Changing the Maintenance and Repair System While Expanding the Connected Vehicles Fleet

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Abstract: Autonomous vehicles have become a logical outcome of the realization to Intelligent Transport Systems direction as a system strategy. The article analyses the directions of road vehicles intellectualization. The problems and ways to improve the safety, reliability and sustainability of transport systems are indicated. It is shown that to control the connected vehicles reliability it is necessary to improve the branded systems of maintenance and repair. This is realized through the improvement of on-board diagnostic systems. The use of sensors that read data on the vehicle's state, its routes and external factors affecting reliability ensure the adequacy and quality of the source information. Using a single information space for generating operational databases as well as a defect codifier for generating failure statistics and their multidimensional analysis will allow us to determine the service strategy and also carry out its adjustment if necessary when changing the failure statistics.

1 INTRODUCTION

The modern cities problem, which is aggravated as they grow, is the transport system, that in many cases, due to its inefficiency, creates a lot of problems, ranging from environmental ones, to difficulties in mobility. Lack of parking space, traffic jams and congestion, problems of economic and infrastructural development of remote areas - these are the consequences of transport system's irrational development that need to be addressed. The road transport development strengthens these problems. According to analysts, Autonomous Vehicles (AV) can solve many of these problems. At the same time, the main trends in improving the transport system efficiency are aimed, firstly, at changing the transportation process, and secondly, at reducing the urban space occupied by vehicles (including the road network and parking lots). This is facilitated by a shift from the model of personal vehicle ownership to a more efficient model of its sharing, which will reduce both the need for parking spaces and traffic, especially during rush hours, since such a model involves using a joint car for regular trips, for example, to work or study. It will also create opportunities for more equable development of urban space, because it will expand the available options for transit to areas that are currently inaccessible.

Automakers are investing in the creation of intelligent and energy-efficient vehicles, because in the face of fierce competition, they are interested in implementing reasonable and effective mobility options. At the same time, both ownership options and the possibilities of structural changes are analyzed, however, as practice shows, consumers are not yet ready to completely trust highly automated vehicles. Numerous studies are devoted to the

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operating autonomous vehicles' problems: the advantages, prospects and features of the transportation process organization. However, almost practically neither of the authors has been the focus to the reliability issues of both the vehicle itself and electronic control systems, although it is known that even small changes in the design entail a number of problems associated with ensuring their trouble-free operation. The branded service system (BSS) is a complex organizational and technical system that is tuned to certain technological processes and, apparently, a change in the paradigm of transport process organizing and a person role decrease in it through the expansion of the unmanned vehicles fleet will require a change in the BSS paradigm. At the same time, a whole series of issues should be resolved both in the technical and organizational plan, as well as in the socio-economic one.

Given that while autonomous vehicles have not conquered the market and potential customers think only about issues of trust in them from the point of view of the transportation process safety, soon enough questions of maintaining operability and warranty will come to the fore. Of particular importance to the customer when buying a vehicle is the issue of providing a guarantee. The new product success depends on both engineering solutions (product reliability) and marketing policy (price, guarantees). Warranty service costs depend on the product reliability, in turn, the manufacturer can expand the warranty if he is confident in the his products reliability. Thus, the issues of reliability, prices and guarantees should be considered together (Byuvol, P.A. et al. 2017). With the expansion of the autonomous vehicles fleet, the question of joint ownership of them will inevitably arise. In this case, the issue of the vehicle technical condition control will become more complicated, which will also have to be addressed through the BSS.

Considering questions about the warranty period cost and duration, the authors of scientific and practical studies note that all models should use information about failures in the warranty period, as well as the fact that the information quality affects to adequacy of decisions depends (Lee SangHyun et al. 2008, Lee SangHyun et al. 2009, Last M.et al. 2010, Xie W., Liao H. & Zhu X. 2014). Since the failures causes can be due by various factors that are heterogeneous and stochastic, it is necessary to have a tool for processing large data amounts, that can be, inter alia, textual (Buddhakulsomsiri J. et al. 2006). For forecasting, various data mining methods are used, including neural network algorithms (Shubenkova, K. et al. 2018).

The article analyzes the reasons for the ambiguous attitude of consumers to autonomous vehicles, the advantages and prospects of this transport systems development direction, especially in the context of the resource conservation paradigm, the 4th Industrial Revolution and Smart City. Thus, the article will consider the concept of an updated BSS, methods and the possibility of their application within the proposed concept framework.

2 PROBLEM STATUS: AUTONOMOUS VEHICLES, PLUSES AND MINUSES

Autonomous vehicles are becoming a promising technology for improving urban mobility while saving space and energy in urban areas. But it should be borne in mind that the positive external effects that are necessary for their non-deployment are not sufficient. Highly automated vehicles are more economical, require less room for manoeuvres and parking, however, all these advantages can only appear if their share in the fleet is significant (Fig.1).

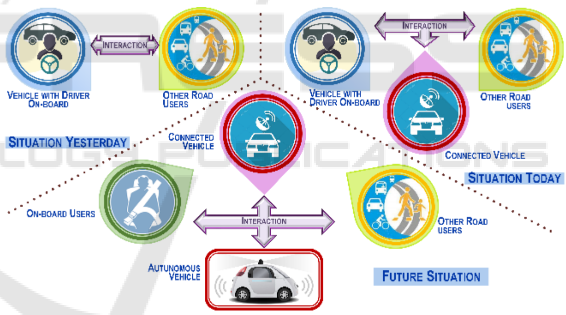

Figure 1: Modification the road user’s interaction with the connected vehicles’ development.

2.1 Connected Vehicles Contribution to Urban Sustainability

The document (Berrada, J. et al. 2017) goal is to describe and classify existing core business models, and then apply them in the autonomous vehicles field. The authors created a rating system using six identified factors that influence value creation, and then evaluated nine business models based on these factors. As a result, the authors found that hybridization of two or more business models is possible. For example, the widespread deployment of private autonomous vehicles may limit the benefits of using shared autonomous vehicles in the same area. The hybridization method would allow taking advantage of each form of the business model and lead to an increase in the service quality.

According to Gartner, Inc. (Gartner Forecasts…2019), by 2023, the increase in the vehicles production which have equipment that could provide autonomous driving without human supervision will reach 745,705 units compared to 332,932 units in 2019. This growth will mainly be observed in the countries of North America, Greater China and Western Europe, as the countries of these regions will be the first to introduce rules regarding autonomous driving technologies. The main obstacle to the autonomous vehicles development and production is the fact that today there are no countries with existing regulations that allow their legal operation. According to analysts, companies will not deploy autonomous vehicles until it becomes clear that they can operate legally without human control, as vehicle manufacturers are responsible for the vehicle actions of the during its life cycle. According to Sean Behr, cofounder and CEO of the company Stratim, which controls more than 10,000 cars and vans from 50 customers, including BMW, Ford and General Motors, by the decade end will begin to shift in the public mind, as the motorization level will decrease due to an increase in the volume of joint transportation services, which will be, at least partially, autonomous.

For corporate fleets, however, the need for preventative maintenance and emergency vehicles repairs will remain unchanged. Peter Smith, that is vice president of vehicle services, Business & Industry, to indicates that ABM currently provides a variety of rental car maintenance services, including fluid inspection, tire inspection, interior and exterior cleaning, and shuttle services vehicles - to ensure a turnover between rentals - for car rental companies. However, he raises the question that, given the existing infrastructure based on oil changes and spark plugs, fleet owners will need to restructure their business to keep their unmanned electric vehicles in good condition and make a profit. According to him, night truck parking should be equipped with charging stations, and maintenance compartments can become high-tech canopies equipped with advanced telemetry systems and serviced by technical specialists. The onboard systems on each truck will report ongoing maintenance and more complex problems. Upon arrival of the truck at the service point, the technician will be able to find and fix the problem. The reality is that while automation will increasingly contribute to increasing the productivity and usefulness of autonomous vehicles, these processes will still require milestones, and people will always play a strategic role in organizing maintenance and operation.

The rapid progress in autonomous driving technology raises the question of suitable operating models for future autonomous vehicles. The key factor determining the viability of such operating models is the competitiveness of their cost structure, for example, due to the development of public transport and car sharing systems, but, as shown in the article (Bösch P.M. et al., 2018), this is effective only in case of increased demand for certain types of transportation.

To prove the new vehicles types competitiveness, the study (Loeb B. & Kockelman K.M. 2019) authors simulated a fleet of shared autonomous electric vehicles serving the requests of 41,242 agents in the Austin, Texas network to determine which fleet scenarios are most beneficial for the operator and users. The study provides detailed cost estimates of the shared autonomous electric vehicles (SAEV) fleet, including the costs of purchasing vehicles, maintenance, batteries, electricity, building charging stations (including land and paving), servicing charging stations, insurance, registration, and general administrative expenses. In addition, strategies to reduce load factors are critical to the viability of this fleet, and they must be modelled to determine their impact on vehicle costs and effectiveness.

As McKinsey's analysts point out, the automotive industry is rapidly turning into a real mobile ecosystem. Connected vehicles can become powerful information platforms that not only improve driver capabilities, but also open up new opportunities for business to value creation (The future of… 2019). At the same time, the basic logic of autonomous driving, especially in cities, will remain unchanged. Shared electric robo-taxis or shuttles can eliminate mobility pain points in cities (for example, traffic jams, crowded parking spaces and pollution), while improving urban mobility, increasing its accessibility, efficiency, convenience for users, environmental friendliness and inclusiveness. With untrammelled integration into the public transport system, this type of transport will become an important factor contributing to the reduction in the current share of transportation by private cars (Change vehicles…, 2019)

2.2 Connected Vehicles and the Service System Role in Expanding Their Fleet

2.2.1 Forecasts of Maintenance and Repair Costs

According to the vehicle service activities' analysis, one of the factors for increasing maintenance costs in

2018 was the increase in prices for spare parts, in particular for the brake and calliper, due to an increase in the number of models equipped with larger diameter tires. Continuous improvement in the vehicles quality, which occurs every model year, contributes to the decrease in the need for complex overhauls, which leads to a maintenance costs reduction. In addition, component reliability is enhanced, which in turn reduces repair costs, helping to offset the continued increase in labour costs and high spare part prices. One of the negative consequences of improving the vehicles reliability is the temptation to extend their service life, which is caused, inter alia, by a decrease in the catastrophic failures frequency of vehicles with high mileage. The vehicles utilization rate can also be increased due to increased reliability. However, as vehicles become more complex, the failures prediction also becomes more complicated, and as a result, vehicles repairs are mainly "in fact" (in case of malfunctions). Although the technological innovations introduced in modern vehicles are very reliable, in the malfunction new component event they are very expensive to repair. This can lead to certain repair costs, for example, on-board diagnostics systems and electronics (in particular, infotainment systems).

A growing number of vehicles are equipped with Advanced driver-assistance systems (ADAS), which have function such as collision avoidance, visibility, lane departure warning, adaptive cruise control, pedestrian protection and blind spot monitoring. While the ADAS advantages outweigh any disadvantages, these are trade-offs that come with high acquisition costs and new maintenance processes.

There are many ADAS types, some of which are built into vehicles, while others are available as the add-on package part. ADAS uses input from several data sources, including vehicle's images, LIDAR, radars, image processing, computer vision and vehicles networks. ADAS systems require specialized equipment and specially trained personnel. Many repairs, which were previously simple, now require ADAS system calibration, which consists of cameras, sensors and controllers, which requires specialized and expensive tools and equipment.

On the other hand, OEMs have improved a number of vehicles, which helped lower costs on vehicles. Examples include built-in diagnostic displays that change the driver behaviour, and diagnostic trouble codes (DTCs) that expand the dealer's ability to more quickly identify maintenance issues. One example of a newer technology that reduces maintenance and repair (M & R) costs is electronic steering, which is more reliable than mechanical hydraulic assistance. Another example of lower maintenance costs due to higher quality components is that brake pad life is extended. As autonomous vehicles become available, maintenance processes, such as replacing tires and oil, and monitoring the braking system, will become more predictable as they will be independent of driver reaction. This will shift costs from using cheaper service / repair providers to using OEM dealerships. Autonomous vehicles also increase the forecasting accuracy the need for maintenance, which will allow for preventive maintenance.

The autonomous vehicle industry is seen by many vehicle manufacturers such as Waymo, Tesla, GM, Ford, Mercedes-Benz, Volvo and many others as revolutionary, while the leadership pursuit in this direction and rapid technological progress in the automotive industry will lead to increased need for more perfect digital skills. According to current forecasts and predictions, by 2021 there will be level 4 autonomous vehicles. Level 5 vehicles are expected to appear by 2030. Politicians who are confident that autonomous vehicles will appear in the near future are already adopting new legislation and government regulations. However, for vehicle services' owners and auto mechanics, the idea of what the new autonomous landscape means is less well known. (The Self-Driving…, 2019).

2.2.2 Mobility-as-a-Service (MaaS), Personnel and Maintenance Requirements

Contrary to the prevailing opinion that autonomous vehicles will reduce the need for the auto mechanics activity, according to experts, automated technologies will create new jobs, which will lead to a demand for continuous training for service technicians. Autonomous vehicles, with the as artificial intelligence (AI) develops, accompanied by machine learning improvement and the advent of many mandatory additional sensors, will require wider diagnostic capabilities. It is expected that future servicing specialists to autonomous vehicle will require advanced degrees to bridge possible skill gaps, which will be implemented, including in a continuing education system.

In order to adapt to new technologies implemented both in autonomous vehicles and in service equipment, the need for maintenance of software and electrical components will increase, but at the same time, traditional automotive systems will also need constant maintenance, which will require skills and experience of highly qualified technical specialists. It should be borne in mind that changing the vehicles fleet structure will lead to a shift in the service processes structure. For example, advanced computerization will help to reduce the number of collisions and traffic accidents associated with a driver's error, which can lead to a decrease in the need for body repair. At the same time, more emphasis will be placed on software programming and data management. Big data and forecasting technology will also play a role in how maintenance personnel will service and repair autonomous vehicles.

Automated vehicles are complete platforms, therefore, for data management and predictive maintenance, it is necessary to create an ecosystem in which service management will be implemented. It is planned that vehicles as a service will play an important role in the ever-growing economy of car sharing, and in this regard, many vehicle components, including infotainment applications such as platforms for connected applications and services, will be oriented towards this new request to "rent on demand". The goal of such integrated consumer systems will be to ensure the passenger personalization and his greater convenience. Obviously, a further increase in the intensity of such services use will require ongoing maintenance.

Analysts predict that vehicle maintenance costs will continue to rise, mainly due to higher labour rates. As the functionality develops and the dependence of the vehicle's performance on electronics and software grows, independent service providers have increased requirements for technician competencies. A modern auto mechanic should develop with the rapid development of the industry, and possess knowledge not only of the simple mechanical and hydraulic vehicle's systems, but also be an electrical engineer, which was facilitated by the OBD (on-board diagnostics) systems appearance. Computerization has introduced many new disciplines that auto mechanics need to learn, such as fuel types and systems, electrical circuits, and troubleshooting computers. The OBD II system advent created a new industry standard, according to which auto mechanics had to be certified in electrical systems for the M&R of modern vehicle components.

Now, auto mechanics need extensive training in repairing autonomous vehicles that will be equipped with much more powerful and sophisticated on-board diagnostic tools than OBD II to accurately troubleshoot and predict component replacement or repair. Between dealerships, independent service providers and fleets that themselves perform maintenance of their own vehicles fleet, intense competition for qualified specialists is ongoing. In view of the new technologies introduction, it is necessary to invest heavily in equipment for diagnosing and eliminating malfunctions using data from the on-board vehicle's computers. In addition, the increased vehicle's complexity requires hiring technicians with higher technical skills, who usually get higher salaries. Demand for these technicians exceeds labour supply. This problem is exacerbated by the smaller number of young technicians who are replacing senior qualified specialists older age, which requires higher wages to attract new talents.

2.2.3 Faults Diagnostics and Processes Organization in the Auto Service

Despite technological advances, autonomous vehicles are still vehicles, each component of which, mechanical or electric, has a limited life cycle. Therefore, the greater the mileage of an autonomous vehicle, the more wear and tear. The higher the degree of difficulty, the higher the risk of technical problems. Until the autonomous vehicles fleet becomes sufficient to obtain large statistical data sets about all failures kinds, there is a significant error probability. This can cause a significant demand for qualified vehicle service specialists, as well as vehicle service system instability.

Vehicle Health Management (VHM) often includes real-time monitoring of operating conditions, as well as decision-making on driving, operating, and maintenance based on anticipated conditions. The article (Jaw L. and Wang W. 2004) presents a universal, flexible integration and testing concept for checking / evaluating control, as well as workability management capabilities, which provide the necessary environment for evaluating effectiveness, including the accuracy of decision-making, algorithms and models for managing workability status in real time and in closed cycle.

Diagnosing faults in automotive systems is critical as it affects repair and maintenance times. One common approach is to use a fault tree diagram. But taking into account the implicit system's structure, the authors of (James A.T., Gandhi O.P. & Deshmukh S.G. 2018) proposed an approach with an explicitly included built-in structure by means of digraph modelling, which uses the graph theory's system approach. The proposed approach contains recommendations for diagnosing the malfunction root causes. The fault tree obtained from the developed digraph system is suitable for computer processing. Therefore, this methodology can be automated to diagnose vehicle malfunctions. The methodology computerization will help in creating a knowledge base about failures, their causes and remedies. Therefore, this approach is especially useful for M & R engineers.

M & R of modern vehicles today is a difficult task, since various causes of failures lead to similar symptoms in very complex vehicles. Existing fault diagnosis processes, based on failure's maintenance manuals to manufacturer standard and personnel experience, are often inadequate and lead to great effort and erroneous solutions. So, the article (Meckel S. et al., 2019) presents methods for extracting knowledge from unstructured and informal materials on online forums with the aim of synthesizing diagnostic graphs from the created knowledge base, which are software part for use in vehicle maintenance, offering more efficient and targeted diagnostic actions and real-time service.

The article (Borucka A. 2019) presents a wear analysis of brake system components using vehicles annual monitoring under various operating conditions as an example. The goal was to study the significance of the selected factors influence on the brakes wear degree, as well as to present possible methods that will be used in this area. This will provide not only a higher safety level, but also more efficient task planning and the necessary expenses inclusion in the company's budget.

The maintenance strategy is keep to in order to ensure consistently high service quality, operability and safe operation of the transport system, which requires an appropriate schedule for vehicle maintenance. As shown in (Kamlu S. & Laxmi V. 2019), maintenance, which based condition, identifies the vehicle condition using either wired or wireless data to failure predicts and implementation appropriate maintenance actions, such as repairs and replacements, before failure happens. In this paper, a Condition-based maintenance (CBM) strategy was proposed that takes into account various uncertainties, such as load, mileage and terrain, to develop a fuzzy model for individual vehicles. Hidden Markov models (HMM) can combine all available prior knowledge in a Bayesian formulation and, thanks to their Markovian structure, provide the development of computationally complex signal processing algorithms.

Improving the vehicle's operation efficiency is the main goal of the diesel engines M & R system, in particular, by reducing the cost of engines maintenance and overhaul, which are the most expensive vehicle system (up to 25%). The article (Biniyazov A. M. et al., 2019) authors study the patterns of the oil volume influence in the diesel crankcase on the intensity of changes in the engine technical condition and the oil aging during operation.

The report (Sharma S., 2018) presents a methodological study on the changes analysis in the lubrication system of various medium-speed engines. In addition, this study includes an analysis of the engine oil pressure effect on friction losses, torque study at various oil pressure values, and an analytical analysis engine lubrication system functioning. Diagnostic data collected from various engines was used as a reliable source for detecting and troubleshooting a lubrication system in an ordinary passenger vehicle.

The study (Börger A., Alfaro J., León P. 2019) goal is to reduce the time required for trucks maintenance. The authors indicate that due to inadequate management and improperly performed maintenance work, their repair time is increased. This work is aimed at improving the terms of repair of trucks using the Lean methodology - a management system whose main task is to eliminate all waste in servise, which reduces time to ensure greater customer satisfaction, improve quality and reduce costs.

The article (Vintr S Z. and Holub R. 2003) discusses the optimizing the maintenance concept method, which allows to reduce the vehicle life cycle costs (LCC) based on operational reliability data knowledge. The authors present a theoretical optimization model that describes the main relationships between LCC of the main vehicle subsystems and the frequency of their scheduled (preventive) repairs. The authors indicate that using the proposed model, it is relatively easy to find reserves in the vehicle maintenance concept and achieve significant savings in the vehicle LCC using a simple measure of administrative change in maintenance periods.

2.2.4 On-board Diagnostic Systems as a Means of Working with Data

Depending on the vehicle driving automation level, the on-board intelligent systems functions set also differs, which, as a rule, includes means to inform the driver, help in difficult situations, to communicate with dispatcher and service operators, as well as to the vehicle condition's identify. So, the article (Nugroho S.A. et al., 2018) authors cite the Car Data Recorder Prototype (CDRP) system, which is able to improve the accuracy of traffic accidents investigation, as it can record the vehicles condition and report an accident by sending a notification in the SMS form using the GSM module. The authors propose the on-board diagnostics-II (OBD-II) function with the parameters recording: the gas pedal position, the engine shaft speed and engine temperature in the specified time range. The article (Datta S. K., Härri J. and Bonnet C. 2018) discusses the importance of future autonomous vehicles geo-temporal awareness: describes the IoT platform for accurate positioning in highly automated driving (HAD), which combines IoT with joint technologies, protocols and ITS algorithms to achieve high-precision localization for future autonomous vehicles. The document (Aljaafreh J A. et al. 2011) presents a vehicle data collection and analysis system for automating fleet management using on-board diagnostics (OBD), GPS, RFID and WiFi technologies, which are successfully integrated to develop this system. The system integrated in the vehicle determines the vehicle location using the GPS receiver, and the vehicle status using the OBD interface, and driver identifies by RFID.

The article (Godavarty S., Broyles S. and Parten M. 2000) describes an approach to developing an online diagnostic system using readily available computing resources, such as laptop computers. You can access this information through the PC interface and some software, which is easier than directly from the modern vehicles' on-board diagnostics systems (OBD II). Online diagnostics can accelerate the new technologies development cycle, such as fuel cell vehicles, as well as provide user support and optimize the such vehicles performance by reducing downtime. However therein, the main problem is the measurement dispersion, caused by numerous interference factors that make it difficult to compare the vehicles behaviour in real conditions with their predetermined reference analogues. The article (Nitsche C., Schroedl S. and Weiss W. 2004) describes an approach in which artificial neural networks are used to facilitate the on-board diagnostics of fuel cell vehicles. The authors believe that this method can be used to diagnose short-term failures / errors, as well as long-term shift in the vehicle power transmission's properties, for example, in accordance with the deterioration of the fuel cells state.

The article (Niazi M. A. K. et al. 2013) describes the development of a universal OBD device and its work with various vehicles based on OBD-TT standards, such as Land Rover Defender. This device displays real-time vehicle system status, including vehicle speed, engine speed, throttle position, battery voltage, engine coolant temperature, etc., as well as diagnostic trouble codes (DTCs) for various vehicles. The DTC from the vehicle microprocessor is generated as a result of a system error or failure.

The document (Lin C. E et.al.,2007) presents a modified system design based on vehicle monitoring technology to present OBD data in real time. The system proposed by the authors combines application development technology for both OBD and Intelligent Transport Systems (ITS) and can meet future vehicle requirements for real-time ITS and ODB applications, and also uses GPRS mobile communications for real-time data transition over the internet.

The article (Wang Y. et al., 2016) authors, in order to reduce vehicle exhaust emissions when using a system with a selective urea catalyst, developed integrated methods for on-board diagnostics and fault-tolerant monitoring. The article presents a method for detecting and troubleshooting a urea injection system using data processing and their validation in the selective catalyst reduction (SCR) system developed by the authors. The article (Hu J. et al., 2011) introduces the vehicle diagnostics methods and the on-board diagnostic system (OBD), compares and analyses several types of diagnostic protocols that are widely used in the OBD system. Compared to manual diagnostic devices, this is a faster diagnostic method that provides powerful help and repair instructions. In addition, the system can be upgraded for more convenient use and expansion of remote diagnostics.

The article (Bostelman R. and Shackleford W. 2010) presents the National Institute of Standards and Technology (NIST) diagnostic tool and its application in NIST automated guided vehicle (AGV), which, according to the authors, is very useful for understanding the vehicle functionality. The manufacturer of AGV can benefit from this tool for design, adjust, and monitor vehicle parameters and control algorithms to enable robust autonomous vehicle control. The article (Zhang J., Yao H. and Rizzoni G. 2017) authors developed a systematic model diagnostic approach based on a structural analysis of electric drive systems, which can serve as the basis for the on-board diagnostics systems for electric vehicles design. Remote technical condition monitoring includes the use of V2I systems for the formation and application of individual M & R systems. The V2I information model developed in (Gritsuk I. et al., 2018) is characterized by the vehicle digital field, limited by regulatory rules, means of monitoring the technical condition parameters and infrastructure components for monitoring each vehicle. The system is based on a general approach to the system study “Vehicle - Driver - Operating Conditions - Vehicle Operation Infrastructure”.

The article (Luka J. and Stubhan F. 1999) authors indicate that the increase in the mechatronic systems use in vehicles requires the diagnostic functions integration, which will be widely implemented in the vehicle on-board software and will allow to improve the diagnostic depth in the future, since they will be based on functional and mathematical models. The data obtained from the diagnostic functions describe the vehicle general condition and are stored in non-volatile memory. The main information source can serve as customer complaints that can be received through the voice channel. Data about the vehicle, as well as information from the driver, are compared with failures that arose earlier in other vehicles. Mobile diagnostics will optimize the diagnosis and repair process, especially in the vehicle emergency event away from the workshop.

3 RESULTS AND DISCUSSION

3.1 The Single Information Space Concept When Creating Infrastructure for Expanding the Autonomous Vehicles Fleet

During the transition to the fourth industrial revolution, cyber-physical systems are formed which connect, through informational interaction, subsystems with different purposes, sizes and properties. So, the connection between the production system and BSS is carried out at the level of material flows using the logistic system, and at the information level - by creating a single information space.

Today, the automobile plants products annually are complicated not only constructively, which leads to the need to improve the service and repair technology, but also intelligently, which is expressed in the emergence of new systems built into the vehicle. These are systems responsible for management, security, and the interface with various services and other entities. Changing the concept of the transportation process and the vehicle operation require careful preparation and adequate processes management in BSS network. In this regard, changes are inevitable in all systems related to the vehicles life cycle: production, logistics and service. The BSS concept will change because the manufacturer needs to qualitatively implement the principle of responsibility for his product throughout the entire life cycle (Embracing Industry 4.0. 2019.), and this is possible only with appropriate control over the processes in all systems, especially at the initial stage AV launching on the market.

As follows from the analysis of consumer opinions and analysts' forecasts, apparently, first of all, the concept of using autonomous vehicles will be implemented in freight logistics. It should be understood that modern trucks, unlike cars, are almost impossible to service in small auto repair shops. Another feature that analysts talk about is the fact that possible maintenance errors can be associated with a lack of reliable information about failures and their causes, which should accumulate as the autonomous vehicles fleet expands. Therefore, its BSS will be a place of collection and storage of information about the features of operation, maintenance and repair of both a particular vehicle and the entire fleet (Fig. 2).

Given that despite the additional control and other intelligent components, the vehicle still remains a complex technical system, therefore a significant part of the service and repair technologies will remain the same. Moreover, intelligent vehicles will make up a small fleet share for a considerable time. Nevertheless, it is necessary to pre-engage in preparing the infrastructure not only for organizing the transportation process, but also for maintaining the vehicle in a healthy and safe condition for reliable operation.

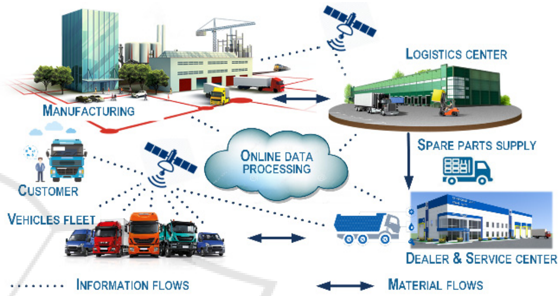

Figure 2: Unified information space of a manufacturer vehicles.

It should be remembered that the logistics of the future, like the entire industry 4.0, will be based on new materials, nanotechnology, RFID technology or cyber networks, so neo-industrialization will vary significantly affect supply chain management and logistics in general. To improve the accuracy of the information necessary for supply chain management, it is necessary to integrate RFID systems into MES systems, which will optimize outbound and inbound logistics. The RFID system allows you to: monitor the supply chain in real time (using web access); track the goods at each supply chain stage; reduce the human factor impact.

The inclusion of each vehicle as an active object by means of the communication channels in the cyber-physical system, will make it possible to obtain information about the state its nodes and aggregates and to predict the residual life. With an adequate sensors selection and on-board diagnostic systems improvement, this allows you to set the wear amount and predict the probable failure moment. Thus, possessing such information and transferring it to the production system's data storage cloud system, it will be possible to predict the need for spare parts for repairs and to establish a unique product samples within the mass production framework.

For the such interaction scheme organization between the service system and the production system, the including on an individual vehicle system of on-board diagnostics and online data transaction is implied. Such systems operate through four main components: GPS satellites, vehicle on-board diagnostic kit, GSM network and the GPS control service provider server. Satellites are used to obtain key information about the vehicle, such as: location, direction and speed. The on-board kit is a GPS-receiver, GSM-transmitter and minicomputer, and also includes on-board diagnostic devices. All the necessary information from GPS satellites, from sensors and / or the on-board computer is collected in the so-called black box, from where it is transmitted through the GPRS local GSM operator channel to the server, where the information is properly processed and transmitted to the cloud data storage. The end user (in this case, a person or a machine) has access to information either through special software, or through a regular Web browser from planet anywhere with Internet access.

The use of wireless signal transaction technologies imposes increased requirements for the transacted data security. The SmartMX type microcontroller, which is certified according to the international Common Criteria standard to the EAL5 + level, will be responsible for data security, which ensures compliance with the highest security requirements. It offers increased attack resistance and high performance, with cryptographic coprocessors and ultra-low power consumption. To serve a number of applications, SmartMX supports proprietary operating systems such as open platforms such as Java and MULTOS (NXP SmartMX…, 2019).

3.2 Reliability Management in BSS to Autonomous Vehicles

Competitiveness issues are addressed at product's life cycle all stages. To a large extent, competitiveness depends on the speed of updating the model range and the reliability of products during operation. Since the vehicle is a complex technical system consisting of many parts, its reliability depends on how reliable these parts are. Although there are not many details limiting reliability, however, the issues of increasing their reliability and predicting possible replacement periods are relevant.

At the vehicle operation stage, which is the longest of all life cycle stages, the main customer's requirement is to maintain the vehicle in a technically sound condition. This activity area acquires particular relevance in connection the design complexity, therefore, the organization of a producer company single information space with all dealer service centers will allow to quickly identify problems and solve them (Makarova, I.; et al. 2012, 2015, 2016).

As a rule, truck service is carried out in specialized service centers operating according to the manufacturer's standards. Since it is important for the vehicle owner that the service is carried out as soon as possible, a large number of scientific papers are devoted to the processes optimization methods. If the failure of any detail or aggregates occurred during the warranty period, then the issue of improving the repair efficiency is important both for the manufacturer and for the vehicle owner. The manufacturer must provide a quick replacement of the failed system, and the client must receive a working vehicle for the implementation of the logistics process and profit. In the transition to autonomous vehicles, the ensuring operability issues will be specific in nature and will be based on information from on-board diagnostic systems, as well as, traditionally, on failure statistics, which at the initial moment of entering AV on the markets will be incomplete.

In addition, it must be borne in mind that, obviously, the regulations for daily maintenance and preventive maintenance will also change, since by removing the person-driver from the control loop, we thereby exclude the possibility of preventing a technical system sudden failure by indirect signs that can be identified either by a person or a specific sensor (if provided in the monitoring system).

Nevertheless, the algorithm for organizing the M & R of autonomous vehicles can generally look like the one shown in Figure 3.

3.3 Methods and Means of Data Aggregation, Analysis and Security

Decision making is based on real data about the managed object, therefore, for analysis, strategy development and operational management aggregated information is used. To storage, integration, updating and coordination of operational data from heterogeneous sources create data warehouses (DW). DWs are necessary for the formation of a consistent and uniform view of the control object as a whole, therefore they contain information collected in real-time from several operational databases of On-Line Transaction Processing systems (OLTP). A multidimensional intelligent data model (OLAP cube) will be located in the single information space's management center of the automotive company.

To implement OLAP, you can use a hybrid option that combines Relational OLAP (ROLAP) and Multidimensional OLAP (MOLAP). This provides higher scalability of ROLAP and faster calculation of MOLAP. Hybrid OLAP (HOLAP) servers allow storing large amounts of detailed information. The database administrator, in this case, will be responsible for entering and updating the information, updating the data in the measurement tables, as well as adjusting the Fact table, if users need new queries.

Data for multivariate analysis can be obtained using a special utility directly from the database by formalizing the selected data array. Reporting Services (SSRS) has a complete tools set for creating, managing and delivering reports, what allows you to create reports for a large data sources number. Reporting Services tools are fully integrated with SQL Server tools and components. (SQL Server…, 2020). In addition, SSRS has APIs through which developers integrate or expand the data processing and reports in user applications.

Given, that connected vehicles have a large different sensors number, it is necessary to provide in BSS the rules for their verification, as well as maintenance and replacement procedures. If there are vehicles of varying intellectualization degrees in the serviced vehicle fleet, their preliminary clustering is required to select the optimal service strategy for each vehicle type. The conceptual scheme BSS management is shown in Figure 4.

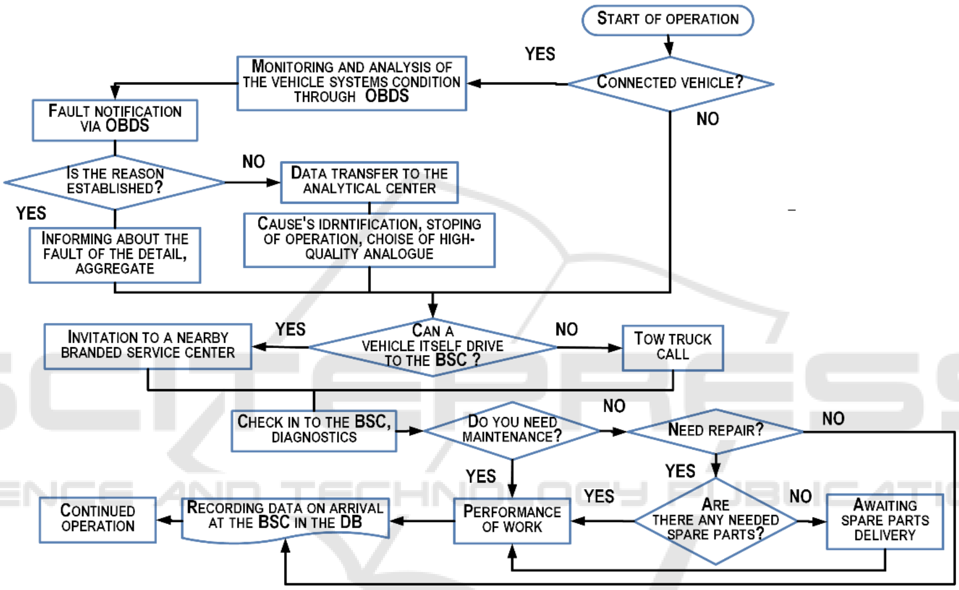

Figure 3: The BSS functioning algorithm when using connected vehicles.

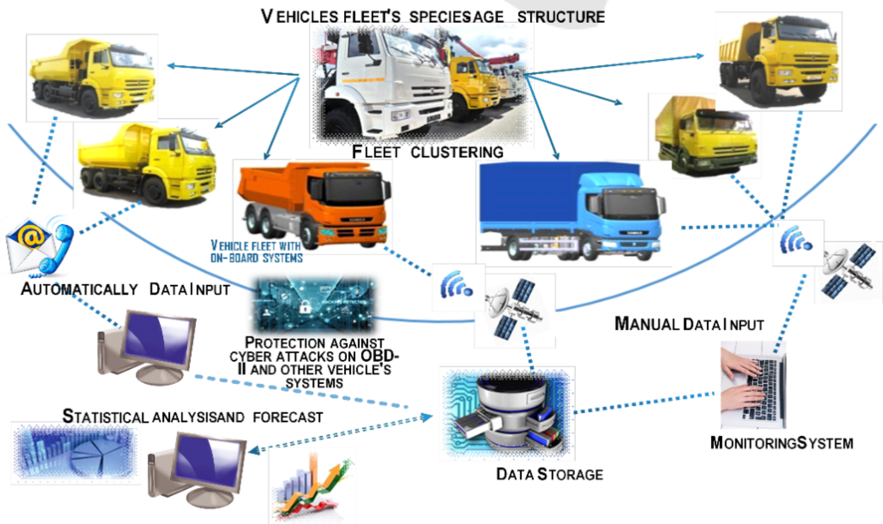

Figure 4: Management organization in the BSS information space.

4 CONCLUSIONS

Executed studies have shown that trends in the automotive industry are due to digitalization and intellectualization, that largely depends on the information quality. Increased requirements for safety and reliability in transport systems increase the requirements for the quality of data necessary for the management and sustainable development of transport systems. In our opinion, only complex solutions can have a positive effect. Growing data volumes increase the analysis tools importance, most of which are based on OLAP principles, modern big data analysis methods and security tools. The BSS development and its improvement, taking into account the entry into the market of intelligent vehicles, a significant part of which will be connected, requires the creation of a single information space for process control throughout the entire vehicle life cycle. This will allow you to timely and effectively solve problems arising in the service system, as well as build long-term strategies based on big data analysis. For this, it is necessary that the design and technological solutions in the production system are combined with rational management, including in the service system. This will allow you to find the optimal processes parameters at all stages of the car's life cycle, as well as make rational management decisions.

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