronic modules and systems, accumulation of knowledge about the variability of road situations and creation of dangerous situations scenarios; development of methods for evaluating and proving the safety of the autonomous control; and implementation of a harmonized reform of the international property and technical regulations with respect to autonomous vehicles.

Proper understanding the inevitability of changes followed by foresight of the technology development and related challenges will allow not only to avoid a chain of industry crises, typical for any revolution and accompanied by losses and bankruptcies, but also to transform both revolutions to a smooth evolutionary process.

Introduction

Revolutionary character of the effects, which may develop the intellectual systems on the transport complex in the future, requires the application of reasonable tools for their forecasting. Changes in the technological package of developed countries which occurred during the recent decades, have been so powerful that it becomes clear that traditional approaches to the formation of this sort of forecasts are no more corresponding to the new realities as their basic assumption is that trends of the past are always having continuation in the future. Today changes are becoming less successive. There appear new, large-scale spheres of technological innovations, which do not have a clearly expressed prehistory of the development. Today unpredictable changes are more and more frequent and they go together with the system interaction, i.e. problems, prospects, and success of development of one economic or technological sphere or any other part of human life and activities are in close interconnection with the situation that is happening in some other spheres. There is growing a demand in interdisciplinary forecast thinking enabling to integrate knowledge needed to the society, science, business, governmental management, and mainly, to the person accepting and implementing decisions, i.e. it is vital to propose not just a forecasting tool, but a decision-making tool.

One of such challenging tools is Foresight - a future studies tool based on leading experts involvement, as well as trend modeling, aimed at development of systemic view of long-term prospects for social-economic and scientific-technological development, prediction of technological breakthroughs enabling to make the maximum impact on the economy and society in the medium- and long-term prospects [1]. As an example, we may give one of the most well-known foresights, i.e. Japanese scientific-technological forecast. The basic method of this forecast which has been regularly arranged since 1971 with five-year intervals, is Delphy, i.e. an inquiry of a big number of leading national experts from various key spheres as arranged in two rounds. At present the ninth version of the inquiry is the challenging one which is developed by the National Institute of Science and Technology Policy (NISTEP) with participation of 2900 experts [2].

1. Image of the future

One of the first who began to apply the word-combination “image of the future” as an independent category was Mr. Ph. Pallack, Dutch sociologist. He determined “image of the future” as a positive model of the expected future making comparison between images of the future existing in our conscience and images of the art [3]. “Image of the future” is understood by the authors as a relatively aggregated picture of the future which is developed at definite time within definite socium, expresses social opportunities of this socium and generates probable prospects of the future.

1.1. Information Revolution

Growth rate of the labor automation in the current economy has created some conditions for the shift of relations based on the exchange of property to the relations based on the exchange of knowledge. Figuratively this process is named “information revolution”. The creation of information product will become the core sector of economic activity. This causes some transformation of public relations, transformation of a new economic structure of the knowledge-based economy. The human has already taught robots to manufacture the material products more qualitatively and quickly than people can do this. On the next stage, we may expect the appearance of computer systems, which will be able to create knowledge more qualitatively, and quickly than people can do this. The current information revolution is based on the asymptotically-tending-to-zero-charges on the information duplexing due to the wide spread of computers joint with Internet. One of the key features of the current information epoch is direct transformation of knowledge into the market product avoiding the stage of manual labor. This is a precondition for a long-term steady exponential growth of technologies applying manufacture principles and multiple application of knowledge.

1.1.1. Laws of exponential growth

In 1965 one of the founders of “Intel” Mr. Gordon Moore discovered a regularity, i.e.: number of transistors approximately doubles when shifting to the every next generation of microchips and thus he came to the conclusion that if keeping this tendency the capacity of computing devices would increase exponentially. This observation is known as “Moore’s Law”. Since then there is a steady exponential growth of complexity of integral microchips [4]. A similar situation is observed in terms of peak capacity of supercomputers. For the 67 years from 1946 to 2013 this characteristic has increased by 6.8 trillion times from 500 FLOPS to 33.86 petaFLOPS. Every two years the capacity of the most high-speed computer on Earth increased in average by 2.5 times. For the half-century from 1961 till 2011 the cost of computing power with the capacity 1 GFLOPS has reduced by 4.56 trillion times from US $8.57bln. to $1.9 (in prices for 2015). Every two years cost of one GFLOPSin average reduced approximately by 3.2 times.

We may say that the steady exponential growth based on the knowledge of industry is not a miracle, but a norm.

1.1.2. Fifth Generation of Computers: Fiasco that Turned into an Unexpected Success

The first four generations of computers were clearly recognizable and were characterized by a qualitatively different element base, i.e. electronic vacuum tubes, transistors, integral microchips, microprocessors.

The Japanese ten-year plan for the development of computer technologies, launched in 1982, envisaged the introduction of the fifth generation of computers, which focused on massively parallel computing and was used as a platform for the further introduction of AI. Although the Japanese program, which rolled out in the 1980s failed, yet all the major tasks assigned to the fifth generation have been resolved. The fifth generation appeared unnoticed by its creators and without much fuss. It sneaked into the everyday life so quietly that until now not all people are aware that the first IBM PCs (microprocessor-based computers designed for individual use) and present-day Internet-connected computers with multi-core processors and graphically parallel arrays belong to two completely different generations.

One of the reasons why the Japanese program didn’t have much success was the underestimation of the development potential of the fourth-generation computers. Notably, microprocessor technologies of the 1980s quickly passed those obstacles that were considered "obviously insurmountable" at the task setting stage. And although the workstations created under the program successfully achieved and even exceeded the required capabilities, the first commercial computers, based on the conventional single-processor architecture that appeared at that time, proved even more powerful. The hardware development prospects were catastrophically underestimated due to the overly pessimistic goals and objectives, while the artificial intelligence development prospects were forcibly overvalued - many tasks associated with artificial intelligence have never been realized in an efficient commercial solution, whereas the performance efficiency of computers has improved dramatically.

"Should the aviation industry be developing as fast as the computing technologies industry over the past 25 years, a Boeing 767 would cost US $500 now and it could make a circle around the Earth in just 20 minutes, consuming 5 gallons (~18.9 l) of fuel. The above figures give a fairly realistic view of the tendency for reduced cost and improved response time and the cost effectiveness of computers”, stated the 8th issue of in a magazine "The Science World" in 1983 [5].

1.1.3. Transformation of Information Industry

Since 2007, IDC Research Inc. has been analyzing and reviewing the major industrial breakthroughs as the signs of formation of the third platform for the intelligent information environment. The first platform was traced by the IDC analysts to the era of standalone mainframes with connected terminals, where the number of users was measured in millions, and the number of applications in thousands.

From approximately 1985, it was succeeded by the era of the second process platform with its main component being personal computers (PC) integrated in local area networks (LAN) with dedicated servers, and later - with worldwide web servers. The constituent elements of the second platform are personal computers, data routing, client-server application architecture, distributed information storage, and information search engines. The number of users at the age of the second platform increased to hundreds of millions, and the number of applications reached tens of thousands.

The key feature, which differentiated the third platform, was the transition to the cloud architecture of server infrastructure. The basic consequence of such transition was the change of the business paradigm from fee-based transfer of intellectual property rights to software programs, to sales of computing resource and information storage and processing services. The main types of such services are SaaS (software as a service), SoD software on demand), PaaS (Platform-as-a-Service), and IaaS (Infrastructure-as-a-Service).

A not less important feature of the third platform is its penetration into personal mobile devices, kept by their owners all day long, social technologies, and IoT (Internet of Things) - the computer network of off-line physical objects ("things") with built-in technologies for interaction with each other or with the ambient environment. IoT is a generator of data flow which, as processed, automatically converts into new knowledge through the use of BigData and FastData technologies. Wireless communications form the basis for data transfer ensuring such penetration.

As a result of the complete transition to the third platform (3rd Platform vision) most people, as well as those things that are equipped with microprocessors, will be fully embraced by the computer network. The number of users will be close to the entire population of the planet, the number of connected devices (things) will amount to trillions, and the number of applications to millions [6].

1.1.4. Forecasting Progress in the Field of Artificial Intelligence (AI)

Since the time the first computers were built, the expectations concerning the progress of AI technology consistently exceeded the actual results, and the forecasts tended to fall flat. Meanwhile, unexpected technological inventions saw the light where computers did exceed not only the forecasts, but also the capabilities of the human brain. In the 1960s, researchers believed that all AI related issues would be solved very quickly, but they found just as quickly that the so far existing computers lacked both capacity and memory. Nowadays, that computer capabilities have long outpaced the most ambitious forecasts of the 1960s, the advent AI era is postponed again and again, because AI theorists immediately transfer the AI related achievements to the field of ordinary computer algorithms.

Today's world most widely and commonly used technologies are conventionally attributed to the AI domain: the world's best chess players are AI systems; the search, translation and some other routine services of Google are essentially one large AI. However, all the achievements of modern AI surpass the human intelligence only in a narrow area.

The failed forecasts, that formed the basis for the Japanese project of creating the fifth-generation of computers, keep proving relevant today. We have exhausted the potential for capacity boost through frequency increase, and we are scaling it up now through a higher number of cores.

In the future, it can be assumed that the worldwide self-developing AI network could regularly replicate the knowledge gained in all individual computers. At this level, AI will hardly consider the “human level of rationality” as an important landmark and will not stop either. This moment will be the start point for a rapid asymptomatic vertical AI development, and the AI capabilities will quickly exceed the threshold of the brain's cognitive ability.

1.1.5. Technological Singularity

The authors understand technological singularity as a stage of civilization development, when the human brain no longer controls, predicts or even understands artifacts and signals generated by the technosphere.

Some advocates of the concept of technological singularity, think it may set on as early as in the 2030s, driven by an increase in the creative potential of self-improving AI, up to a level that exceeds the human one [7,8,9,10]. The authors believe that there will be no particular moment in time marking the beginning of the technological singularity era. Currently, the flow of information has increased to such an extent that it became impossible to read all new publications, even for a specialist of an ultimately narrow domain. This is mainly explained by the reduced cost of publicizing due to the omnipresent nature of Internet. And cost reduction inevitably leads to impairment of the quality of publications. Therefore, the task of differentiating useful information from useless, incorrect, or harmful information is often commensurate with the synthesis of similar knowledge, in terms of its cost and complexity.

The development of software design technologies resulted in the creation of areas lacking a human insight into the mechanisms of new software or hardware operations. No human being is able to keep in mind a program with a source code of at least one million lines, the more so to predict in detail its behavior. No one is able to study the logical description of a modern microprocessor with a few millions of transistors and determine the cause of its malfunctioning without computer-aided simulation. And this is not all: programs are executed as machine code, and chips are made with the use of templates showing their topology. People have long stopped even trying to understand the specifics of machine code or topology of integrated circuits made by computer systems, whereas they have to rely on robustness and credibility of at least automation software, thoroughly ignoring the fact that they no longer have any math tools to prove the conformance of these programs with their description.

It should be clear that the above is not about our future - rather about our present and past. Singularity occurs imperceptibly. The computer plays chess better than the man, the computer chooses routes including jams better than the man, or the computer conducts an orchestra at least as good as a man. Each of these accomplishments is classified by AI theorists as routine algorithms.

At the same time, people are rapidly losing the ability to develop new things on their own without the aid of computer technologies. It has long been impossible to design a new car model, develop process procedures, or programs for flexible welding, painting or assembling automatic lines, or to arrange for supply of components without the use of computers. Computer technologies have arrived so gently and gradually that we never think how much we depend on them, what role they play and how this role evolves with time.

Technologies and industries, where the technological singularity age took place, show an exponential growth of complexity and opportunities of completed products. Fulfillment of the Moore's Law in microprocessor equipment is a clear proof of the fact that we are not talking about our future only, but also about the events that have long been part of our reality.

An important economic consequence of the industry transition to the information era is the rapid market monopolization. The company to be the first to cross the exponential growth threshold will gain an unrivaled competitive edge. Such companies will be well positioned to "skim the cream", recruit the brightest talents, and buy in the most promising technologies. As a result, these companies quickly turn into "compact clustered hyper-concentrations of talents creating intellectual property" [11].

1.1.6. Cyber Threats

Cybernetic threats appeared simultaneously with computers. Numerous and diverse efforts aimed at preventing them failed to bring any positive result. Virus technologies develop in parallel with antiviral protection technologies using the "gun-and-armor' principle. The provisions of the modern theory of functional safety are described in IEC 61508 "Functional safety of electrical / electronic / programmable electronic safety-related systems" [12]. This standard defines the terms "harm", "hazard", "safety", etc. The underlying principle of the standard is the principle of inaccessibility in a general case of safety integrity: the higher the complexity level of a control system, the more cost-intensive will be the effort to reach the required safety integrity level (SIL).

The main sources of safety hazards are occasional and systematic failures; the latter are associated with erroneous or deliberate human actions or omissions. Human errors causing system failures are errors that arise during setting the initial requirements, engineering, manufacturing, installation and operation of hardware, as well as during design and development of software. Deliberate actions may be taken both by external intruders and developers alike. External attackers can make use of errors (vulnerabilities) of software (malware), or intercept control with the use of software embedded backdoors.

Experience shows that modern computer systems used in vehicles do not offer guaranteed immunity against computer attacks. For example, an identified vulnerability in Fiat Chrysler Automotive (FCA) car system UConnect (UConnect system) allows finding remotely a vehicle and intercepting the control of its critical functions [13]. In September 2015, the software of Volkswagen cars appeared at the center of a scandal. The car manufacturer programmed the electronic control unit (ECU) in such a way that the nitrogen oxide (NOx) emission rates were only met during testing and were optimized during driving a ECU vehicle in order to reduce the fuel consumption, while NOx emissions increased up to 35-fold. Earlier, a similar technique was used by General Motors [14], Honda Motor Company [15] and other companies [16]. These incidents show that the introduction of undocumented opportunities is the normal practice in the SW development for car manufacturing.

Over time, the two main vulnerability factors - system complexity and connection to communication networks - will be augmenting driving an increase in safety threats and security costs. Similarly to the world of desktop computers, mass epidemics of computer break-ins are possible here, but in the case of vehicles, consequences will not be limited to the information environment and it will inevitably affect transportation with a possibility of causing damage to life, health and property of people. Multiple incidents associated with injuries are highly likely to cause irreparable damages to the reputation of manufacturers exposed to vehicle attacks. Besides, computer attacks may be used as a form of illegal competitive battle, aimed at distributing market shares.

1.2. Transport of the Future

1.2.1. New Types of Transport

The development of new advanced types of transport normally stems from at least two desires of the humankind: to move in space at a faster pace and in a more energy effective way.

Any marked increase in the average speed of accessible transport means, increases the demand for transportation in the form of increased mobility of people and freight volume. This is explained by the so called space contraction effect: a five-time increase of carriage speed allows covering the distance per hour which took five hours before the increase. The man of the future will not have to endure the hustle of a metropolis throughout the day just because his cultural and business life may be constrained by the need to spend too much time using his own vehicle or public transport, should he live hundreds of kilometers away from the metropolis. Taking into account that the adoption of autonomous vehicles (car sharing) may ensure accessible traffic convenience when reaching a final destination from a rapid transport network station, we observe a unique opportunity to simultaneously achieve a high level of average traffic speed and its sufficient comfort. The space is contracting, offering billions of additional opportunities to live a comfortable and healthy life in a remote place far from the noisy center, while having a fairly wide range of potential job destinations. As we see, the development of the advanced transport types may result in a reduced urbanization level.

One of the potential solutions for the traffic jam issue is leaving the two-way world of ground transport for the overhead third dimension of flying personal cars. These will be the habitual cars with wheels and without wings or tails protruding outside the clearance. And there is another issue concerning limited energy resources. Today, many of us have heard of the daring idea of Elan Musk to upgrade the public transportation system up to a pipeline called Hyperloop. The Hyperloop is described as a steel pipe supported by aluminum capsules to move at a speed close to the speed of sound using solar energy.

When analyzing the Hyperloop real-life prospects, we may recall that already in 1972 a physicist R.M. Salter presented his VHST (Very Highspeed Transit System) project [17]. However, the prospect remained on paper only due to the absence of the technologies necessary for its implementation. But the currently announced project of Elan Musk has all chances to become real, considering the available choice of new technologies.

1.2.2. Decreased Attraction of Vehicle Owning

Recently, the developed economies and even certain cities have seen the trend of a decreasing weight of such motorization indicators as the gross mileage of the entire vehicle fleet and number of vehicles per 1,000 people. As an example, consider Milan, where the number of registered vehicles per 1,000 people keeps consistently decreasing. In the early 1990s, this figure was estimated at 700 vehicles, and in 2010 - 500 vehicles. Over a few years it is expected to decrease to 300 vehicles. According to some experts, the hundred-year era of the motorization trends going upward and vehicles dominating cities, as in the city of vehicles of Robert Moses, is coming to its end [18,19].

The attraction of owning a vehicle decreases not as much through the reduction of the purchasing power of population, as due to lifestyle changes, urbanization growth and the existence of economically justified traffic alternatives, with the emergence of the new formats of public transport [20]. New mobile applications in combination with ideally operating public transport allow metropolis inhabitants to optimize their routes while minimizing the time and material expenditures [21].

A new alternative pattern of the use of vehicles, so called car sharing, will entail a potential reduction of the vehicle fleet and the number of vehicle owners. In cities, the tried and proven car sharing practice will gain popularity and allow for a five-times reduction of the number of vehicles without compromising the consumer benefits.

In rural areas and in vast North-American suburbs, a personal vehicle is a must, but eventually with the invention of AV, a potential reduction in the number of vehicle owners and vehicles in households, through the shared family use of one autonomous vehicle in return-to-home driving mode, will allow reducing the count of vehicles from 2.1 to 1.2 per household [22].

It should be noted that one of the possible reasons for the decreased attraction of vehicle owning in a city is the so called controlled vehicle ratio that proved itself in Singapore and Tokyo. This trend is based on the model of William Spencer Vickrey later called Vickrey Auction Scheme [23]. Today, this model regulates the demand and supply for the throughput capacity of the street and road network in overloaded urban centers. For instance, in Singapore a citizen who wishes to buy a car should first buy a purchase voucher at an auction, where the cost of a voucher is sometimes three-time higher than the price of a car. Also, Singapore has the electronic road pricing system for city traffic, with the price varying depending on the density of traffic flow, time of day, *etc.* [24,25].

Still, all the above does not fully explain why metropolises become unattractive in terms of owning a personal vehicle. Talking about the attractiveness of vehicle owning in a city, we should not forget the fundamental value - the value of time. Today, metropolises attract, in particular, numerous highly qualified specialists who value free time just as high as their office time paid for by the employer, and do not want to spend hours in urban traffic jams.

Therefore, the combination of efficiency, convenience and quality characteristics of personal transport services leads to changes in life style and, as a result, to a reduced interest of metropolis population in vehicle owning.

1.2.3. Intelligent Transport

The reputed foresight studies throughout the world pay close attention to the development of advanced technologies in the transport sector. Intelligence of various modes of transport is meant to be one of the key trends, defining the future development prospects for this sector [2, 26].

According to the ninth Japanese forecast, we will see a whole range of innovative transport technologies bound to emerge by 2017 - driver assistance systems used both to prevent collisions with vehicles ahead or objects suddenly appearing on the road, and to allow forecasting any engine or tire problems with the help of various sensors; as well as road construction technologies, signage and alert devices set to factor in deterioration of the characteristics of such objects (visibility, response time, etc.) along their aging. A little later - by 2018 - the forecasts envisage technologies optimizing vehicle speed and other motion parameters depending on traffic lights. In 2019, specialists predict the emergence of safe traffic technologies detecting and addressing driver's mistakes. The 2020 target is the development of a cargo traffic system allowing for a 50% reduction in time, costs and environment pollution through streamlining traffic flows between various types of transport hubs - rail and motor roads, ports and airports.

Moreover, the introduction of advanced driver assistance systems (ADAS) will ensure a 90% decrease in the road accident ratio and the amount of resulting damages. By the estimates of NHTSA, the amount of damages from road accidents in the USA totaled some US $910 billion in 2014 [27].

1.2.4. Autonomously Controlled Transport

The largest players in the automotive industry - Audi, BMW, Daimler, Tesla, General Motors, Nissan, Volvo and KamAZ - have announced or implemented their programs associated with control automation. Component suppliers, such as Bosch, Continental, Delphi Automotive, Mobileye, Valeo, Velodyne and Nvidia, are also getting prepared for the new autonomous vehicles (AVs) reality. The introduction of fully AV is expected by 2025 [28].

In 2014, Daimler AG unveiled its plans about making the transport of the future even safer, more efficient and more fully integrated into the common network. In July 2014, the world's first pilot-controlled truck Mercedes-Benz Future Truck 2025 was demonstrated in action over an enclosed stretch of the À14 highway near Magdeburg. In May 2015, the Inspiration truck of Freightliner using the automatic control system Highway Pilot has become the world's first pilot-controlled truck permitted for use on highways in the State of Nevada. Mercedes-Benz exhibited its futuristic controlled-vehicle concept F 015 at the CES 2015. Singapore and Great Britain have launched the first robotaxi, and China has released an autonomously driven bus cruising on the public roads of Zhengzhou.

Volvo has spent several years working on the Drive Me project with a fully autonomous vehicle as the target outcome. The pilot version is already on the road and by 2017 Volvo plans to release 100 fully autonomous vehicles. Nissan has been working on its Autonomous Drive project featuring the autonomous Nissan Leaf model.

Audi, in conjunction with Delphi, has already produced a few pilot models that recently have made a series of journeys mainly in standalone driving mode. The first commercial autonomous Audi model (new Audi A8) is expected around 2017.

This means, the fully autonomous control of aboveground transport may be referred to the contemporary stage, rather than to an uncertain future. Once the technological issues have been resolved, the only thing left to be done now is to confirm the safety level, allocate responsibility for incidents and adjust the legislation. For many reasons, some of which were discussed in the second part of the article, the modern transport with hybrid automatic and human control will not last long. This period may cover two or three vehicle lives, which is 12-20 years.

In the end, public roads will be served exclusively by automatically controlled vehicles, and the traffic will be organized in a synchronized collective control mode based on the dedicated optimization function, which first of all maximizes the safety performance, and second, minimizes overall traffic costs for all or most of its participants. AV control will be coordinated autonomously following the unified traffic rules and emergency response regulations, which promises to significantly reduce the number of road accidents.

1.2.5. Unified Traffic Environment

Today, we face structural problems associated with the transportation of consumer packaged goods (CPG) and the need to optimize the cargo traffic capabilities [29]. Logistics companies are increasingly forced to make inconvenient compromises: paying more in order to ensure that the service is in line with expectations or cost effective, often at the expense of speed and supply reliability.

The prospective image of an efficient traffic environment is based on multi-modal carriage involving various modes of transport, where every mode optimally suits the dedicated delivery segment. The main problem preventing the setup of this environment is the absence of appropriate cooperation. The above level of transport interaction requires alignment and even synchronization of activities of traffic participants, as well as enhanced reliability of meeting delivery schedule. This results in a reduced cost of cargo delivery due to competent cargo consolidation and balanced logistics, and in a decreased overall load on transport infrastructure.

This way, carriage will transform into an end-to-end process, with consolidated and centralized cargo delivery based on a two or three level network of classification/transshipment warehouses. Where permitted through a high level of synchronization, board-to-board transshipment mode will be used, bypassing warehouses. On the lower level of this hierarchy, communal cargo cells will be provided in each building. Such cells will be adapted for loading cargoes automatically immediately from a vehicle, or with the use of an aboveground manipulator drone , and will be opened by electronic keys kept by individual cargo receivers.

Buyers of goods will mainly use Internet-based delivery services, and where physical presence in the shop is required (for example, to watch and try alternative options), "baggage" (heavy and large-size goods) will be delivered from the shop to the buyer's cell in the building over a period comparable with the time it takes the buyer to return home from the shop.

The common traffic environment will be used for passenger carriage as well. Due to a high quality and accessibility of combined (multi-mode) carriage, the demand for owning a personal vehicle will decrease. For example, one of the options of efficient support of the most actively used daily commuting routes in metropolises could be a two-level transport system consisting of a rapid public transport network and a well-developed short-term AV rental (car sharing) network.

1.3. Transformation of Automotive Industry

1.3.1. Threat of Diminishing Car-Makers' Role to No-Name Producers of Vehicle Components

The traditional model of rigid hierarchical control showed a satisfactory efficiency under the conditions of stable and predictable development of the automotive industry. However, the more complex a corporation is, the longer the hierarchical stair for a decision to be made. Technical progress brings about an increased importance of quick decision making and dynamic adjustment to changes in the technological environment, together with added complexity of governing giant corporations. This creates objective premises and ample opportunities for fast market penetration by relatively small innovative companies, the so called "startups".

Most startups terminate with a near-zero score, but occasionally some of them reach fantastic results and become the leaders of new market segments. Due to inter-segment competition, consumers are gradually flowing over from traditional to innovative segments. Such overflow may be the reason for loss of business, even for mega-corporations. Thus, IBM leading the personal computer industry stopped developing the operating system OS/2 after losing the competitive battle to Microsoft originally brought to market by IBM. Another example is the acquisition of the Moscow based fixed line telephony service provider (MGTS) with an almost half-a-century experience by a market newcomer providing cellular communication services. This happened primarily because MGTS, resting on the laurels of its multi-million subscriber network, failed to see the innovative markets of wireless telephony and Internet services.

The emergence of horizontal network structures, which can make arrangements and share information without limits, implies a high likelihood of dismissing the conventional hierarchical control model. The network structure dramatically changes the concept of business organization compromising the need for having unique competences, or accumulating necessary administrative weight and status. Any network agent having the largest amount of information and sufficient interest may, at any time, assume the hub role. This way, vertical integration transforms into a horizontal one, where the integrator company acts as the main link of the business chain. It produces the finished product assembling it from purchased components based on its own specifications and design. It also gains the right to brand the product and the bulk of added value . In the future, this transformation will affect the automotive industry as well as the role of the existing vehicle manufacturers, who failed to take the central position in their networks, may reduce to the role of impersonal (no-name) suppliers of components. For modern buyers, it is totally irrelevant which plants assemble smartphone components, but they do care about the operating system and label on their smartphones.

Along with a decrease in the relevance of automobile OEMs as integrators, the automotive market is facing a new situation associated with non-barrier penetration of new no-name producers of automobile components in the automotive business, and the opportunity for a quick change of the production profile and scope for the existing companies. The automotive industry may assume a development model similar to the production of computers and other HI-Tech products - fast and unexpected appearance of "new players" and strategic alliances comprising various companies. As is the case of the modern production of electronic components, made for various brands on the same plants, owned by generally unknown firms, the future car manufacturing will be efficiently concentrated through narrowing the specialization of plants. This way, manufacturing is becoming small-scale and personalized. Plants will be owned by companies that will rent them out, fully or partially, or perform contractual manufacturing services using customer provided materials. One of the main business tasks of a contemporary integrator is to source out the best manufacturers for optimized logistics.

The intellectual component in the cost of car manufacturing - first of all the cost of software engineering - is rapidly gaining importance. Thereby, the cost of mechanical parts keeps plunging along with the emergence of new technologies. A vehicle, historically being a plainly mechanical product, is acquiring the properties of an information product and drifting towards the market relations characteristic of the information industry. This implies the prospect of appearance of many new market brands offering information vehicles like Teslà. The market will be getting ever more diluted, where marketing advantages will be gained by the most innovation-focused brands, technological advantages will be reserved by innovative companies, and cost advantages will be shared by companies using special productions and efficient logistics, while the market role of the current automotive industry leaders will depend on how efficiently they will integrate into the new industry paradigm.

Therefore, the ongoing development of the automotive industry may relatively safely be called the beginning of the redistribution of the huge worldwide automotive sector.

1.4. Social changes

1.4.1. Transfer from post-industrial economy to knowledge economy

In view of the global challenges of the innovative sphere, new advantages are being developed to resolve the strategic tasks, including the transfer to a new techno-economic paradigm - knowledge economy, the economic system driven by knowledge and innovations as the key factors of economic development. The distinctive features of this system were formulated by K. Kelly who defined them as first, the global nature of ongoing changes; second, a high importance of operations with intangible resources (ideas, information); and third, close connection and interaction between various economy segments [30]. Interpretation of the term "knowledge" as the new productive force is multifaceted. Thus, according to the classification suggested by experts of the European Commission, this may include scientific, technical (technological) knowledge, innovations, intellectual capital, qualifications (competences) obtained as a result training, as well as information and communication technologies [31]. In a broader sense, knowledge formation is contributed to by all elements of the innovative system - educational and scientific organizations, as well as real economy enterprises.

At this stage, the role of intellectual resources of the society as a production factor - along with natural, labor and capital resources traditionally considered by the economic science - increases multiply. The society is increasingly faster moving towards a state which is conceptualized as an information society, i.e. a society where most working people are employed in production, storage, processing and release of information. The information society sees changes in production and the lifestyle as a whole, including the system of values and the enhanced role of cultural involvement against tangible properties. As compared with the industrial society, where all resources are allocated to support production and consumption of goods, the information society consumes mostly intelligence and knowledge, which enhances the share of brain work. An important trend in changing the economic structure becomes the advanced growth of the sector of intellectual services [32].

One of the products of innovation based economy is the concept of shared property use, the so called sharing economy. According to Forbes, the current-year turnover of the sharing economy will exceed US $3.5b [33]. "The humankind keeps distancing itself from the model where everything is tied to property, and nearing the model based on property access," says Lisa Gansky, the cofounder, CEO and chairman of Ofoto.

The sharing economy creates markets of things, which could not even be associated with monetization just a few years ago. This economy suggests that property owners would refer to online platforms to capitalize the unused part of their property, and consumers would rent it from owners. It is worth noting that this largely pertains to durable goods, such as, in particular, vehicles. The changing mobility paradigm leads to a critical review of the methods for vehicle use. BMW is already positioning itself in the future as a "mobility provider, rather than a conventional carriage fabricator".

In the recent past, the cost of owning a personal vehicle was lower than its rental cost; now, in particular due to the development of information technologies, vehicle maintenance costs vehicle owners more than using Uber. In rural areas and North-American suburbs, where personal vehicles are indispensable, changes in transport logistics will be associated with a multi-mode nature of carriage: a personal vehicle will only take its owner as far as to the nearest transfer hub. In cities, increasingly popular will be car rental services with per-minute billing - car sharing that implies the alternative use of vehicles .

1.4.2. Changes in Consumer Sentiment

The "consumer sentiment" indicator takes into account the feelings of an individual about his or her own current financial standing and the health of economy in general, in the short and long run.

Until recently, the potential market demand as the indicator of real needs of the population was dictating orders. Today, new technologies allow the translation of latent demand into actual demand - not only demand boosts supply, but new supply can create new demand. This is the force that forms new markets shaping the image of the future.

The poll conducted by BCG in 2014 showed that the public opinion is very favorable toward AV [34]. Thus, 60 to 80 per cent of 1520 polled American consumers believed AV would benefit the society. About half of the respondents are ready to buy an AV.

At the same time, the expectation of a "smart car" generated by broad acquaintance of the public with the capabilities of information technologies resulted in heightened concerns about data protection and safety of automobile systems. Design changes and transformation of a vehicle into an information system susceptible to failures, program errors, cyber attacks on systems of all levels, navigation system errors, malfunctioning of safety devices, etc. make a vehicle more sophisticated and as a result, less reliable. This circumstance is responsible for the lack of consumer confidence and consequently for individual and social pessimism toward intelligent vehicles, setting an additional barrier for their broad deployment [20].

This inconsistency between the sentiments and the expectations of consumers immediately affects the formation of consumer demand for intelligent vehicles.

1.4.3. The impact of the Demographic Situation

In the developed economies, the population size changes insignificantly, but the life expectancy extends together with the middle age. Simultaneously, due to a high rate of technological growth, there is a ‘youthification’ of developers of high-technology products, where university graduates are most creative and informed about new technologies.

In terms of ergonomics, we expect that the developed markets will show a deepening discrepancy between progressive solutions, suggested by even younger developers, and the mentality of aging consumers. More solvent consumers, above the middle age, are less inclined to accept technological novelties. Even a middle-age person may feel uncomfortable driving an autonomous car through gates 15 cm wider than the car size at 60 km/hr. Young people, who are more prepared to accept and use new gadgets, are not always positioned to buy upscale products. Advanced goods for the developed countries should also have the most affordable price. This way, the introduction of technological innovations into the range of goods intended for solvent consumers, in the developed economies will have to be artificially constrained.

In the developing economies, the middle age extension pace is less pronounced. The average life expectancy here increases primarily through the reduction of infant mortality, and the birth rate remains traditionally high. As the number of children in a family increases, the agriculture fails to cover the needs of the growing population. The older generation in the emerging economies for the most part is not accustomed to use vehicles, and therefore little interested, as they are more concerned with breadwinning for their children. Young car owners in these countries mostly represent the first generation of drivers and form a fast growing target market segment, for which the wow effect determined by the appearance and set of electronic functions is the prevailing factor in choosing a vehicle model. In view of the above, the emerging markets are likely to become more adapted to mass deployment of catchy technical novelties within the next 15-25 years.

1.4.4. Impact of Automation on Labor Market

The economic prospects of transport automation appear oppositely directed: on the one hand, reduced labor costs offer considerable gains from payroll reduction to be shared between car manufacturers, leasing companies and carriers; on the other hand, this will raise the issue of employment for unemployed drivers. The first automobile revolution in the beginning of the 20th century faced the lack of work for carriage drivers. At that time, this problem was partly resolved through upgrading them to the level of car drivers.

Now the unemployment issues, generally arising through automation, will inevitably hit all those who earn their living as professional vehicle drivers and service technicians [35]. For instance, a reduction in road accidents will make the demand for car repairs drop. Drivers of heavy duty trucks will at best become security guards and freight forwarders of automatic vehicles, with further loss of qualification and reduction of employment as it will eliminate the need for workmates. For taxi drivers the situation looks even worse - the demand for taxi services will drop to zero as soon as the autonomous car sharing service emerges.

Apparently, transport automation will cause increased demand for electronic system fitting and maintenance personnel. However, these will be fundamentally different specialists as compared to those currently employed in the automotive industry. It will probably be easier to teach young people these professions from the very beginning, than to retrain existing car mechanics.

Therefore, the affected third party (drivers and maintenance workers servicing conventional vehicles) may become a source of active resistance to transport automation. A timely response to mitigate this threat may be deployment of state sponsored personnel retraining programs.

2. Mitigation Options, Possible Actions to Avoid Negative Future Outcome and Increase the Likelihood of the Desired Future

Foresight is not confined to forecasting one of the future options, or predicting events that are expected to occur. It is based on the multi-optional future concept according to which one of the options may become reality depending on present actions or omissions. The future isn’t inevitable and unavoidable; the fate of the vehicle manufacturers will depend on how well they will understand and predict the overall image of the future, forecast future trends, and how adequate their actions will be in the context of this forecast.

Forecasting the future is simultaneously a simple and a very difficult task. It is very easy to forecast the future without any reliability evidence at hand. In the very beginning of the 20th century, Henry Ford declared at the session of carriage makers, discussing quite earnestly, in particular, the issues of developing a slurry tank and inflated tires for carriages, that in less than 3 or 4 years nobody will buy their products. The transformation of urban mobility took place yet in 1908, driven among other things by the contribution of Henry Ford who arranged for commercial production of Model T cars [19].

It is no secret that future forecasts can be sold; moreover, trading in future is one of the most ancient professions. Modern future trading technologies are not fee based, for many centuries ago, future traders understood that using predictions to change the behavior of people in the present allowed earning more than charging payment for predictions. Politicians are a group of people who benefit most from trading in future. According to the vivid expression of Winston Churchill, a politician needs "the ability to foretell what is going to happen tomorrow, next week, next month, and next year and to have the ability afterwards to explain why it didn't happen" [36]. Any political analyst knows that people are prone to support those who create the most attractive images of the future for supporters. As an additional support, an alternative negative scenario is simultaneously developed to describe troubles and grievances of those who refuse to follow the future provider.

This means we should beware of the "future traders". Before making any decisions regarding the present actions based on a specific image of the future, it is very important to learn to differentiate good-faith forecasts from mercenary and populist ones. According to the authors, no forecasts should confidently present any non-optional future scenario based on the only assumption that this scenario is reasonable and capable to prevent a national or global tragedy.

Despite the opportunity to shape the future, it is not advisable to overuse it. To ensure the successful manipulation of the future, care should be taken to understand the limits of the affordable future corrections. It is necessary to learn to distinguish between inevitable trends and occasional fluctuations and effects similar to fashion fads. Any attempt to slow down the advance of the future, or to radically change an inevitable future scenario, may eventually lead to devastating defeats and downfalls of individual companies and possibly the industry as a whole.

The future is like a resilient mechanical structure - just as a buffer spring the future may deform, transforming the future shaping effort into accumulated potential energy. Later, the accumulated deformation energy may be used for good cause, but light-minded transition beyond a certain critical threshold may reach a point of no return. The deformation energy will inevitably transform into a catastrophic "revolutionary" upheaval, comparable with an earthquake, that is known to release deformation energy stored in the earth crust with accompanying fast-going destructive shift of rocks. Loss of markets, business, jobs, financial collapse of shareholders, and panic at stock exchanges - these are typical "revolutionary" consequences of an economic earthquake.

Goal setting should be a step-by-step process putting forward simple and easily achievable goals leading to a target point as part of the set strategy, which corresponds to the objective course of society development. Evolutionary approach alone will allow avoiding accumulation of beyond the range of stability deformation energy of the future, and help the current industry leaders not only retain, but to also extend their market presence and explore new market niches.

2.1. The Desired Image of the Future

Among the most important foresight concepts is the cross-functional approach, exploring the synergy moving over from future forecasting to its implementing subject to *opinions of various experts* on the likelihood of the appearance of breakthrough technologies and products, and new markets [37, 38].

The overall vision of the future for the car manufacturers is largely based on, firstly, the universal mission of any business activity, and secondly, the common striving of people for progress, enhanced quality of life and environment. The first category includes the efforts to expand markets, increase the scope of production and sales, and improve profitability. An intangible side of any solid business is its ability to guess and meet the needs of people, offer the most relevant and useful goods and services, and provide well-paid and interesting jobs for employees including professional and career enhancement opportunities.

By approximately 2050, the public traffic system will fully switch to automatic control of ground vehicles. All AVs will be moving in synchronized collective control mode based on the dedicated optimization function, which first of all, maximizes the safety performance, and secondly, minimizes overall traffic costs. When the throughput capacity of certain road sections is exhausted, meaning traffic will reach a critical point where any further increase of traffic density will decrease the traffic intensity, the traffic optimization system will limit the flow of AV to such sections [39].

In case of safety hazards, AV will take mutually coordinated actions to ensure minimum possible harm in case of a negative scenario; in case of V2V (vehicle-to-vehicle) failures such actions will be coordinated autonomously according to the unified emergency response regulations.

2.2. Formula for Success

The top prize in the forthcoming endurance race is the opportunity to “harness” new technologies developing in line with the exponential law. Bad news is that all those who came late or lingered at the start will most probably never catch up with the leaders.

Even if several companies are simultaneously positioned at the beginning of the “exponent”, the lion's share of the market will eventually be controlled by a single company that was a little faster at the initial stage than its rivals. Its "weak sisters" may strain their muscles trying to create new market areas offering exponential growth. But even this will be extremely difficult to do, as the market leader will automatically gain a financial advantage with the opportunity to invest into a broad array of prospective fields. The examples of success are the stories of such companies as Microsoft, Google, Facebook, and Intel, where each totally dominates a respective market sector. The future will show how many independent sectors will be found on the automotive market.

To learn to guess the promising directions at early lifecycle stages in order to concentrate on their development is the main formula of success for the knowledge based economy.

2.3. Safety Assurance

Vehicles are a major hazard; annually, more than a million people die in traffic accidents [27,40]. Despite the decreased fatality ratios achieved in the advanced economies, the relevance of the traffic safety issue will not wind down, and the ratio of aggregate safety related costs to the achieved results will be growing over time.

According to the definitions adopted in IEC 61508-4:1998 [41], **hazard** is a potential source of harm - physical injury or damage to the health of people caused both directly and indirectly as a result of property damage and environmental deterioration; **safety** is the absence of risk considered inadmissible under given circumstances in line with the current values of society. In its turn, **risk** is defined as a combination of the likelihood of harm and severity thereof. Using this system of definitions, it is possible to develop a methodology for safety level assessment tied to a monetary scale. This methodology may, in turn, be used to create algorithms for searching optimal solutions for safe vehicle driving, or algorithms for searching optimal control solutions, where the degree of risk reduced to the monetary scale will be taken into account along with the cost of time, fuel and other factors.

For the time being, the key part in a traffic accident is played by the human factor during the vehicle operation. Along with transport automation, the relevance of human factor at the operation and production stages is expected to decrease, while its role at the vehicle development and testing stages will become more important.

Currently, the first vehicles with automatic control are operated in some quarries and motor roads across the planet. This event is a landmark of the new age of vehicle safety - automation of transport control. Automation addresses the most hard-to-control hazard - human factor. Probably, the first steps of automation will be met with mistrust and apprehension with respect to automatically controlled vehicles. This effect will explain multifold public outcry after each traffic accident involving automatic transport. However, due to the electronic and informative nature of the automatic control system, the knowledge and skills of electronic drivers can and should be upgraded, first of all, promptly, and secondly, in a centralized manner.

2.3.1. Safety of Innovations

There is a Russian proverb saying "learn from mistakes", and another proverb specifying that “only losers learn from their own mistakes”. The vast majority of electronic systems, unlike people, use others' losses to learn their lessons. Each traffic accident caused by a "robot" will be subject to comprehensive analysis, computer-aided simulation of a hazardous situation, adjustment of control algorithms and expansions of testing programs for all manufactured and operated control systems. The improvement of the safety of fully autonomous vehicles will be rapid, as the ban on human-driven vehicles on public roads will come unexpectedly fast for most people. The main reason for the adoption of such ban will be the human factor as the key source of traffic hazard. Let's be honest, the chances that everything will go smoothly and the adoption of automatic control systems will not be paid in human blood are slim. Unfortunately, car accidents through the fault of automatic drivers will hardly be avoided. Even though there is an approach reducing the likelihood of autonomous traffic accidents through a considerable slowing in introduction of automatic control systems, this approach will provide for an extended period of transition from manual vehicle operation, and a resulting increase in the total number of casualties caused by human drivers. This means the artificial extension of the period of transport adjustment to automatic control will be equivalent to artificially increasing the number of casualties. This of course should not be considered as an appeal to release underdeveloped products on our roads. The public reaction to this "double edged sword" will as usual mostly depend on the tone set by media. One and the same result can be presented as a threat to the humankind ("watch robots killing people"), and as a reduced threat of traffic accidents with an overall reduction of the number of casualties.

Special attention should be paid to the information security and reliability tasks, in other words, to verification of algorithms and control systems, and their protection from information attacks. We are not going to discuss these common IT issues in our article in order to focus on issues associated with traffic safety.

2.3.2. Emergency Situations

Even after the complete integration of perfect cybernetic automatic control systems and placing a total ban on manual vehicle control, there will still be a nonzero probability of traffic hazards because of occasional failures, falls of meteorites, and appearance of people or animals on the road. In order to mitigate the risk of occasional failures, the onboard control system shall have an intelligence level such as to allow identifying critical situations and ensure smooth degradation and passive failure of autonomous vehicles .

At the current stage, human factor remains the major source of accident hazard. In case of a fatal accident, the generally accepted routine includes an investigation into whether the non-violating driver could avoid the accident. This practice will undoubtedly be used for accidents involving autonomous vehicles. Therefore, in order to exclude inadmissible risk, it is critical not only to ensure that the automatic control systems unconditionally comply with the traffic rules, but also to teach these systems to respond to hazardous situations caused by other traffic participants. For this the control system should be able to analyze the behaviors and forecast actions of people driving vehicles. The control task involves the continuous forecasting of hazardous situation development scenarios, assessment of related risks and response options and implementation of preventive actions. Please note that reliable forecasting of human actions is an extremely difficult task requiring considerable investments. But the result of such forecasting will be used to determine the matrix of probabilities of possible actions.

In situations where an accident is unavoidable, the control system should select the optimal controlling action which, regardless of the behavior of other traffic participants, will help minimize risks related to the following three hazard ranks: firstly, risk of fatality, secondly, risk of personal injury, and thirdly, risk of damage to property and environment. The development of predictive models for assessment of such risks, depending on specific accident conditions, is the relevant topic for the scientific research encompassing the vehicle movement theory, medicine and economics.

2.3.3. Collective Safety

Traffic accidents may follow scenarios that cannot be avoided through optimal control of only one vehicle. There may be cases when an independent optimal solution of the accident response task for each of the involved vehicles may result in an even more serious accident, because their own response maneuvers may not take into account maneuvers of other traffic participants. There may be situations involving both automatic and manually controlled vehicles, as well as situations when automatically controlled vehicles have disturbed utility lines, or situations when physical collision of vehicles is the only possible outcome, and it is required to find a collision scenario that will first of all help minimize the likely injuries, and secondly, the combined damage to property.

This is probably the major safety issue. We have come to an understanding that the safety assurance task may not be resolved by an individual producer, and requires joint efforts of all designers and producers at a national and international level. This involves the setup of a uniform set of justified rules for response to hazardous situations agreed by all producers, development of a common mathematical platform for optimizing traffic objectives, the first of which will be safety assurance. The next level includes the unified real-time algorithms used to assess the probability of damages and injuries in various types of accidents.

2.3.4. Virtual Polygons

One of the prospective tasks of the vehicle motion theory is the identification of potential instability zones - critical modes "provoking" maneuvers of vehicles moving closely in the same or opposite direction, after which the tested system is likely to stop its normal functioning mode.

In accordance with the up-to-date approaches to safety assurance, the system safety level cannot be determined based on the individual safety integrity analysis of system components. In other words, the level of vehicle safety cannot be determined based on the safety levels of its individual components: braking system, steering system, engine, body, etc. because of the synergetic connection of components affecting vehicle safety as a whole, and the synergetic connection affecting safety of the "driver-vehicleenvironment" system on the next system level. In each particular case, the specific safety related actions will depend on many factors and characteristics of a particular application. Considering that safety is achieved through the use of several protection systems comprising various technologies (mechanical, hydraulic, pneumatic, electrical, electronic and programmable electronic); therefore, the safety assurance strategy shall take into account not only all elements of individual systems (such as sensors, controllers and actuators), but also all safety related subsystems comprised by the combined system.

The wide range of road conditions, traffic, weather and climatic situations, and the extremely stringent safety requirements do not allow fully relying on the results of field tests of a sufficient duration. The conditions of the most perfect polygon cannot reproduce the versatility of possible road situations. This explains the relevance of creating computer models to simulate vehicle motion dynamics suitable for verification and assessment of the safety level of transport systems through a computer aided experiment. After resolving this task, the testing process will be reduced mainly to the automatic selection of a set of situational tests, where the list of such tests will be extended along with the identification of insufficiently tested occurrences.

At the same time, the making of such set of testing, requires addressing three main sub-tasks:

- creation of environment model;
- creation of vehicle model;
- Identification of optimal testing sequences.

The environment model is a 3D terrain model supplemented with the mechanical properties of the soil where necessary (for testing off-road vehicles).

The vehicle model should be developed in conjunction with the vehicle designers subject to the required level of adequacy, for instance, subject to suspension oscillations, transmission vibrations and torque fluctuations that depend on the vehicle operating conditions. Obviously, such model shall cover the haulage capacity of the power generating unit.

On the first level, the task of creating new sequences may be solved conceptually, but to draw up a comprehensive list it will be necessary to thoroughly study real-life road situations, and accumulate the initial set of knowledge with a sufficient versatility of traffic situations. Such work can be done both through analyzing indirect data, for example, reports on causes of road accidents, and through special observations. This way, a required set of data can be accumulated if self-monitoring vehicles with 3D video recording of ambient environment will be used throughout the world. The number of regions identified for data collection may reach some 2000-5000 (geographic versatility requirement). The period of data collection shall be at least one year for each region (seasonal versatility requirement). The total covered length of road may vary from 30-100 thousand to 2-5 million kilometers per region depending on traffic intensity (situational versatility requirement). For efficient testing, the combined set of data shall be ranked by the level of uniqueness of traffic situations, where same type situations will be attributed to the same cluster and generalized. Testing scenarios may be based on the "training" principle moving from simple to complex situations, and on the "screening" principle moving from the most complex to simple situations.

2.4. Competition between Vehicle Manufacturers and IT Companies

Today, the vehicle manufacturers are bound to leave the comfort zone of intra-industry competition and struggle for market share of the period that was characterized by the consolidation of companies and the creation of a limited number of large national and global players. At this stage of competition, the industrial standards were predetermined by the preferences of the market leaders. It is these standards for the new market that guaranteed the leading companies the position of a natural monopoly while dramatically limiting the market entrance opportunities for new players .

In the foreseeable future, the IT development level will determine the state of the art in any industry branch, whereby "I" in IT is gradually transforming from "information" to "intelligence" technologies. The absence of "boundary" industrial IT standards for vehicle construction means a low barrier for market entrance for new players. We should not lose sight of the already started process of moving the creation of added value from production facilities in the engineering and design centers. In contrast to the restrictions on intellectual property use, the sophistication of engineering solutions will allow the new players to quickly become valid competitors to the current industry leaders. A typical example of this is offered by Tesla, the company that disclosed all its patents considering its available technological reserve sufficient to keep it at a safe distance from its competitors.

In the opinion of the authors, the idea that IT companies and designers of IT systems will lend a helping hand to car manufacturers seems illusive, even considering the desire of the latter to follow the aimed synergy route.

In a situation where the most profitable resources and (most important) the resources set to shape the future living environment - startups and talents - are slipping from their hands, the vehicle manufacturers will struggle for retention and expansion of their control over such resources. For this, they should be able to launch their own startups, engage the brightest talents, thereby exploring new business spheres, and minimize the lead time for new technologies focused on knowledge economy. The vehicle manufacturers have to stop considering investment in the development of new information technologies as a source of (potential, short-term and minor) profit. It should be clear: those who own technologies based on knowledge processing will own the future. This way, an IT startup in vehicle manufacturing is not a sand box for fledgling talents, but a strategically important line of business ensuring control of future markets.

Undoubtedly, an important feature of the forthcoming competitive standoff between vehicle manufacturers and developers of information products, between "mechanics" and "programmers" will lie in the fact that future market struggle will be on the “home ground” of companies active in the information industry. IT penetration in the automotive industry products will require transfer to the paradigms of information technologies and information based economy. How well the vehicle manufacturers are prepared for this is a question they should ask themselves. Obviously, there is a risk of shortage and dilution of high-level specialists capable of independent creative thinking and prepared to make key decisions in developing products based on the new paradigm of knowledge economy. The number of such people is fairly limited, this is why those who will be able to track and employ them, provide a creative environment and use the advanced cross-functional training methods, identify talents among first-year students, bearing in mind that the production of good IT specialists goes faster than the production of a good design engineer or designer, will be the winners.

Additionally, in order to preserve their market dominance the vehicle manufacturers should secure the most recent or more advanced (than that of their information industry competitors) IT based enterprise resource planning and product lifecycle management system, including team work, joint decision making, goal setting, planning, development, procurement, production, finance and logistics management, marketing (CRM), outsourcing, *etc*.

2.4.1. Different Approaches of Vehicle Manufacturers and Software (SW) Developers

The automotive industry is a technical sector with a history covering more than a hundred years, which has long coined the concept featuring a vehicle as a source of major hazard, and developed the tradition of safety integrity and product reliability testing. Numerous litigations ensure “natural selection” and elimination of unscrupulous vehicle manufacturers. The surviving market participants undertake responsibility for their business, in particular, in the field of software reliability.

The current economic structure mostly provides for an opposite approach to SW introduction to the market: the most important thing for a startup is to bring a new, even "raw" (underdeveloped and unreliable), product to a market, arrange for its widest possible distribution building on the wow effect, and occupy a new market niche. Thereby, it is totally irrelevant how many bugs the first version will contain; moreover, the efficient introduction strategy implies shifting the burden of testing to buyers. This way, any company thoroughly verifying its program code for brand new products is destined to lose the market initiative and face nearly insurmountable difficulties when bringing its product to the market.

Besides, reliability requires not only a significantly longer design period, but also additional financial resources. The cost of development of a reliable software product may be tens and hundreds times higher than the cost of a visibly identical application developed with the use of an accelerated process. The difference between the first and the second option may be reduced to a single occasion in a hundred or hundred thousand cases where a combination of circumstances would cause a potentially fatal road accident.

Another problem is the increasing number of messages on errors and vulnerabilities identified in the fleet of sold vehicles. Such events downgrade the difference between programs that were approved and not approved by the vehicle manufacturers. Chip tuning has become ever more popular. The audience accustomed to unrooting smartphones does not conceive the hazard of removing protection and using a third party code in onboard devices. Why does tampering with the braking or steering mechanics lead to prohibition of vehicle driving, whereas unauthorized change of the program controlling such systems entail no legal consequence?

In order to address this inconsistency, primarily in favor of the end users, and secondly for the interests of good-faith vehicle manufacturers it is necessary to develop and adopt tough measures, to ensure technical regulation in terms of securing evidence-based reliability and safety, as a minimum, of the critical part of the program code used in vehicles. The pilot version can be based on the standards ensuring the required level of lifecycle reliability used in aviation.

2.4.2. Use of IoT as a Means to Protect Market Positions

There is a sphere where automobile companies may gain a stable competitive edge. This includes the collection of data on operating modes and failures of vehicles necessary for the creation of reliable failure forecasting models. Such data will be required for the period of the transition from the vehicle operation based on its useful life to the operation based on the actual condition, i.e. from vehicle maintenance intervals a priori set by the manufacturer to replacement of worn-out vehicle components as needed. Those who own such data will secure a unique commercial proposal.

This technology is being actively introduced in aviation and in some other industries, where it helps saving up to 75% of maintenance costs [42].

The first players who understood the commercial importance of vehicle operation data acquisition were insurance companies. Failing to reach an agreement on their right to manage such data, insurance companies started rejecting the data collection and transfer services and introducing their own insurance related telematics services [43]. The vehicle manufacturers, using their dealer networks of warranty maintenance, have an economically sound opportunity to use the data accumulated and periodically read them as part of maintenance. There is also an opportunity to arrange wireless data transfer through the use of the "connected car" concept. Such transfers may be arranged on a time-controlled basis (transfer of accumulated data portions), and on an as needed basis (in case of component failure, or achieving threshold values used to forecast the threshold failure probability).

2.5. Upgrading of Product Lifecycle

The mechanical science progress is generally close to its end point; therefore innovations based solely on the development of mechanical structures will become less and less relevant. New opportunities should be looked for at the interface of technologies. Since the most stable exponential growth is observed in digital microelectronics, serving and relying on information technologies, the most positive business opportunities should be encountered in those innovative vehicle manufacturing spheres, which are most closely connected with information technologies. Therefore, the focus on information technologies should be assumed as the focal point, and the business strategies ensuring exponential growth, through the use of information technologies, should be assumed as the most promising role models.

At the same time, it should be reminded that in the near future of the next twenty years, design engineering and manufacturing of vehicle components will most probably become a routine process, and creative work will gravitate towards the development of programmable electronic systems used for the control of mechanical units.

This will necessitate a serious revision of the product lifecycle methodology in the automotive industry.

2.5.1. Introduction of New Business Models

Vehicle ownership is a coin with two sides, and the primary task of vehicle manufacturers will be learning to do business on both of them.

Over the next few years, vehicle manufacturers will see the most efficient sales of their vehicles on the emerging markets, where the first generation of vehicle owners prevails - those whose parents did not have a car. These are markets where the population is still excited about driving personal vehicles (e.g. China - the third market by scope of production).

The tendency will be the exact opposite in the countries with a steady tradition in vehicle owning, where people understand that a vehicle is not an object of luxury, but a means of transport [44]. People since their childhood are familiar with the issues associated with vehicle owning in a social environment overloaded with transport: the problem of finding a parking space, the need to buy a voucher for vehicle registration, fee for entering the city center, road and insurance rates, rising fuel prices, cost of vehicle repair.

2.5.2. New Market Opportunities of New Economic Era

According to the general understanding, which prevails in the computer information industry, the principal feature of transitioning from the post-industrial economy to the knowledge economy will be a transition from ownership to the rendering of services. The rapid development of the cloud services SAAS, PAAS, IAAS is the most vivid confirmation of this trend. The software giants have already found the gold mine and are actively tapping it: sales of services proved more profitable than sales of licenses to software products. Besides, such sales can be organized in a way ensuring a simultaneous reduction in consumer spending. Nothing illegal - the secret lies within the time-based shared use of resources, so that the same resources are alternatively released to those users who need them. Thus, if a consumer uses a vehicle just one hour a day - half an hour in the morning to get to work from home, and half an hour in the evening to get home from work - then during the other 23 hours per day the vehicle is not only useless, but also seems to be an analogue of a Tamagotchi demanding care and attention, e.g., payment for a parking lot.

According to the authors, similar market trends will develop in the automotive industry as well, placing the issue of a new business strategy to be faced by the vehicle manufacturers. They will either have to focus on supplies of vehicles ordered by the vehicle rental companies rapidly monopolizing the market, or start rendering the vehicle rental services. The first option will help to minimize risks at the initial stage, and the second option will improve the chances to win the strategic dominance.

2.5.3. Design

Evolution of Control Systems

The authors hold the view, that already in the first half of the 21st century, we will see the two fundamentally different stages of developing vehicle controls.

The distinctive feature of the **nearest stage** will be the appearance of vehicles with full or partial automatic control on public roads. The main focuses of the vehicle theory will then be the issues of autonomous control and integral optimization of vehicles being currently developed: designs and consumer properties; structures and elements of road infrastructure.

The target function of such optimization will require simultaneously satisfying conflicting and hard-to-align requirements of environmental friendliness, safety and comfort of vehicles, combined with minimized consumer expenditures, and enhanced profitability of design and production. Probably, the option best meeting this set of conflicting requirements will be commercial modular platforms featuring the basic vehicle modification, with advanced capabilities and conforming to the end user demands and forecasted operating conditions. Determining the user demands and forecasting the operating specifications, along with the unification of platform modules, may become the important aspects of the ground vehicles theory. Another key discipline will be safety studies requisite in the development of control algorithms for critical situations, including forecasting of personal injury and property damage rates for various accident scenarios.

A step change distinguishing the **next stage** of vehicle theory development will be the transition from the tasks of personal vehicle optimization to the tasks of collective traffic optimization. An option of the target function of such optimization can be the reduction of combined transport costs borne by the society as a whole, without compromising traffic safety and compliance with individual consumer demands. The research commissioned in this area is expected to provide the collective systems for synchronized control of traffic flows, algorithms for early prediction of safety hazards, methodologies for coordinated collective response to hazardous situations and maximizing the throughput capacity of highways. Since the development of the scientific thought in the field of autonomous vehicle control, it was from the start focused on the collective transport media optimization tasks, the difference between the two stages is likely to be expressed primarily by the degree of access of autonomous and human-controlled vehicles to public roads.

In order to secure the scientific and technical reserve for the above two stages of the current development of autonomous vehicles, firstly, it is necessary to develop a mathematical tool and technical systems of high-accuracy positioning and reliable prediction of vehicle position on the road. Most promising for ensuring the appropriate accuracy characteristics is the area of interconnected systems consisting of GNSS modules, inertial navigation systems, magnetic compass systems, kinematic navigation systems (KNS) and optical navigation systems. It is necessary to develop the methodologies for synthesizing evolution matrices, observation, management, covariance for Kalman filters to allow consolidating the flows of signals from such systems, subject to the varying accuracy characteristics, into a common navigation solution. The enhanced KNS accuracy will require the development of models simulating changes in the effective wheel rolling radius, and in the general case, tire deformation depending on the road profile and the wheel loading characteristics.

The requirement for a reliable medium-term prediction of future vehicle positions, is reduced to resolving a model task of intelligent control of possible connection of trajectories, with a mandatory consideration of special motion cases, associated with wheel sliding against the bearing surface and possible evolvement of lost-control effects. In order to determine the optimal trajectory and motion dynamics, it is necessary to build the models of fuel consumption and wear of vehicle mechanisms depending on the motion conditions and the bearing surface relief.

The solution to the above tasks mainly lies within the competence of mechanical engineers. Timely and consistent surveys in this area will allow not only to reduce the number of casualties and improve the economic efficiency of new generations of vehicles, but also to ensure the future market dominance by the vehicle manufacturers.

From Mechanical to Mechatronic Parts

One of the modern paradigms of designing prospective vehicles relies on the use of the mechatronics principles [42]. Among the mechatronic systems are thrust control, electronic directional stabilization, and active torque systems, various types of active suspensions, active lateral stabilizers, active steering, safety shield, hybrid-electric, fully electric vehicle transmission and others.

The mechatronics principles provide for replacing the complex, expensive and sensitive components of mechanical systems with reliable, inexpensive and flexible programmable electronic components. This tendency reflects the transition to brand-new designs of vehicle systems, ensuring compliance with ever more stringent requirements. For example, conventional and advanced mechatronic modules and systems may facilitate the integration of easily adaptable systems into vehicle design.

The mechanical part of vessel design tends to become simplified, and the programmable electronic and information part becomes more complex. The emergence of computer-aided design technologies means that sooner or later there will be a time when the development of vehicle mechanicals will no longer be a creative procedure and it will turn into routine process.

Vehicle manufacturers should understand this trend and take actions to use it in their interests, where one of the possible steps is the transfer of modular platforms to design engineering.

From Model Families to Modular Platforms

The key consequence of transfer to mechatronic systems is the opportunity to design vehicles based on sets of unified modules. This approach allows cutting-down the design cycle for new vehicles and the production cost through mass-scale production of modules at highly specialized facilities. The idea of an all-purpose modular platform is based on a well-developed platform with a standard set of basic modules (suspension, engine, interior, body, electrical), which can be freely combined so that millions of vehicles could be produced under hundreds of brands. As a result of the transfer to large-scale deployment of a modular paradigm, the world of vehicles is expected to change as dramatically as the world of computers had changed with the invention of the IBM PC platforms as a de-facto industrial standard.

Thus, Volkswagen has already started the production of Audi, SEAT, Skoda and Volkswagen vehicles based on modular platforms with transversely mounted engine (MQB). While so far the total number of orders for identical vehicle components was within some 5-6 millions, this figure may increase 5-10-fold for modular platforms. This will help to drastically reduce the cost of development of vehicle components per unit and further optimize the vehicle components.

For the vehicle manufacturers, the possible negative consequence of transfering to modular platforms is the threat of losing the vehicle brand identity. The mechanical design and mechanical capabilities of modular vehicles of the same class will be so close to each other that unbranded assemblers will be able to compete with the renowned brands. It is advisable to consider the options to mitigate this threat from the success stories of personal computer brands. For example, the traditional motives for buying a more expensive computer of a well-known producer are prestige, higher confidence in compatibility of components, quality and reliability of design, extended warranty, technical support, maintenance, ergonomics and additional software capabilities.

Based on the aspects discussed in section 2.5, the vehicle manufacturers should understand that modular platforms are "home ground" for IT companies. In the IT industry, modular platforms have been built for more than half a century - over this time, the immense experience of wins and losses has been accumulated in various business strategies associated with evolution of parallel, complementing and competing modular platforms. We will not dwell on these issues in our article and will only recommend that special attention should be paid to the story of interaction between IBM, Intel and Microsoft during the time of the invention of the IBM PC platform; the early stage of the evolution of the operating systems from CP/M © Digital Research up to OS/2 © IBM and Window NT/95 © Microsoft terminated by the transformation of the unknown company Microsoft into the leader of the IT industry; the reasons for success of the IBM PC XT/AT platform that exceeded all expectations, and the failed attempts to transfer to the IBM PS/2 platform. The experience on the sustainable evolution of programmable platforms gained by Microsoft, starting from the "parallel" platforms Window NT and Windows 95 for various market segments, and ending by the appearance of the totally universal platform Windows 10 with the default opportunities of transfer to cloud technologies, support of mobile computers and devices of IoT. It is impossible to leave unnoticed the successful experience of OS UNIX evolution with the use of the open-source methodology. It is also advisable to thoroughly analyze the efforts of DEC and Sun to create their technically relevant platforms Alpha and SPARC/Solaris that were completed by the acquisition of the companies promoting these platforms. Moreover, the entire history of DEC that created one of the first modular computer platforms to ensure the appearance of such advanced technologies as Ethernet, RISC and ARM used as the foundation for most contemporary computer systems, deserves the most careful review, especially at the final stage.

Modular Software Platforms

Comparable prospects in terms of modular design and unification open for the software parts of vehicle control systems. For unification of the suggested software solutions, it appears promising to explore the already known programming approaches applied to a new sphere of forward-looking real-time information systems:

- implementation of large-scale template;
- implementation of individual modules for connecting to various application systems;
- development of combinations of model algorithms for processing visualized data to solve middle-level tasks (more complex than identification of various image indications, but not requiring the use of feature of the target task).

The suggested approach to building software (SW) for information support of unmanned mobile devices has the following specific features. The software architecture ensures the possibility of cross-platform development based on all-purpose CPUs and quick transfer to specialized computer platforms through splitting SW into a set of interacting parallel subsystems. The specialization of the original framework for real-time computer vision is expanding as part of the architecture currently being developed for interaction with unmanned vehicle navigation subsystems. The above discussed approaches to building intelligent pilots allow promptly configuring information support systems for various mobile devices.

Optimization of the Entire Lifecycle

Currently, the vehicle manufacturers lose interest in the vehicle lifecycle properties immediately after sale, since consumers, when making a decision on a model, are basically unable to use any verified estimates of future lifecycle cost at the buying stage. The inevitable consequence of the replacement of a single-sale market paradigm with a paradigm of vehicle rental is the need to transfer from the optimization of commercial efficiency at the development, manufacturing and sales stages to coping with optimization tasks as part of the entire lifecycle of vehicles.

In the impending shared-economic future, the market situation will change, and the advertising and marketing practices of promoting new models will give place to the substantiation of choice based on a thorough and pragmatic calculation. The reason is that the vehicle manufacturers themselves, or large companies capable of optimizing their costs and dictating their will to the vehicle manufacturers will sooner or later become owners of shared cars. In the first case, the vehicle manufacturers will have to take into account their costs not only in the development, manufacturing, marketing and logistics, but also in further operation and maintenance cycles, together with indirect costs, for example, those associated with the level of potential damage in case of accident as a factor of vehicle safety performance. In the second case, after-sale costs will be taken into account by large-scale consumers who will be making decisions guided not only by the reputation of the vehicle manufacturer, but also by the convincing cost forecasts provided by the manufacturer. In any case, most popular in their consumer classes will be vehicles offering the minimum cost over the entire lifecycle.

As a result of such transformation financially critical will become such issues as reduced fuel consumption and extended lifecycle of consumable materials factored in a component useful life. The importance of such issues will be commensurate with the issues of production cost, as it will come to saving each dollar per unit of product. The practice of unjustified "just in case" increase of the frequency of maintenance and preventive replacement of components will be ousted. The relevant tasks will include implementing the "condition-based maintenance" principle already adopted in aviation based on the prediction of the residual useful life of components depending on the operating conditions and preventive efforts. As a result of the accumulation of statistical data and building of mathematical models with a sufficient level of reliability, there will be an opportunity to find the optimal solutions supported by the existing opportunities .

The initial direction in the scientific research exploring this topic may be determined with the use of the experience of financial leasing relations in aviation, for example, rendering the Sale & Leaseback (SLB) services, where the basic estimation principle requires the justified calculation of financial compensation for costs associated with bringing the vehicle to a state in which it was provided.

Client Oriented Optimization (Customization)

The authors expect that the next step after obtaining the opportunities to optimize the entire lifecycle will be the development of technologies for vehicle adaptation to local operating conditions or owner preferences. Thus, the consideration of the climatic factors no longer seems an innovation in vehicle construction. Production of a vehicle well suitable for operation both in Arctic and Sahara will inevitably require excess funds. Still, the vehicle manufacturers, lacking a priori information on the conditions of use of a specific model, have to provide a universal design with customization options.

There is an opportunity to materially limit the versatility of climatic and road modes of use of vehicles intended for the car sharing practice, which allows producing the series adapted to specific regions of operation.

If a vehicle is intended for individual use, this can mean catering a single vehicle for individual preferences, driving style specifics and region of driving. The initial data for individual customization may be obtained through saving and analyzing personal data of the monitoring system obtained for other vehicles.

In this case, an additional task in the development of the vehicle theory - falling outside the mechanical scope and nearing the psychological sphere - will be the issue of predicting consumer's behavior dynamics as a result of changes of the consumer properties of a new vehicle model.

Collective Control Optimization

The progress in the field of automatic route planning, including avoidance of jams, has created a new class of problems associated with knowingly ineffective results of individual or, as it is also called, egoistic route optimization. Egoistic optimization gave excellent results so far as it was used by few people, but after getting on a mass scale, the situation changed to the opposite. Jam sensitive routes mostly started to increase time spending.

The reason is quite simple. Just 10% of the vehicles on a highway are capable of forming long inescapable jams on adjacent minor roads, if the universal traffic analysis system gets notified of a jam on the highway and suggests similar options of bypass routes.

After the large-scale adoption of automatic vehicle control, the above described effect will become fatal, will cause irregular chaotic transport redistribution between various driving options, and eventually exacerbate traffic jams. This problem can be resolved by a transfer from egoistic individual to collective optimization. The goal of collective optimization will be the performance of a set of tasks with minimal combined costs, where costs mean the combined spending of all traffic participants: time, fuel, depreciation of components, safety hazards. Monetary evaluation can provide a uniform scale for summing up costs of various categories.

The initial models and algorithm for such optimization can be borrowed from the technologies of management of rail and air traffic. This will require joint efforts of all designers of vehicles, or this problem may be tackled by a single supplier in a given region.

Rapid Development of Vehicle Theory Focusing on Future Achievements of Information Technologies

Currently, diagnostics of vehicle systems require visual inspection, testing on special benches and testing of onboard digital systems, using programs of an external computer. The accomplishments of mechatronics show that the near future may bring about the opportunities to equip a vehicle so that no other monitoring means will be needed apart from self-diagnostics from the onboard computer. This target can only be reached when all lifecycle processes are simulated in mathematical models, starting from the quality of fuel combustion or power consumption, and interaction between suspension and external objects, and ending with the depreciation of tires and the aging of paint coating.

Borrowing Technologies from Aviation, Space Industry and IT Industry

The auto transport development area will include not only the adoption of specific technologies, but also the adaptation of technological solutions developed in other sectors of the transport complex, e.g. in the aviation and space industry. A summary of the results achieved in various fields where control systems are developed for targeted movement of autonomous vehicles may be reflected in the motto "Rigid generalization, smooth degradation and passive failure".

Rigid generalization means information presented at higher levels lacking some specific details. In the up-to-date systems based on artificial intelligence rigid generalization is more customary. As a result, the upper (semantic) level of presentation cannot precisely reflect low-level measurements.

Smooth degradation. The developed mechatronic systems have control systems that remain operative after several failures. This mode of operation gained currency in the development of the reusable space system Shuttle in the USA and was called "smooth degradation".

The term "passive failure" was suggested by Japanese scientists exploring the reliability theory. It means that in case of failure of a control system with smooth degradation, there is an opportunity to test the system unit by unit. In this case, a remote operator may try to replace the control monitor calling units in the required sequence. Following this motto in developing prospective vehicles allows achieving the desired results.

V-Model Based Lifecycle Methodology

Before a vehicle becomes a complete product it follows a specific sequence of lifecycle stages determined by the manufacturer. Modern vehicles are becoming increasingly sophisticated, which in turn increases probability of design errors. Most critical are errors arising at the initial stages of a lifecycle, and are extremely hard to identify with the variations of the waterfall lifecycle model.

In the 1980s, the V-Model was independently developed in Germany for the Ministry of Defense, and in the USA for satellite systems. The current version of the V-Model is VModel XT validated in February, 2005. The model is based on the fact that acceptance tests primarily rely on requirements, individual system testing - on requirements and architecture, comprehensive testing - on requirements, architecture and interfaces, and component testing - on requirements, architecture, interfaces and algorithms [45]. The V-Model helps to achieve the following goals:

- Minimization of risks;
- Improvement and assurance of quality;
- Reduction of the overall project cost;

- Improvement of the project participant coordination.

Model Based Design (MBD)

Model based design provides the technological basis for transfer to the V-model paradigm of product lifecycle and assures the enhanced quality at reduced development cost, including time and funds.

Essentially, the arrival at model based design implies a transfer from mechanical design engineering to data based engineering, or in other words a transfer from the postindustrial to the information age. The use of model based design becomes a key competitive factor for hardware producers. A correctly arranged process of model based design allows obtaining not only product descriptions suitable for replication without a pilot version, including programs for making such products on flexible automatic lines, but also to the opportunity for multiple use of knowledge necessary for exponential development, namely - a model description of systems to be designed. This reminds of the following example: in digital electronics, this was MBD along with automation that proved to be the key technology that ensured the exponential growth described in section 1.1.

The model based paradigm offers opportunities, unavailable when using the classic approach. It is sufficient to mention the thrust control, electronic directional stabilization, and active torque systems, various types of active suspensions, active lateral stabilizers, active steering, safety shield, hybrid-electric, fully electric vehicle transmission and others. All the above systems are essentially mechatronic. They operate in real time (with a guaranteed response period) and provide a guaranteed accuracy level in executing commands. Such systems may be characterized as fast-response systems - with quick adaptation and performance optimization exclusively through MBD.

Agile Development Methodology

The agile development methodologies were initially used solely for software development, and are designed to create the fundamentally new products without prototypes or a clear understanding of the target characteristics and useful properties of the deliverable.

The set of Manifesto for Agile Software Development principles includes:

- Individuals and interactions over processes and tools;
- Working software over comprehensive documentation;
- Customer collaboration over contract negotiation;
- Responding to change over following a plan.

As an additional principle there is a stipulation about flexibility of processes as such "while there is value in the items on the right, we value the items on the left more" [46]. The agile development concept drastically differs from the standard approaches to system based engineering and project management, for instance from what is described as lifecycle stages in the standard ISO/IEC 15288:2002. Agile development promises the most valuable results in research studies, especially those based on loose task setting ("go wherever, bring whatever") and uncertain result through lack of its understanding at the initial stages of research.

In many cases, software development teams, using this concept, obtain more efficient results over a shorter period of time. This is why the vehicle manufacturers intending to follow the new pace of technological progress are expected to know, understand and be able to use the agile development methodologies, such as Scrum, XP, DSDM, FDD, etc. But, most importantly, it is vital to understand the applicability and limitation of such approaches, and be able to select the most adequate one that will secure an efficient result.

2.5.4. Production

In the foreseeable future, technologically feasible and cost-effective will be considered the rejection of the classical model of mass production car, and the transition to the production of an individual product on a new technological base. The opportunity to create vehicles with sets of unified modules will help shorten the design cycle for new vehicles and reduce the prime cost through large-scale production of modules at highly specialized facilities located near consumption centers. Final assembly companies with production scope of 5-10 vehicles per year will cover the needs of a relatively small region. This, in turn, will highlight the role of mini-plants located in close proximity from consumers and operating similarly to computer firms providing "Complete Knock Down" computer assembly services under individual orders.

Individual assembly of vehicles will depend on the financial capabilities of the customer and product performance requirements. For vehicles designed for rent, customization will be confined to performance optimization according to the customer usage specifics and preferences existing in the region.

2.5.5. Marketing

The Use of 'Car Renting' Desire

As soon as automatically controlled vehicles appear on public roads, the market situation in the vehicle rental area [1.4.1] will change dramatically. Namely, the difference between renting a manned and unmanned vehicle will disappear. More simply, it will eliminate the difference between the car sharing service and a taxi ride. The new key feature of shared vehicles - return to the place of current demand - will allow addressing the gap in this technology and efficiently implement these opportunities in the new multi-mode environment of passenger carriage, combining speed, accessibility and throughput capacity of public transport with the comfort of a personal vehicle. A two-level configuration may be used in such environment, where high-speed public transport will commute between hubs, and the car sharing service will be used for the delivery from hubs to destination points.

Once the aggregate prime cost of such services becomes lower than the cost of driving a personal vehicle, the era of urban demand for personal vehicles will start coming to its end. This process may be fast and irreversible, and the vehicle manufacturers proclaiming their power may be left with nothing.

Mitigating the Popularity Loss of Personal Vehicle

After the automotive industry is reoriented from selling to renting vehicles, there will be three market segments where the demand for vehicles will remain. Firstly, there is the above mentioned market of the first wave of vehicle owners, secondly, markets in regions with a critically low population density (e.g. rural areas), and third, the relatively small but quite solvent market of luxury connoisseurs.

The situation on the markets of the first and second types will basically be similar to the existing market situation; this is why we will pay closer attention to the third market segment. Here, primarily the automobile concerns can borrow certain marketing "secrets" from the fashion industry. One of the main ways of promoting the luxury market is the use of varieties of the "You deserve it" marketing slogan, through the assurance of the unique nature of a product and frequent change of its version (models), thus offering broader opportunities to choose models subject to individual requirements.

Along with the individualization, a vehicle progressively turns into a part of personal living space, where a person wants both safety and comfort. The consumer arrives at a so called comfort zone with his or her personal unique vehicle, which becomes a replica of the house.

In order to meet the person's need to distinguish him/her from others, a vehicle should provide an increasing number of possible variations and methods of individualization. Among such attributes are the development and perfection of extreme comfort technologies, up to borrowing the traditionally haute couture features: contour chairs, unique wheels, pedals, arms, buttons and keys designed to meet the individual characteristics of a person.

The fashion industry has for a long time and successfully deployed a monetization technology to quick changes of trends. Unsatisfied with the two seasons: autumn-winter and spring-summer, many upscale fashion brands have long switched to four seasons by adding pre-fall and cruise collections, released during the quiet fashion periods. Another example is the multiple achievements of Apple in creating a speculative demand by changing its iPhone platforms. Similarly, a quick change of design trends in vehicle construction will help boost sales through a reduction in the average period of vehicle owning.

Vehicle decoration can step beyond the interior; the slogan "buy a new dress for your car" ,promoting tuning, will convince demanding consumers of the need to pay more. This will be the same vehicle, but in a new cover, new "dress", so that over the average period of owning a statement car (3-5 years), its configuration can be changed once every half a year or year.

Very probably, in the near future we will witness built-in dynamic systems for monitoring the critical health parameters of the driver. Together with the psychological profile of the driver stored in the computer memory, this will enable the vehicle to give advice to the driver, like a friend, psychotherapist or therapist, for starters - regarding the optimal choice of the driving manner based on the driver's psycho-emotional condition. In the case of autonomous vehicles, such humanization will provide the opportunity to automatically select the most comfortable driving mode guessing the owner's mood. This level of humanization will entail the personalization of a vehicle and the formation of a personal attachment to the vehicle, as a pet, or even as a friend.

2.6. Specialist training

The high rates of knowledge aging, dictate the need for a regular and systematic update of the knowledge required for the qualification of a specialist. In the developed countries, the change of technology and hardware generations is accelerating, but due to a longer life span, the process of physical replacement of specialists slows down. The possible solution to this discrepancy is the adoption of regular upgrading cycles with assumption of new competences, or transfer to the continuous remote on-demand education concept. For example, an engineer, who receives a new task, spends from 1 to 4 training hours every day to upgrade his or her competence in the knowledge area relevant to the current work. From the educational point of view, the residual working hours of the engineer may be referred to "hands-on training".

Conclusions

This article provides a systemic analysis of the image of the future and offers certain actions, necessary to preserve the market positions of companies, operating in the automotive industry, during the transfer from the post-industrial economy to the knowledge economy.

Understanding the inevitable changes, the acceptance of their objective nature, the sound forecasting of the development of socioeconomic relations and technologies, the systemic approach to risk management, will allow avoiding the chain of industrial crises typical for any revolution and entailing losses and bankruptcies, as well as replacing the revolution prospect with a consistent evolutionary process.

The authors make no claims as to the sufficiency of the actions discussed in the article; however, even the highlighted set of measures are proved to be critically complex and inaccessible for any, even major, vehicle companies. In this regard, it would be relevant to consider implementing industrial arrangements for the coordination of the activities of the industry participants within the framework of agreed goals and plans.

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Contact information

Victor Osipkov
11@laserart.su

Dr. Tatiana I. Ksenevich
taxen@mail.ru

Prof. Boris Belousov
belousovbn@yandex.ru

Prof. Sergei Sokolov
sokolsm@list.ru

Dr. Oleg Karasev
k-o-i@yandex.ru

Dr. Mykola Rudinetc
rudinetc@mail.ru

Dr. Mykola Skalyga
cnn1101@mail.ru

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Abbreviations

AI - artificial intelligence

PC - personal computers

LAN - integrated in local area networks

NOx - nitrogen oxide

ADAS - advanced driver assistance systems

CPG - consumer packaged goods

MGTS - Moscow based fixed line telephony service provider SW software

MBD - model based design

IoT - Internet of Things

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