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Assessment of the Structural Reliability of the Braking System Affecting Road Safety

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Abstract. *The article is devoted to the development of an effective system to ensure the operational condition of vehicles and braking system based on diagnostic information on vehicles. Due to the low coefficient of output of cars on the line, the daily costs of their downtime are calculated in millions of tenge. One of the main reasons for failure is poor technical condition. The cost of maintenance of vehicles in technically good condition is 15-20% of the total cost of transportation. It is based on a complex method of diagnostics of vehicle safety systems. A very important issue is the development of an effective system for assessing the effectiveness of vehicles. It allowed to control the technical condition and predict safe working hours.*

Keywords: *transport, traffic safety, braking system, anti-lock system, ability, diagnostics, indications.*

Introduction

Nowadays, the importance of the transport industry in the economy of each country is growing, as the level of transport development has a direct impact on the competitiveness of the economy and the security of the country. The transport structure is an important sector of the domestic economy of Kazakhstan, which makes a significant contribution.

Despite the global financial and economic crisis affecting the economy of the Republic of Kazakhstan, high demand for cars remained and there was an increase in annual freight and passenger turnover. High demand for transport services has led to an increase in the level of automation in society.

Research results

The material and technical base of road transport enterprises, the quality of maintenance and repair have a significant impact on the level of performance of cars. Due to the low utilization rate of cars (about 70%), the daily costs of their downtime are estimated in millions of tenge. One of the main reasons for the delay is unsatisfactory technical condition. The cost of maintaining vehicles in good technical condition is 15-20% of the total cost of transportation [2,4].

The goal of transport is to increase the efficiency and quality of transport operations, ensuring the safety of transport and passenger traffic, to fully and timely meet the needs of the transport economy and the population.

Reliability is one of the most important characteristics of the product: performance, reliability, durability and serviceability, serviceability, which directly affect road safety. The overall level of vehicle reliability can be improved through systematic measures during the 'life cycle' period.

The reliability of the car is set in the design, provided in production and one of the most important operational properties of the car is reflected and preserved during operation. Reliability during operation depends on the measures taken to protect the vehicle assembly (assembly, assembly, mechanism) from harmful factors, taking into account the statistics on the reliability of individual elements.

Improvement of vehicle calculation methods, design and production technology, introduction of science-based methods of technical operation, reliability in the operation of the vehicle will be close to constructive reliability.

The reliability of the car is not stable during its service life. In addition, the frequency and quality of maintenance and repair, the properties of the working materials, the conditions and mode of operation of the vehicle have a significant impact on its reliability.

During the analyzing the reliability of a complex product, all its elements and parts can be divided into the following groups [3].

1. The elements whose failure does not affect the performance of the product (deformation of the coating, changes in surface color, etc.). Failure of these elements can be considered separately from the system.

2. Elements (pedestals and body parts, hydrostatic bearings, high-strength low-load bearings), the

performance of which does not change during the period under consideration.

3. Elements that can be repaired or adjusted during operation of the product or during downtime that does not affect its efficiency.

4. Elements that lead to product failure.

Thus, only the elements of the last group are considered, which usually have a limited number. They mainly limit the reliability of the product and are the object of study.

If the complex system is divided into individual elements, for each of which the probability of continuous operation can be determined separately, block diagrams are widely used to calculate its reliability.

In these diagrams, each element i is characterized by the value of Pi and the probability of its failure for a certain period of time.

Figure 1 shows a diagram of a two-loop brake system for a rear-wheel drive bus with an anti-lock braking system (ABS) [4]. In case of an indicative failure of the anti-lock system, the electronic control unit disconnects the system, avoiding the possibility of incorrect impact on the control of the braking system during the movement of the vehicle. Thus, the braking system maintains its efficiency.

In most cases, the failure of the anti-blocking system is due to unreliable electrical components of the modulation valve, corrosion and wear.

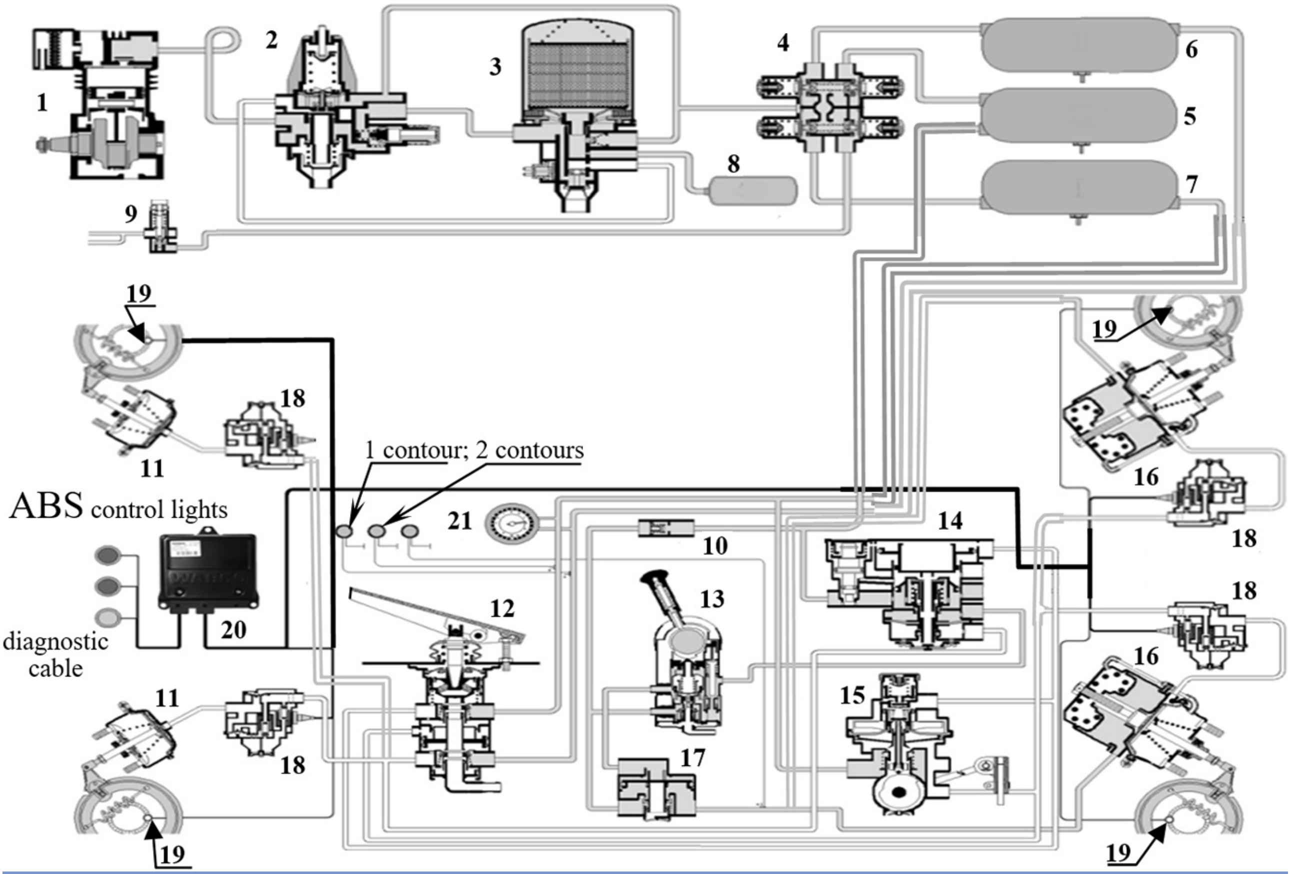
The structural scheme of the reliability of the braking system, developed on the basis of the features of its design (Figure 2, a) determines the functional relationship between the operation of subsystems (or elements) in a particular circuit.

As the anti-lock system does not affect the operation of the brake system, it is located parallel to the main elements of the block diagram and allows you to remove the device from the anti-blocking system and create a new block diagram (Figure 2 b).

The brake force regulators of the rear axle wheels shown in Figure 2 are not provided in this design. Due to this, the braking system will brake in the event of a failure of the ABS unit, but without the ABS the braking system will not be effective.

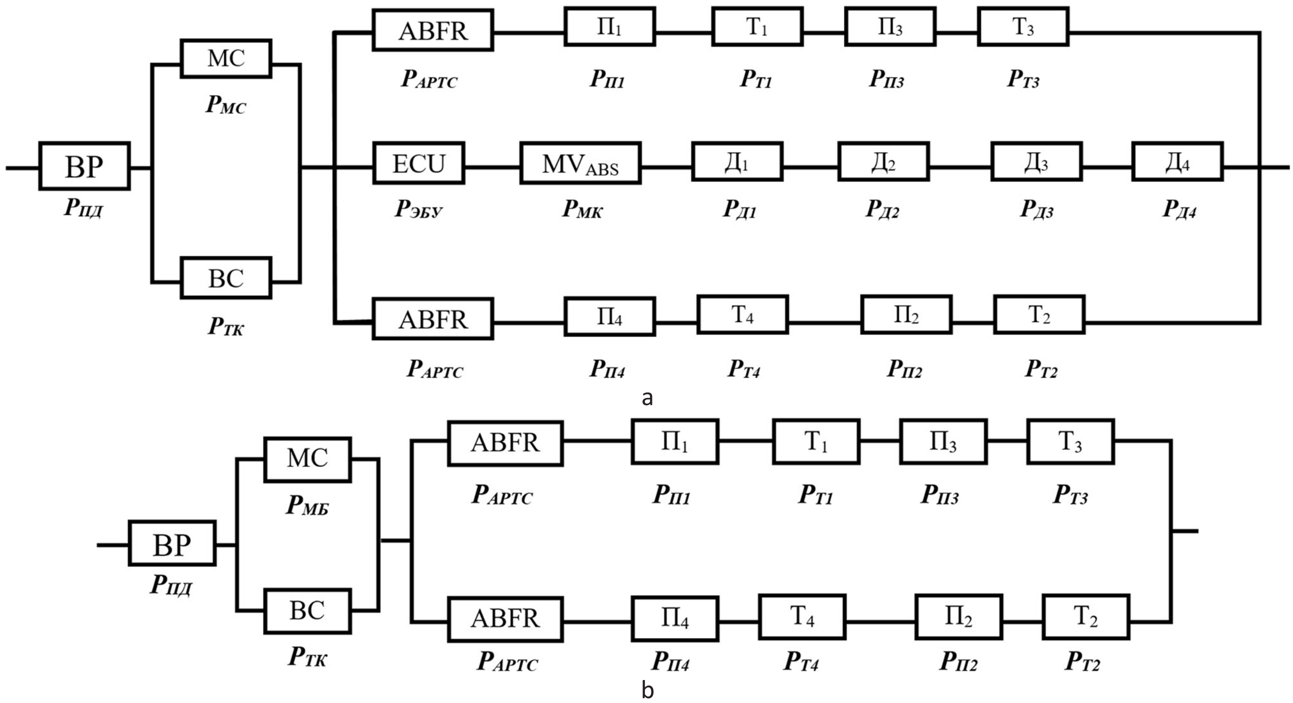
However, the reliability of such a block diagram is high in the block diagram shown in Figure 3, which corresponds to the level of probability that P (t) will work without accidents [3].

To qualify the reliability of the inspected vehicles, we determine the probability of their failure. For the



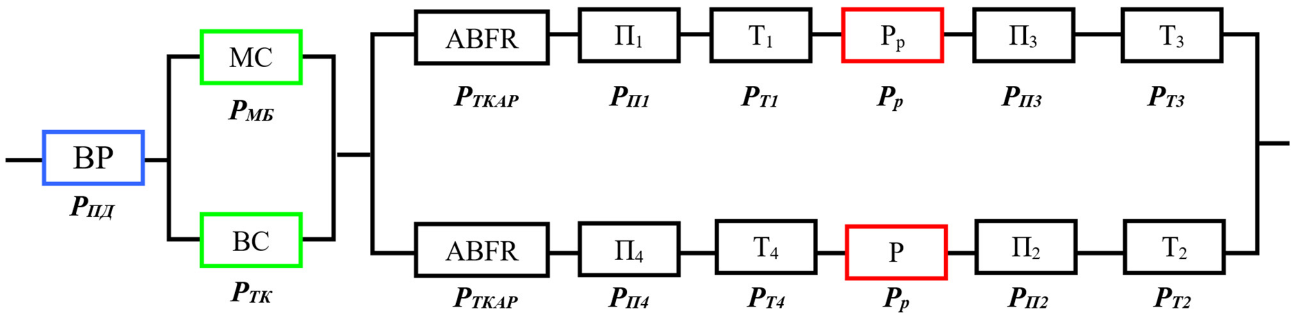
1 – compressor; 2 – pressure regulator; 3 – air dryer; 4 – four-way pneumatic protection valve; 5, 6, 7 – compressed air receivers; 8 – humid air tank; 9 – compressed air for additional devices; 10 – non-return valve; 11 – brake chamber; 12 – the brake valve; 13 – parking brake crane; 14 – two-way two-position valve; 15 – automatic brake force regulator; 16 – pneumatic cylindrical power accumulator; 17 – the accelerator valve; 18 – ABS solenoid valve; 19 – the sensor; 20 – ABS control unit; 21 – manometer

Figure 1 – Scheme of the bus brake system



a – ABS is able to work; b – ABS is out of operation: BP – brake pedal; MC – mechanical connection; BC – brake crane; ABFR – automatic brake force regulator; ECU – electronic control unit of the ABS; MV_{ABS} – ABS magnetic valve; Pi – wheel brake drive (pneumatic cylindrical power accumulator); Ti – wheel brake mechanism; Di is a wheel angular velocity sensor

Figure 2 – Scheme of a bus double-loop brake system



BP – brake pedal; MC – mechanical connection; BC – brake crane; ABFR – automatic brake force regulator; Pi – wheel brake drive (pneumatic cylindrical power accumulator); Ti – wheel brake mechanism; Pp – brake force regulator

Figure 3 –Block diagram of a two-contour brake system (with a brake force regulator)

conditions of use of the vehicle in accordance with the diagram (Figure 2, version a) P(t) is defined in the formula:

$$P_{general} = (P_{CP} \cdot (1-(1-P_{MC}) \cdot (1-P_{BV})) \times \\ \times (1-[1-(1-(1-P_{BC} \cdot P_{BW}^2 \cdot P_{BM}^2)^2)]) \times \\ \times [1-P_{ECU} \cdot P_{RP} \cdot P_{SV} \cdot P_{EMRP} \cdot P_{WSS}^4]) \quad (1)$$

there $P_{general}$ – the total probability of system failure;

P_{CP} – the probability of continuous operation of the control (pedal);

P_{MC} – the probability of continuous operation of the mechanical connection;

P_{BV} – the probability of continuous operation of the brake valve;

P_{BC} – the probability of continuous operation of the main brake cylinder;

P_{BW} – the probability of stationary operation of the brake wheels;

P_{BM} – the probability of failure of the brake mechanism;

P_{ECU} – the probability of uninterrupted operation of the electronic control unit;

P_{RP} – the probability of continuous operation of the return pump;

P_{SV} – the probability of continuous operation of solenoid valves;

P_{EMRP} – the probability of continuous operation of the electric motor of the return pump;

P_{WSS} – probability of continuous operation of wheel speed sensors.

According to the proposed block scheme in Figure 2, the probability $P(t)$ is expressed as follows:

$$P_{general} = P_{CP} \cdot (1-(1-P_{MC}) \cdot (1-P_{BV})) \times \times (1-(1-P_{BC} \cdot P_{BW}^2 \cdot P_{BM}^2)^2) \quad (2)$$

For the scheme diagram in Figure 3, the probability of continuous operation is as follows

$$P_{general} = P_{CP} \cdot (1-(1-P_{MC}) \cdot (1-P_{BV})) \times \times (1-(1-P_{BC} \cdot P_R \cdot P_{BW}^2 \cdot P_{BM}^2)^2) \quad (3)$$

there P_R – the probability of continuous operation of the brake force regulator.

Nowadays, classifiers are being developed in various fields of engineering, which are divided into categories according to the probability of failure (or duration of operation) of all major components and components of a particular product.

For devices and systems that ensure traffic safety in the vehicle, the unauthorized operating mode is considered to be 0.95.

Using the following formulas (1), (2) and (3), we find the probability of failure of each of the systems under consideration for different values of $P(t)$.

The observed difference in the obtained values of the probability of failure of the elements is explained by the different number of parts used in the system and additional redundancy, as well as by the fact that there is a probability of occurrence of a situation of prevention of the elements of the ABS, which significantly affects the operation of the brake system as a whole, and initially the control unit cannot be recognized as defective.

Therefore, it is necessary to increase the level of probability of failure of system elements to a value of 0.9705. If the control unit detects a malfunction that has occurred, the software is turned off and the brake system is activated. The probability level of this random $P(t)$ operation is 0.9509, and the braking efficiency, on the contrary, is significantly reduced.

While determining the failure of the resulting parametric system based on the values of diagnostic indicators, we check all possible causes (i.e., considering the total set of factors as a single one), the total cost of recovery (adjustment work, scope of control, etc.) becomes very important.

It is unknown the exact cause (factor) that led to the loss of the functionality of this system. Therefore, in order to reduce the cost of detecting a fault, it is necessary: first, to reduce the cost of identifying specific causes (or a complex of causes) by means of preliminary elemental diagnostics; secondly, it is rational to form a set of verifiable factors [3].

Therefore, it is necessary to develop an algorithm for the sequence of verification and elimination of certain controlling factors.

Y_{np} set the boundary value of the value of the specific braking force in the system «limit-permissible». Then the rule for making a decision on the technical impact is written as follows:

elimination

To consider at the general scheme for forming a multi-factor model for finding defects. From figure 4, it can be seen that in the mixed period with the initial set of different factors (reasons for which diagnostic parameters exceed acceptable values) $\{Fi\}$, there is a

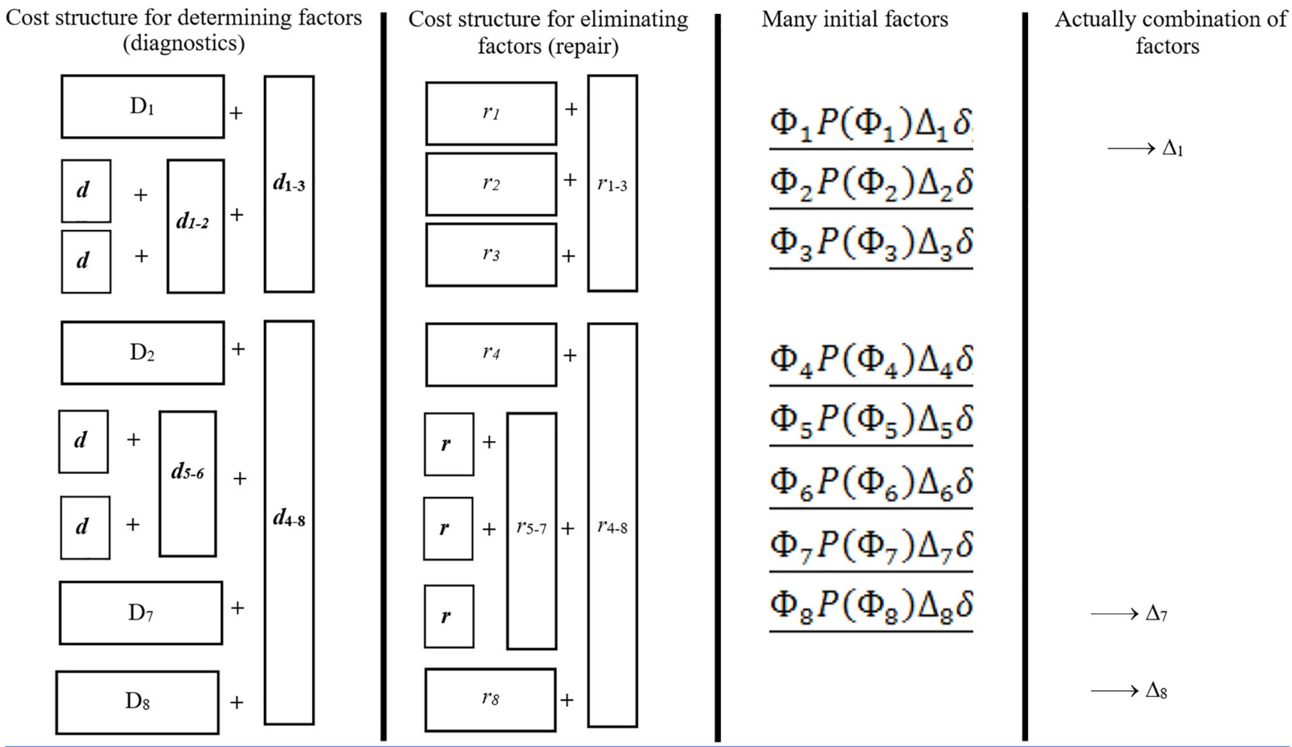


Figure 4 – Possible scheme for forming indicators for a multi-variable model

probability of their manifestation $P\{Fi\}$.

In addition, the appearance of an individual factor Fi leads to an increase in diagnostic parameters by a random variable Δ _ (in %), the characteristics of which(mean ΔI and variance Di) can be determined from experimental data.

Let's assume that the operating time before the defect occurs is subject to the law of exponential distribution, then the probability is equal to $P(Fi)$ [3]:

$$P(Fi) = 1 - e^{-\lambda l_i}, \tag{4}$$

here λ are the indicators of the distribution law (in this case, the intensity of the coefficient Fi);

l_i – average time between factors.

During this period, one or more factors may occur. At the same time, the degree of influence of each factor on the final result is unknown, so it is necessary to build a mathematical model that correctly describes the process under study. The task of this model is to determine the degree of influence of various factors on the studied parameters.

In general, the form of this dependence can be expressed by the regression equation of the form [64]:

$$y = \varphi(x_1, ..., x_n; z_1, ..., z_m, w), \tag{5}$$

there y – optimization indicator, in particular, an indicator that characterizes the technical state of the system;

x_1, ..., x_n – factors, i.e. controlled, independent variables (each factor can have multiple values or levels in practice);

z_1, ..., z_m – variables that affect parameter optimization are unmanaged.

The regression equation and the constraints imposed on changes in variable factors are called a mathematical model. A mathematical model is a representation of the most important aspects of the process. The variety of combinations of arguments and determines the surface of the answer (the function under study). It can be assumed that the functions in the space under consideration are linear and can be expressed by regression of the form:

$$y = b_0x_0 + b_1x_1 + b_2x_2 + ... + b_nx_n = \sum_{i=0}^{n} b_i x_{ij}, \tag{6}$$

there b_i – model coefficients that indicate the degree of influence of this factor on the response function (for example, its own braking force); the residual method describing the average value of the response function at $b_0 - x_i = 0$; x_0 = fixed variable, equal to one.

Quantitative values of the factor (x_1, x_2, ..., x_n) are determined by experimental data, and the coefficients (b_1, b_2, ..., b_n) that can be said about the effect of each factor on the essence are calculated using experimental planning methods [6].

Figure 5 shows a block diagram of the model of reliability management of the transport system, which affects traffic safety.

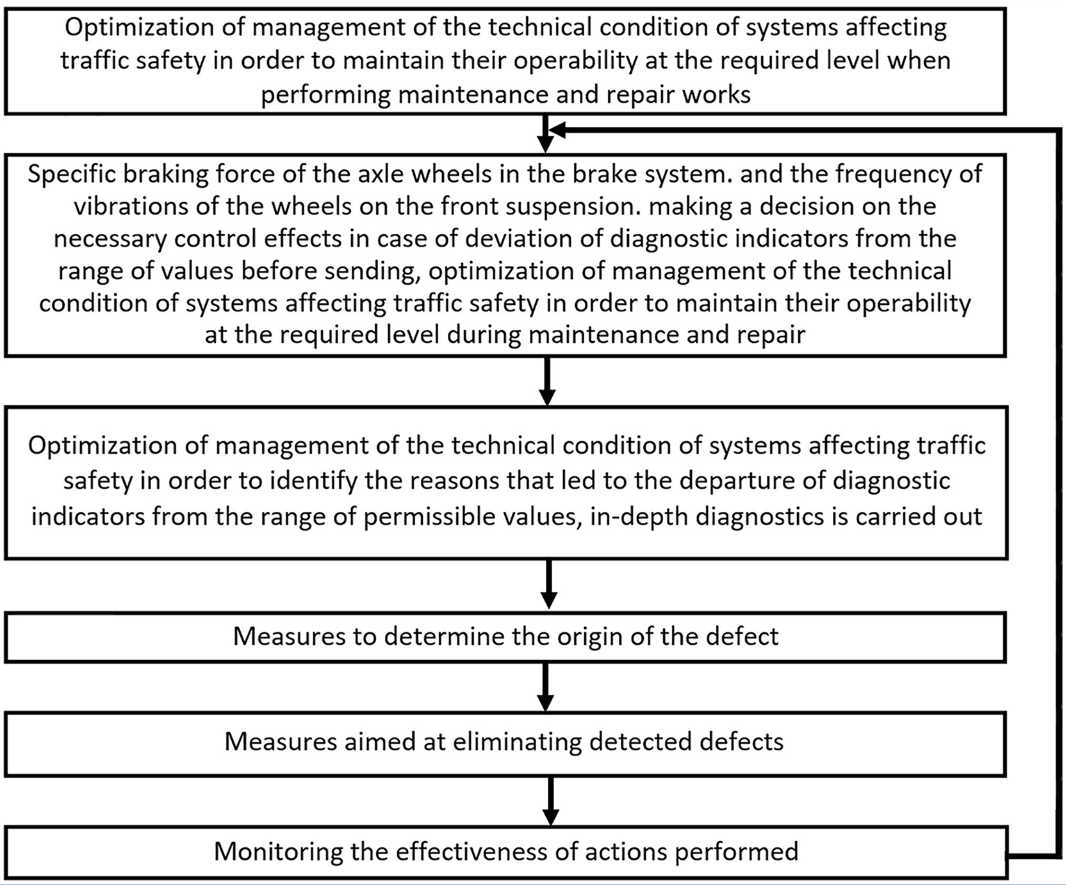


Figure 5 – Flowchart of the expansion reliability of the car system affecting traffic safety

Conclusion

The development of an effective system for evaluating the effectiveness of vehicles based on a comprehensive method of diagnostics of Vehicle Safety Systems is a very relevant issue, as it made it possible to monitor the technical condition of the vehicle and predict safe working hours in advance.

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Аңдатпа. *Мақала көлік құралдарына диагностикалық ақпарат негізінде тежеу жүйесін және автокөлік құралдарының пайдалану жағдайын қамтамасыз етудің тиімді жүйесін әзірлеуге арналған. Автомобильдерді желіге шығару коэффициентінің төмендігінен олардың тұрып қалуынан күнделікті шығындар миллион теңгемен есептеледі. Тоқтап қалудың негізгі себептерінің бірі-қанағаттанарлықсыз техникалық жағдай. Автокөліктерді техникалық жағынан жақсы жағдайда ұстау құны тасымалдаудың жалпы құнынан 15-20%-ды құрайды. Көлік құралдарының қауіпсіздігін қамтамасыз ету жүйелерін диагностикалаудың кешенді әдісіне негізделген. Көлік құралдарының тиімділігін бағалаудың тиімді жүйесін әзірлеу өте өзекті мәселе болып табылады. Ол техникалық жағдайды бақылауға және қауіпсіз жұмыс уақытын алдын ала болжауға мүмкіндік берді.*

Кілт сөздер: *көлік, қозғалыс қауіпсіздігі, тежеу жүйесі, бұғаттауға қарсы жүйе, қабілеттілік, диагностика, көрсеткіш.*

Оценка конструктивной надежности тормозной системы, влияющей на безопасность дорожного движения

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Аннотация. *Статья посвящена разработке эффективной системы обеспечения эксплуатационного состояния автотранспортных средств и тормозной системы на основе диагностической информации на транспортные средства. Из-за низкого коэффициента вывода автомобилей на линию ежедневные затраты от их простоя рассчитываются в миллионах тенге. Одна из основных причин отказа – неудовлетворительное техническое состояние. Стоимость содержания автотранспорта в технически хорошем состоянии составляет 15-20% от общей стоимости перевозки. Основана на комплексном методе диагностики систем обеспечения безопасности транспортных средств. Очень актуальным вопросом является разработка эффективной системы оценки эффективности транспортных средств. Она позволила контролировать техническое состояние и предсказать безопасное рабочее время.*

Ключевые слова: *транспорт, безопасность движения, тормозная система, антиблокировочная система, способность, диагностика, показания.*

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