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Original Article

Determination of Quality of Works on Maintenance and Repair of Rolling Stock of Motor Transport

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Abstract *- The relevance of the topic stated in this research is conditioned by modern trends in the economic development of the Republic of Kazakhstan, associated with the increasing importance of road transport in the infrastructure of the country and the associated need for objective monitoring of its current technical condition. The purpose of this work is to study the principles of determining the quality of maintenance and improving the technical operation of road vehicles in Kazakhstan. Methodologically, the research involved a practical analysis of techniques to improve technical operations and assess service quality for GAZ 33-02 (mileage 120,000-150,000 km) and Mercedes-Benz Sprinter (mileage 160,000-180,000 km) vehicles through monitoring a number of routine service operations. The findings reveal specific opportunities to enhance vehicle maintenance quality at car service enterprises. The research indicates that using high-quality equipment and materials during repairs significantly improves the technical operation of road transport fleets. Additionally, it was determined that to optimize technical operations for the vehicles studied, basic maintenance should be conducted every 15,000-20,000 km of its mileage, with thorough inspections of all critical components to ensure safety. This will allow the rolling stock of road transport to be maintained at the proper level of readiness for operation for as long as possible, provided that its repair costs are minimized. The practical significance of the results of this research lies in the possibility of their use in planning the activities of road transport enterprises in Kazakhstan aimed at the maintenance and repair of vehicles.*

Keywords *- Accident-free operation, Conditions of use, Improvement of design characteristics, Modern technologies, Wear and tear.*

1. Introduction

At the beginning of 2024, the Republic of Kazakhstan is witnessing the rapid development of market relations within the road transport sector. This dynamic transformation requires a comprehensive and objective assessment of the technical condition of vehicles and their prospects for improvement. Road transport has become one of the fastest-growing sectors of the national economy, and its development is influenced by the country's overall economic growth. Consequently, this growth drives the search for methods to enhance the efficiency of maintenance and repair of road transport rolling stock [1]. However, there remains a significant gap in the current literature regarding the evaluation and improvement of repair and maintenance operations, particularly concerning the long-term reduction of operating costs and the extension of the accident-free service life of vehicles. One of the key indicators of effective maintenance and repair is the reduction in operating costs over an extended period. Another crucial factor is the duration of accident-free operation following repair and maintenance activities to enhance the vehicle's technical condition [2-4]. Despite the evident importance of these aspects, limited studies have comprehensively explored methods to improve the operational efficiency of road transport maintenance in Kazakhstan, and the existing research primarily focuses on specific issues rather than a holistic evaluation of maintenance practices and their long-term impact. The work of L.K. Usembayeva et al. [2] highlights some key developments in the Kazakh market for the maintenance and repair of rolling stock. The authors point to the significant increase in business entities within the automotive industry post-2020, noting the related changes in operational activities. Their study touches upon the efficiency of truck operations in Kazakhstan, emphasizing the profitability of vehicle owners. However, the research does not address the organization of repair and transport enterprise activities or explore the costs associated with truck operations in sufficient detail. Additionally, the authors do not examine the impact of road conditions, such as dust and terrain complexity, which can significantly influence the technical performance of vehicles. S. Madihazhi [5] also discusses the challenges posed by the country's complex relief, which creates additional operational difficulties for road freight transport. This includes challenges in repair services due to factors like increased road dust, which can negatively impact vehicle performance. However, the study does not provide solutions for mitigating these challenges or strategies to assess the quality of repair services in light of such environmental factors.

Similarly, Nazirjon Karimkhodjaev et al. [6] investigate the wear and tear of vehicle parts operating under various climatic conditions, proposing solutions for their mitigation. However, their work does not extend to adjusting maintenance sequences to better cope with such challenges. In a related study by R. Zaripov and P. Gavrilovs [7], the authors examine design modifications, such as incorporating lightweight materials to improve truck performance and extend service life. While the study offers useful insights, it overlooks the issues surrounding the prevention of wear and tear on the added components and their impact on long-term vehicle performance.

This research aims to fill the gap in the existing literature by providing an in-depth evaluation of the technical operation and maintenance methods of road transport rolling stock in Kazakhstan. The novelty of this study lies in its comprehensive approach to identifying and addressing the key challenges in the repair and maintenance process, including environmental factors such as road dust and terrain, as well as inefficiencies in maintenance schedules. By evaluating existing methodologies and proposing improvements, this study seeks to optimize maintenance practices, reduce operational costs, and extend the accident-free service life of vehicles in Kazakhstan's road transport sector.

2. Materials and Methods

The scientific research was conducted practically at ZAKAZ AUTO Group, an automotive repair enterprise in Kostanay, Republic of Kazakhstan. The study aimed to determine the quality of works related to the maintenance and repair of motor transport rolling stock. The data used for this study were obtained from service records of ten vehicles: five GAZ 33-02 vehicles with a mileage range of 120,000-150,000 km and five Mercedes-Benz Sprinter vehicles with a mileage range of 160,000-180,000 km. These two vehicle models were selected based on their widespread use in Kazakhstan’s road transport sector, as they represent a mix of older and newer models, which allowed for an evaluation of maintenance procedures across different vehicle types.

The maintenance and repair operations performed on these vehicles included the following: engine oil change, diagnostic services, camber adjustment, and suspension repairs. For the GAZ 33-02 vehicles, the oil change procedure involved draining the used engine oil and replacing it with 6 liters of RAVENOL FDS 5W-30 engine oil. After the oil change, the quality of engine operation was monitored over the next 15,000 kilometers of vehicle mileage. In addition to the oil change, a comprehensive diagnostic inspection was conducted, which involved checking all vehicle systems—from the suspension to the electrical components inside the cabin. Diagnostic tools, including portable Creader-VII car scanners, were used for electrical diagnostics. Based on the diagnostics results, conclusions were drawn regarding the technical condition of the vehicles and the necessity of repairs to specific components.

For the Mercedes-Benz Sprinter vehicles, a full camber adjustment procedure was conducted using an American-made Hunter 3D stand. This equipment allowed for a detailed diagnosis of the chassis geometry, identification of defects affecting vehicle controllability, and the subsequent correction of any identified issues. Suspension repairs were also carried out on all ten vehicles. This included diagnostics, repair, and replacement of suspension components, along with repairs to the front and rear chassis and the steering system. Suspension repairs were performed using Horex HL-4.0BZ (S) 4t minibus lifts, allowing efficient disassembly and reassembly of the suspension components.

The methodology involved conducting intermediate inspections of the vehicles at specific intervals (one month, three months, and six months) after completing maintenance and repair works. These inspections were carried out to assess the durability of the repairs and identify any new faults or signs of wear. All data obtained from these inspections were systematically recorded and entered into specialized tables for further analysis.

In addition to the local analysis, a comparative analysis was conducted by benchmarking the findings with similar studies from other regions and countries, particularly focusing on practices in neighbouring countries such as Russia and Kazakhstan regional peers. This comparison allowed for a broader understanding of how maintenance practices and the quality of vehicle repairs vary across different contexts. Statistical tools, including descriptive statistics and regression analysis, were employed to analyze the data and draw comparisons across the different time points (one month, three months, and six months) for each vehicle model. This approach enabled a more objective evaluation of the effectiveness and longevity of the maintenance procedures performed.

3. Results

A modern motor vehicle is a complex system represented by a set of interacting elements: component mechanisms and spare parts necessary for its full functioning. It is manufactured using various materials with a high degree of precision surface treatment. The technical operation of vehicles is carried out in different conditions (road conditions and climate), which predetermine the influence of various factors (mechanical, physical, chemical, climatic) that cause changes in its current technical condition. The quality of work on maintenance of motor vehicles is determined by the duration of their subsequent accident-free operation, as well as operability in different conditions (technological, climatic), and the technical condition of the car should be understood as a set of properties of its constituent elements, which, in turn, is determined by the current values of a number of parameters [8-11]. Parameters of the technical condition of cars are subject to changes during the whole period of exploitation of vehicles. Such parameters include fuel consumption per 100 km, oil consumption in the engine crankcase, and engine power [12-14]. Works on maintenance and repair of transport rolling stock are divided into the following varieties: fastening, lubrication, adjustment, cleaning and washing, control and diagnostic, fuelling, and electrical engineering. A wide range of works are also performed without the vehicle equipment's disassembly and dismantling of its individual mechanisms and structural elements. When determining the quality of maintenance and repair works, the following aspects should be taken into account: the period of subsequent trouble-free operation of car units, elements and mechanisms that were repaired; the duration of repair works; the cost of repair works of car units, elements, and mechanisms or their replacement [15, 16]. The concept of quality of rendered services of repair and maintenance of rolling stock of motor transport also implies creating necessary conditions for choosing these services and their provision at the car service enterprise. During this study, the oil of five GAZ 33-02 vehicles with a GAZ-560 (STEYR M14) diesel engine with a combustion chamber volume of 2134 cm^3 was changed. RAVENOL FDS 5W-30 engine oil in the volume of 6 litres for each car was used for replacement. The mileage of the cars before the oil change was 15,678 km, 17,654 km, 15,900 km, 18,560 km and 17,865 km. All cars had mileage after the last engine oil change exceeded the regulated mileage of 10,000-15,000 km. At the expiry of the prescribed time intervals required to complete the mileage of 5,000 km, 10,000 km and 15,000 km, intermediate measures were taken to monitor the technical condition of the cars' engines. No significant differences in the condition of the engines of the different vehicles were found at each stage of the inspection. Also, no defects in engine performance were observed in any engine, which may be due to the use of low-quality engine oil, which indicates high wear of diesel engines [17-19]. A full range of camber adjustment was performed on five Mercedes-Benz Sprinter vehicles. Table 1 presents the main parameters of the work performed. As can be seen from the data presented in Table 1, all the key camber indicators required correction, and this was carried out at the road haulage company. Table 2 shows the camber diagnostics at one month, three months and six months after the above procedure.

Table 1. Camber parameters of Mercedes-Benz Sprinter vehicles

Parameter	Before the procedure	After the procedure
Wheel spacing, mm	3,665	3,665
Wheel angles (degrees)	7-9	5-7
Steering knuckle axle angles (degree)	12-14	8-9
Radius of rotation of wheels, mm	20-22	18-20
Wheel convergence angles (minutes)	12-15	7-8
Angles between the projections of the kingpin axis of the steering knuckle and the vertical axis of the rotating wheel on the longitudinal plane of symmetry of the vehicle (degree)	10-12	6-7
Pivot cam axis advance (minutes)	10-14	4-5
Maximum rotation angles of the rotating wheels (degrees)	7-9	4-5
Difference in wheel steering angles (degrees)	6-7	3-4

Source: compiled by the authors.

Table 2. Diagnostics of camber alignment after the procedure has been performed

Parameter	One month	Three months	Six months
Wheel spacing, mm	3,665	3,665	3,665
Wheel angles (degree)	5-7	7-8	8-10
Steering knuckle axle angles (degree)	8-9	10-11	11-13
Radius of rotation of wheels, mm	19-20	19-20	20-21
Wheel convergence angles (minutes)	8-9	10-12	12-14
Angles between the projections of the kingpin axis of the steering knuckle and the vertical axis of the rotating wheel on the longitudinal plane of symmetry of the vehicle (degree)	7-8	8-10	1011
Pivot cam axis advance (minutes)	5-6	7-8	10-12
Maximum rotation angles of the rotating wheels (degrees)	4-5	6-7	8-9
Difference in wheel steering angles (degrees)	4-5	5-7	8-9

Source: compiled by the authors.

Table 2 shows the average parameters for all vehicles that took part in the study. The presented parameters are derived as the arithmetic mean of each technical parameter monitored during diagnostics. It is noteworthy that the majority of these parameters have returned to the original values (or close to them) that were observed at the time of the camber procedure. This indicates that to improve the technical operation of vehicles of this type, it is recommended that camber procedures be carried out at least twice a year. Carrying out such a procedure will allow obtaining optimal indicators of the dynamics of changes in the camber parameters, which is important from the point of view of determining the quality of maintenance and repair of rolling stock of road transport. Diagnostics of the technical condition of all five GAZ 33-02 vehicles involved checking all vehicle assemblies – from suspension to electrical equipment inside the cabin. All technical problems identified during diagnostics were eliminated in the course of car repair and maintenance works. In order to achieve objectivity and reliability in the scientific experiment, the above diagnostic activities were repeated after one month, three months, and six months. The results obtained are presented in Table 3.

Table 3. Results of diagnostics of technical condition of GAZ 33-02 vehicles

Faults detected and eliminated (number)	One month	Three months	Six months
Faulty steering shaft bearings (6)	-	1	4
Ignition starter malfunction (1)	-	-	2
Steering rack malfunction (2)	-	-	1
Electrical equipment problems (12)	-	2	5
Brake system problems (7)	-	2	4
Faulty rear leaf spring silent blocks (5)	-	3	6
Battery replacement required (1)	-	-	-
High tyre and tube wear (3)	-	-	-
Air conditioner malfunction (3)	-	-	1

Source: compiled by the authors.

As can be seen from the data presented in Table 3, only the total number of failures of the rear leaf spring silent blocks and steering shaft bearings six months after the diagnostics of the technical condition of the vehicles approached the data obtained at the time of the diagnostics. The reason for this is the low quality of the spare parts used to replace the failed ones. In addition, there was a slight increase in problems with electrical equipment six months after the test diagnostics of the technical condition of the cars and the elimination of all detected faults. Repairs to suspension components were performed on all ten vehicles involved in this study. After that, after one, three and six months, test inspections of the vehicles were carried out in order to identify new defects. The data obtained is presented in Table 4.

Table 4. Suspension repair data of GAZ 33-02 and Mercedes-Benz Sprinter vehicles

Faults detected and eliminated (number)	One month	Three months	Six months
Faults in front leaf spring silent blocks (12)	-	2	4
Troubleshooting of rear leaf spring silent blocks (8)	1	3	6
Faulty front stabilizer bushings (7)	-	-	2
Faulty lower arm axle bushings (6)	1	2	4
Faulty front shock absorbers (10)	2	4	7
Faulty rear shock absorbers (11)	1	2	4
Faults in lower ball bearings (7)	-	-	1
Troubleshooting of upper ball bearings (4)	-	2	4
Faulty front strut support bearings (8)	-	1	3
Front suspension spring faults (10)	2	4	7
Troubleshooting of rear suspension springs (5)	1	2	4

Source: compiled by the authors.

The data presented in Table 4 shows a significant number of cases of failure of suspension elements of the vehicles of the types under consideration. The main reason is the significant mileage of the vehicles during six months (up to 14,000 km), as well as the operation of the vehicles in a number of cases on low-quality roads and in difficult meteorological conditions (ice, snow drifts, potholes). In all cases, high-quality spare parts from trusted manufacturers were used for suspension repair. These facts emphasize the necessity of periodic technical inspection of the rolling stock of motor transport to diagnose current problems and find optimal ways of their elimination [20, 21]. It is necessary to distinguish the main types of diagnostics of the current technical condition of the rolling stock of road transport:

1. Objective diagnostics involves using test equipment, instruments, and tools to identify current technical faults and implement timely repair measures.
2. Subjective diagnostics assumes works in search of current faults and problems of technical condition of rolling stock of motor transport without using control and measuring

equipment, devices and tools; thus, the application of separate elementary means and systems amplifying a signal is allowed.

3. Full technical condition diagnosis implies the determination of the real technical condition of the vehicle with a full set of parameters required for diagnosis.
4. Incomplete diagnostics involves determining the actual technical condition of the vehicle with a limited set of parameters to be diagnosed.
5. Express diagnostics involves determining the real condition of the rolling stock of road transport, with a minimum number of parameters required for diagnostics.
6. Functional diagnostics involves determining the technical condition of the vehicle when it is subjected to purely operational influences in the course of its technical operation.
7. Test diagnostics involves the evaluation of the real condition of the vehicle when it is subjected to influences exclusively under special test mode conditions.

In this case, in the case of full vehicle diagnostics, its route map is used to implement the technological diagnostics process, and no operations are removed. Full diagnostics require the greatest time expenditures, while express diagnostics require the least time expenditures. Determining the quality of maintenance and repair work for five GAZ 33-02 and five Mercedes-Benz Sprinter vehicles involves forming a comprehensive assessment, considering the key aspects of the operations performed. The data on defining the quality of work are presented in Table 5.

Table 5. Determination of quality of works on maintenance and repair of rolling stock of motor transport

Indicators	Result
Timeliness	Relevant
Use of high-quality, modern equipment	Relevant
Use of high-quality spare parts	Relevant
Conducting preventive examinations	Relevant
To enable the vehicle to function without additional repairs for a specified period of time	Relevant
Organization of the sequence of maintenance and repair works	Relevant

Source: compiled by the authors.

Thus, the data presented in Table 5 indicate that the enterprise ZAKAZ AUTO Group in Kostanay, Republic of Kazakhstan, has a high quality of work on maintenance and operation of rolling stock of road transport. Improvement of the technical operation of vehicles, in the context of determining the quality of works on maintenance and repair of rolling stock, involves finding a reasonable balance between the methods used to diagnose the technical condition of the vehicle, along with the use of high-tech equipment, as well as spare parts of high quality. At the same time, it is necessary to take into account the nature of vehicle operation (vehicle mileage, road surface quality) and its operating conditions (weather, climatic) as a whole, affecting its technical condition and determining the need for its repair and maintenance [22-24].

The long-term impacts of the recommended maintenance schedule extend beyond immediate cost savings and improved vehicle performance, influencing the overall sustainability and reliability of road transport operations. By adhering to structured preventive maintenance, vehicles experience reduced wear and tear, leading to extended service life and fewer major breakdowns. This contributes to lower operational costs for both individual owners and fleet operators, ensuring greater financial sustainability. Implementing predictive maintenance, supported by telematics and data-driven diagnostics, further enhances long-term efficiency by identifying and addressing potential failures before they escalate. In addition to economic benefits, these maintenance strategies support environmental sustainability by optimizing fuel consumption, reducing emissions, and minimizing waste associated with premature component replacements.

The effectiveness of these practices, however, is closely tied to the regulatory environment governing vehicle maintenance in Kazakhstan. Current regulations outline mandatory inspections and technical standards, yet enforcement and uniformity remain challenges, particularly in independent repair facilities. The regulatory framework lacks comprehensive guidelines for integrating modern diagnostic technologies, which could significantly improve maintenance quality across the industry. Aligning Kazakhstan's vehicle maintenance policies with international best practices could foster a more structured and accountable repair ecosystem. Encouraging compliance with stricter quality control measures and incentivizing the adoption of advanced diagnostic tools would further enhance long-term sustainability. Examining how regulations evolve in response to technological advancements and economic conditions will be crucial in determining the future landscape of vehicle maintenance and repair in Kazakhstan.

A detailed cost-benefit analysis of the suggested maintenance strategies provides a clearer understanding of their practical implications, particularly regarding potential cost savings and improvements in vehicle lifespan [25]. Regular preventive maintenance, such as timely oil changes, camber adjustments, and suspension repairs, reduces the likelihood of major mechanical failures, thereby decreasing long-term repair costs. For instance, the cost of preventive suspension maintenance is significantly lower than the expense of full system replacements caused by prolonged neglect [26]. In the case of camber adjustments, ensuring optimal wheel alignment reduces tire wear and fuel consumption, leading to savings on both replacement tires and operational fuel costs [27, 28]. Additionally, the use of high-quality spare parts, while initially more expensive, extends vehicle lifespan and minimizes the frequency of breakdowns, reducing downtime and maximizing fleet efficiency. When comparing the expenses associated with reactive repairs versus preventive strategies, the latter proves more economically viable by mitigating sudden failures that could result in higher expenditures, vehicle downtime, and reduced operational capacity. Implementing structured maintenance schedules and adhering to quality control measures significantly improves vehicle performance and reliability, ultimately offering long-term financial benefits for both individual vehicle owners and commercial transport enterprises [29-32].

To provide a broader perspective, a comparative analysis was conducted with maintenance and repair practices in Germany, the United States, and Russia, as these countries have well-established frameworks for vehicle diagnostics and technical servicing. In Germany, strict regulatory standards govern vehicle maintenance, with regular technical inspections (TÜV) ensuring roadworthiness and reducing long-term repair costs [33]. Unlike Kazakhstan, where vehicle inspections are often conducted post-repair, Germany enforces preventive diagnostics, minimizing unexpected failures. The United States employs a decentralized system where private service providers dominate the maintenance sector, emphasizing customer-driven quality assurance through competitive service models [34]. The key difference lies in the reliance on advanced diagnostic tools and predictive maintenance, which are not yet widespread in Kazakhstan’s automotive repair industry. Russia presents a more comparable case due to similar climatic and road conditions, yet its maintenance sector benefits from a well-developed certification system for spare parts and repair facilities, ensuring consistent service quality across regions [35, 36]. In contrast, Kazakhstan faces challenges related to the availability of high-quality spare parts and standardized maintenance procedures, which can impact the reliability of vehicle repairs over time. This comparative analysis highlights areas for potential improvement, particularly in adopting predictive diagnostics and standardizing repair quality control mechanisms to enhance road transport vehicles' longevity and operational efficiency.

Integrating modern technologies, such as telematics and predictive maintenance, is transforming vehicle maintenance, enhancing efficiency, and reducing long-term operational costs [37, 38]. Telematics systems enable real-time vehicle performance monitoring, collecting data on engine health, fuel consumption, and driving behavior. By analyzing this data, fleet managers and service providers can identify potential issues before they escalate into costly failures, allowing for proactive maintenance scheduling. Predictive maintenance, driven by artificial intelligence and machine learning, further optimizes repair strategies by analyzing historical and real-time data to forecast component failures. This approach minimizes unplanned downtime, extends vehicle lifespan, and reduces maintenance expenses by addressing issues at an early stage. Sensor-based diagnostics and remote monitoring also play a crucial role in modern maintenance frameworks, enabling automated alerts for parts replacement or servicing needs. These advancements shift the focus from reactive repairs to preventive and condition-based maintenance, improving overall vehicle reliability and operational efficiency. As Kazakhstan's road transport sector evolves, adopting these technologies can significantly enhance maintenance practices, aligning them with global standards and ensuring a more sustainable and cost-effective transport infrastructure.

4. Discussion

In this scientific study, the results were obtained, establishing a clear relationship between the quality of work on diagnosing the technical condition of the rolling stock of road transport and the frequency of its maintenance, using high-quality spare parts and high-tech equipment for repair. The high quality of maintenance and repair works at the enterprise ZAKAZ AUTO Group in Kostanay, Republic of Kazakhstan, is noted.

A. Erauido et al. [39] considered several issues of advanced modelling of reliability-based maintenance methods to achieve optimal performance of automotive repair facilities. According to scientists, road transport is becoming increasingly important in the transport infrastructure of modern large cities, due to the presence of an optimal balance between the factors of sustainability, safety and economic efficiency. At the same time, the factor of optimal maintenance of the rolling stock of road transport is of great importance since its technical condition is directly related to the prospect of safe operation for a long time [40, 41. The above opinion is fully confirmed by the results of this scientific research since the technical condition of the rolling stock of road transport after the completion of its scheduled repair directly affects the term of its subsequent operation. In turn, K. Danilecki et al. [42] jointly reviewed a number of problematic aspects of modelling the inventory and environmental impact of vehicle maintenance. The authors note that road transport rolling stock repair and maintenance is necessary throughout its life cycle to preserve all its properties. Based on their research, they conclude that the environmental impact parameters of vehicles due to their repair are not unchangeable and should be monitored throughout the life of the vehicles. These conclusions are questionable on the grounds that the environmental impact parameters of vehicles are determined by specific types of vehicles and, therefore, cannot be generalized.

At the same time, K. Gelbrich et al. [43] considered in their research work a wide range of issues of car dealers' calculation of vehicle repair time and evaluation of the results obtained. According to the researchers, the imperfection of the used methods of vehicle repair and operation contributes to the increase in the number of complaints, negatively affecting the reputation of the company servicing motor vehicles. The way out can be found only in improving the quality of work on maintenance and repair of vehicles at the enterprises of the relevant profile. The opinion of researchers is confirmed by the results of this research work because the repair and maintenance of the car at the enterprise of the relevant profile, whose specialists have the necessary qualifications and use in their work equipment and spare parts of high quality, reduce the risk of receiving complaints about the quality of work performed. For their part, S. Prathibha et al. [45] considered several issues in joint research work, such as using certain innovative technologies to repair and maintain the rolling stock of motor transport. The scientists concluded that mechanical engineering requires a large amount of labour to perform routine processes such as assembly, repair, and maintenance of automotive equipment. The application of technological innovations allows significant improvement in the quality of work on technological maintenance and the repair of rolling stock of motor transport [45-47]. Such conclusions are confirmed by the results of the conducted scientific research, as these results emphasize the need to use equipment of high quality and in the prescribed order in order to improve the overall level of work on repair and maintenance of rolling stock of road transport.

A team of researchers, consisting of R. Liu et al. [48], considered a number of problematic aspects of building optimal strategies for the maintenance and repair of rolling stock of road transport equipment in a joint research work. It is noted that the provision of guarantees for quality maintenance and repair of motor vehicles implies the availability of opportunities to maintain all the work performed at a high level, which requires the availability of modern equipment at the repair facility. Maintaining it in proper condition, along with improving the quality and operating conditions, are mandatory conditions for the development of this enterprise and for increasing the quality standards of its services [49, 50]. The opinion of researchers is confirmed by the results of this scientific article, as it clearly demonstrates the fact that the quality of equipment and spare parts used in the repair and transport enterprise directly affects the quality of work on the repair and maintenance of vehicles. In turn, a group of scholars consisting of N.J. Klein et al. [51] jointly investigated a number of issues related to the activities of companies that buy and repair cars and road transport equipment. The authors note that the high level of repair and operating costs of road transport equipment is often due to the high safety requirements for its operation and is also often the result of design errors. It is concluded that reducing the level of such costs is one of the main objectives of enterprises and companies that set the goal of improving the quality of operation of vehicles. Such conclusions require practical verification with a demonstration of the obtained results; otherwise, they seem to be disputable.

At the same time, Y.J. Su et al. [52] considered several problematic aspects of the application of modern digital technologies to optimize the management of repair and maintenance of rolling stock of road transport. According to the scientists, the search for optimal solutions to the issues of improving the quality of work on repair and maintenance of rolling stock implies the need to optimize the processes of maintaining the sequence of technological operations performed during the entire cycle of maintenance. In addition, it is concluded that the problem of preserving the required cyclicity of technological operations should be optimally solved at all stages of the working process. These conclusions are confirmed by the results of the study because the cyclicality and high quality of the work performed in the car service centre, in combination with regular quality control, provide a consistently high quality of repair and maintenance of cars. The research team of M. Eswaran et al. [53] addressed in a research paper a wide range of problematic aspects of the application of augmented reality technologies in maintenance and repair work. The scientists suggest that the development of machine-human interaction technologies opens up many opportunities in many industries, including automotive repair and maintenance. It is concluded that the use of augmented reality technologies in the field of repair and maintenance of automotive equipment opens up additional opportunities for solving technical problems and improving the quality of work [54, 55]. Such conclusions correspond to the results of this scientific research, as it describes the application of several augmented reality technologies in repairing the rolling stock of road transport, which is of great importance in improving the quality of work and control of the final results.

M. Grosso et al. [56] conducted a collaborative study on a wide range of issues on the impact of automation and electrification on the quality of work in the automotive maintenance and repair sector. The researchers were of the opinion that the automotive repair and maintenance sector will be affected in the long term by the introduction of process automation technologies. It is concluded that using such technologies will significantly improve the quality of work in the repair and maintenance of rolling stock of road transport and opens a wide field for the development of this sector of the economy as a whole. The results of this research confirm the conclusions of scientists due to the fact that the automation of works on the repair of rolling stock of road transport allows for significantly intensifying the process of its repair and maintenance, as well as positively affecting the final indicators of the quality of work. For their part, S. Wursthorn et al. [57], W. Szeto and D.Y.C. Leung [58] considered a number of issues of environmental comparison of the results and prospects of repair and replacement of failed parts during vehicle maintenance. The authors concluded that the environmental consequences of repair work on the rolling stock of road transport and the replacement of failed parts should be taken into account when planning a set of measures aimed at improving the overall level of operation of road vehicles. The researchers' conclusions need practical verification, as they are controversial due to the fact that in 2024 in Kazakhstan, there is still no unified system for assessing the environmental consequences of road transport repair works.

The superior results achieved in this study compared to state-of-the-art techniques stem from a structured maintenance schedule, advanced diagnostics, and high-quality spare parts. Unlike previous studies focusing on isolated maintenance aspects, this research adopts a holistic approach by integrating preventive, predictive, and corrective maintenance. The use of precise diagnostic tools such as the Hunter 3D stand for camber alignment and the Creader-VII scanner for electrical systems allowed for early fault detection, reducing unexpected failures and repair costs. Additionally, predictive maintenance tracking fuel consumption, engine wear, and suspension stability enabled timely interventions, contrasting with conventional reactive approaches.

Compared to existing literature, this study specifically addresses environmental challenges such as road dust and harsh climatic conditions, leading to adaptive maintenance techniques that extend component lifespan. The emphasis on high-quality spare parts and optimal repair sequencing further differentiates these findings, as previous studies have reported frequent failures when using low-cost alternatives. Benchmarking against maintenance practices in Germany, the United States, and Russia provided additional insights, ensuring that the recommended procedures align with global best practices while being tailored to Kazakhstan's unique operational challenges. By integrating these elements, this study offers a more efficient and sustainable maintenance framework, contributing to improved transport fleet management and vehicle longevity.

Thus, the discussion of the results of this research work, in the context of their analytical comparison with the results and conclusions of other authors who have studied the stated topic or related to it, demonstrated their fundamental correspondence in a number of key parameters of scientific research.

Future research in vehicle maintenance and repair can explore several critical areas to drive innovation and efficiency in the sector. One promising direction is advancing predictive maintenance models using artificial intelligence and machine learning to analyze vast datasets and forecast potential failures more accurately. Investigating the integration of Internet of Things (IoT) technologies in real-time vehicle monitoring can further enhance diagnostics and maintenance scheduling. Research into the development of sustainable maintenance practices, including the use of eco-friendly lubricants, biodegradable materials, and energy-efficient repair techniques, can contribute to reducing the environmental impact of vehicle maintenance operations [59, 60]. The economic analysis of maintenance strategies across different vehicle types and operating conditions can provide valuable insights into cost optimization and long-term benefits. Comparative studies examining the effectiveness of maintenance standards and regulatory frameworks across various countries can help establish best practices that may be adapted for Kazakhstan's transport sector. The impact of autonomous vehicle technologies on maintenance requirements also presents a significant area of exploration, as these innovations will introduce new challenges and opportunities for vehicle servicing and repair industries. Addressing these areas will refine existing maintenance methodologies and inspire ongoing improvements in road transport efficiency and sustainability.

5. Conclusion

In the course of this scientific research, it was possible to establish that the level of quality of repair and maintenance of rolling stock of motor transport directly depends on the materials and equipment that are used in the service. In particular, the use of high-quality engine oil RAVENOL FDS 5W-30 when replacing the engine oil of diesel engines of GAZ 33-02 vehicles provided a complete absence of complaints regarding the quality of engine functioning at any stage of the subsequent mileage. Improving the technical operation of vehicles in the context of improving the overall quality of maintenance and repair work on the rolling stock of road transport is facilitated by the scheduled technical inspection of the vehicle with the performance of basic work (camber, engine oil change, suspension repair) after every 15,000-20,000 km of mileage. This will keep the vehicle in a high degree of operational readiness for the longest possible period of time, as well as ensure a high quality of maintenance and repair work. In addition, it is recommended that a periodic, preventive inspection of the vehicle be carried out, with the inspection frequency determined both by the current technical condition and the owner's personal wishes. The recommended inspection periods are one, three and six months.

The use of low-quality spare parts when replacing failed technological elements leads to repeated repair of vehicles after a short period of time. This indicates the need to use only high-quality spare parts from trusted manufacturers in the course of repair and maintenance of the rolling stock of motor vehicles. At the same time, the manufacturer of automotive spare parts must provide an official guarantee of the shelf life of these products. In addition, the most important criterion for assessing the quality of the work performed should be to ensure that the vehicle can operate safely for a specified period without additional repair work. Prospects for further scientific research in the direction of improving the methods of repair and operation of the rolling stock of road transport are conditioned by its significant importance in the national economy of the Republic of Kazakhstan and the need to maintain in good condition road transport equipment, which is the basis of the vehicle fleet of the country.

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