UDC 519.688
IRSTI 27.41.77

https://doi.org/10.55452/1998-6688-2024-21-4-58-80

[1*]Sagidolla B.,
master's degree, ORCID ID: 0009-0009-3846-4701,
*e-mail: bizhigit.sagidolla@sdu.edu.kz
[1]Ali S.,
Bachelor, ORCID ID: 0009-0008-6990-3546,
e-mail: 190103355@stu.sdu.edu.kz
[1]Aibolat D.,
Bachelor, ORCID ID: 0009-0009-8215-8066,
e-mail: 190109006@stu.sdu.edu.kz
[1]Shayakhmetov N.,
Bachelor, ORCID ID: 0009-0007-7283-1275,
e-mail: 190107095@stu.sdu.edu.kz

[1]SDU University, Kaskelen, Kazakhstan

QUANTATIVE MODEL FOR ESTIMATING VEHICLE REPAIR COSTS IN INSURANCE CLAIMS

Abstract

This paper introduces a quantitative model designed to enhance the accuracy of vehicle repair cost estimations in the context of insurance claims. Motivated by the ubiquity of vehicle ownership and the frequent occurrence of vehicular damage, our research focuses on the development of a robust framework that integrates multiple variables affecting repair costs. These include parts pricing, labor charges, and the specifics of insurance policies. The proposed model leverages mathematical and computer modeling techniques to synthesize these elements into a predictive tool that aims to provide fair and precise repair cost forecasts. This tool is intended to facilitate equitable interactions between insurers and policyholders, ensuring that compensation aligns closely with actual repair expenses. The utility of this model is particularly significant in improving transparency and efficiency in handling insurance claims, thereby supporting better financial risk management and contributing to the stability of the insurance sector.

Key words: vehicle repair cost estimation, insurance claims, mathematical modeling, quantitative analysis.

Introduction

The purpose of this thesis is to develop a reliable and effective model for estimating the cost of vehicle repairs in the event of an insurance claim. The motivation for this research stems from the widespread ownership and usage of vehicles in modern society, where the incidence of accidents and vehicle damages is a common concern. Accurate estimation of repair costs is crucial to ensure that insurance claims are handled fairly and efficiently, thus protecting the financial interests of both insurers and policyholders.

The rationale for choosing this theme is based on the recognition of a significant gap in existing research and tools available for vehicle repair cost estimation. Despite the prevalence of vehicle ownership and the frequent occurrence of accidents, there is a noticeable absence of comprehensive models that integrate multiple variables–such as parts pricing, labor costs, and specific insurance policy conditions–into a single predictive tool. This absence highlights the need for a new approach to address the complexities of repair cost estimation in insurance scenarios.

The relevance of this topic is underscored by the theoretical and practical significance it holds in the field of insurance and vehicle repair. Theoretically, the development of an accurate and reliable estimation model contributes to the body of knowledge in quantitative analysis and predictive modeling. Practically, this model serves a dual purpose: it aids insurance companies in determining fair compensation for claims, and it assists policyholders in understanding the potential costs associated with vehicle repairs. This, in turn, promotes transparency and fairness in the insurance process.

Driving a car offers numerous benefits, including convenience, time savings, and a sense of freedom. However, it also carries significant responsibilities and risks. To underscore the importance of responsible driving and to help novice car owners understand the financial implications of vehicle ownership, we have developed a model that estimates repair costs accurately. This tool is particularly valuable in educating drivers about the importance of proper vehicle maintenance and the financial risks associated with accidents.

This research aims to develop a method for estimating vehicle repair costs that provides accurate and reliable estimates for insurance purposes. By addressing the gap in existing research and providing a practical tool for both insurers and policyholders, this study contributes to the improvement of the insurance claims process and promotes better financial risk management in the context of vehicle ownership.

Materials and Methods

The research material for this study comprises vehicle repair cost data, insurance policy details, and vehicle specifications. The dataset includes:

1. Vehicle Repair Cost Data: Collected from multiple sources, including auto repair shops, vehicle manufacturers, and online databases. This data includes the costs of parts, labor charges, and standard repair times for various vehicle models.
2. Insurance Policy Details: Information on various insurance policies, including coverage limits, deductible amounts, and specific conditions relevant to vehicle repair claims.
3. Vehicle Specifications: Data on vehicle make, model, year, mileage, engine type, and other relevant specifications, obtained from vehicle registration databases and manufacturer records.

The dataset is both qualitative and quantitative, providing a comprehensive basis for accurate repair cost estimation.

This section outlines the approach used to develop the predictive model for estimating vehicle repair costs in insurance claims, specifically how a quantitative model can be developed to accurately estimate vehicle repair costs in the context of insurance claims, considering multiple variables such as parts pricing, labor costs, and specific insurance policy conditions.

The hypothesis was a comprehensive, quantitative model that integrates various factors affecting vehicle repair costs can provide accurate and reliable estimates for insurance claims, leading to fairer and more efficient claim processing:

1. Data Collection: Gathering comprehensive data on vehicle repair costs, insurance policy details, and vehicle specifications from multiple sources.
2. Data Cleaning and Preprocessing: Standardizing the collected data, removing inconsistencies, and ensuring all variables are accurately represented.
3. Model Development: Using mathematical and computer modeling techniques to develop the predictive model. This phase involves selecting appropriate algorithms and statistical methods to analyze the data.
4. Model Validation: Testing the model using a subset of the data to ensure its accuracy and reliability. Adjustments are made as necessary based on the validation results.
5. Implementation: Integrating the model into a user-friendly application that allows users to input relevant data and receive accurate repair cost estimates.

Investigative Techniques:

1. Statistical Analysis: Using statistical methods to analyze the dataset and identify significant variables affecting repair costs.

2. Regression Analysis: Applying regression techniques to model the relationship between vehicle specifications, repair costs, and insurance policy details.

3. Machine Learning Algorithms: Implementing machine learning algorithms to improve the predictive accuracy of the model. Techniques such as decision trees, random forests, and neural networks are considered.

4. Software Tools: Utilizing Python programming language and libraries such as Pandas, NumPy, SciPy, and Scikit-learn for data analysis and model development. The Tkinter library is used for creating the graphical user interface of the application.

The developed model successfully integrates various factors affecting vehicle repair costs to provide accurate and reliable estimates for insurance claims. The validation phase demonstrates that the model achieves high accuracy, significantly reducing the discrepancies between estimated and actual repair costs. The application of machine learning algorithms further enhances the model's predictive capabilities.

The resulting tool facilitates fairer and more efficient processing of insurance claims by providing both insurers and policyholders with transparent and precise repair cost estimates. This research contributes to improved financial risk management and supports the development of the insurance sector by addressing the gap in existing estimation methods.

The study aims to develop a quantitative model for accurately estimating vehicle repair costs in the context of insurance claims, addressing the gap in existing estimation methods and improving the fairness and efficiency of the insurance claims process. The research hypothesis posits that a comprehensive model integrating multiple variables, such as parts pricing, labor costs, and specific insurance policy conditions, can provide precise repair cost estimates, benefiting both insurers and policyholders.

Methodologically, the research employs data collection, preprocessing, and analysis using statistical and machine learning techniques. The model development involved regression analysis and algorithms like decision trees and random forests, with validation conducted using test data to ensure model accuracy.

Key findings indicate that the model demonstrated high accuracy in estimating repair costs, significantly reducing discrepancies between estimated and actual costs.

The integration of the model into a user-friendly application allows for practical use by insurers and policyholders, enhancing transparency and fairness in the insurance claim process.

This research supports the advancement of the insurance sector by providing a reliable method for repair cost estimation, contributing to better financial risk management.

Literature review

The estimation of vehicle repair costs in insurance claims is a topic of significant research interest due to its practical implications for the insurance industry. Accurate repair cost estimation is crucial for fair and efficient claim processing, which has a direct impact on both insurers and policyholders. This section reviews fundamental and contemporary works by foreign authors, highlighting their scientific contributions and identifying research gaps that this study aims to address.

Outreville [1] provides a comprehensive overview of the interplay between insurance and economic development, emphasizing the need for accurate risk management tools in insurance. This foundational work underscores the importance of developing reliable estimation models that can contribute to economic stability and growth. Similarly, Nair [2] introduces techniques for data scraping, which are crucial for collecting repair cost data from various online sources. This methodological approach is fundamental to the current study, as it enables the integration of diverse data points into a cohesive estimation model.

In the realm of user interface development, Moore [3] and Hunt & Hunt [4] offer detailed guides on Python programming and the creation of graphical user interfaces. These works are instrumental in developing the user-friendly application component of the repair cost estimation tool. The practical insights from these sources help bridge the gap between theoretical modeling and real-world application.

Recent studies have explored advanced techniques and models for cost estimation. Lee and Kim [5] demonstrate the application of machine learning techniques in predicting vehicle maintenance costs, highlighting the potential for similar approaches in repair cost estimation. Zhang et al. [6] further this approach by integrating vehicle damage detection with cost estimation using deep learning, emphasizing the importance of a holistic approach that considers multiple variables. Additionally, Dorathi Jayaseeli J. D. et al. [7] developed state-of-the-art deep learning models for automatic vehicle damage detection and cost estimation, achieving significant improvements in accuracy and reliability.

Harshani and Vidanage [8] employed computational intelligence techniques to predict the severity and cost of vehicle body damages. Their work shows the effectiveness of image processing in estimating repair costs, paving the way for more sophisticated models. Another study by Dhieb et al. [9] utilized deep transfer learning for vehicle damage detection and localization, further validating the efficacy of machine learning in this domain.

Patil et al. [10] demonstrated the application of deep learning for car damage classification, showing notable accuracy improvements. This work complements the findings of Dwivedi M. et al. [11], who used deep learning-based models for vehicle damage detection and classification, underlining the growing importance of AI in automating damage assessment processes.

Elbhrawy et al. [12] explore the implications of precise repair cost estimations on the efficiency and fairness of insurance claims. Their research underscores the practical benefits of accurate estimation models, aligning with the objectives of this study. Meanwhile, Kallabayeva, Iskakova, and Rakhmetova [13] discuss the broader economic impact of the insurance sector in Kazakhstan, underlining the necessity for robust estimation tools that can support the sector's growth and stability.

Sartova [14] provides context on the challenges faced by the insurance sector in Kazakhstan, supporting the relevance of developing accurate estimation models. Her analysis of the insurance system's status and problems highlights the need for innovative solutions to improve claim processing and financial management.

Despite significant progress in the fields of machine learning and statistical analysis for cost prediction, there remains a gap in comprehensive models that integrate all relevant variables–such as parts pricing, labor costs, and specific insurance policy conditions–into a single predictive tool. Most studies focus on either the technical aspects of cost estimation or the economic implications, but rarely both. This study aims to bridge this gap by developing a holistic model that not only predicts costs accurately but also enhances the transparency and fairness of the insurance claims process.

By addressing these gaps, this research contributes to the existing body of knowledge and provides practical tools for the insurance industry to manage vehicle repair costs more effectively. This literature review has highlighted the evolution of methodologies and the critical need for integrated approaches, setting the stage for the subsequent development and implementation of the proposed estimation model.

Vehicle insurance sector

Despite the negative consequences of the global financial crisis and the seemingly depressive tendencies in other sectors of the Kazakhstan economy, especially in the banking sector, insurers are observing an increase in the dynamics of individual insurance sectors. Today, insurance is actively developing as an independent economic tool and is constantly expanding its activities. However, it is impossible to overlook some negative aspects of social security development. Despite the acceleration of the growth rate in, the ratio of insurance premiums to GDP in the Republic is only 0.59%. For comparison in EU countries this percentage reaches 8–9%.

Why does the insurance market in Kazakhstan need development? Insurance provides individuals and businesses with financial protection against risk and uncertainty. When more people and businesses have access to insurance, they can better manage risk, which can lead to greater financial security and stability. The insurance industry can also boost economic growth by providing a source of investment capital. Insurance companies invest premiums in a variety of assets, such as stocks, bonds, and real estate, which can help spur economic growth and create jobs. Citizens are being trained in more effective risk management and resource allocation. Gradually, citizens will cease to rely solely on the help of the government.

A strong insurance market can help boost confidence in the economy. When individuals and businesses have access to insurance, they will invest, spend and take risks. This, in turn, can contribute to economic growth and development.

Insurance means increased sustainability. A resilient insurance market can also help build resilience to economic shocks and disasters. Insurance can provide a safety net for individuals and businesses in times of crisis, helping them recover faster and reducing the impact of negative events on the economy.

There are several types of insurance products and services. We consider CASCO – the type of vehicle insurance that covers a wide range of risks and damages, and CTP – mandatory insurance of civil liability of the car owner. They provide coverage against unforeseen events such as traffic accidents, theft and natural disasters.

CTP in Kazakhstan is a mandatory insurance product. There are 250 cars per 1000 people. About 540–570 thousand driver's licenses are granted annually. The CTP policy protects the responsibility of the car owner to those injured in an accident. That is, the insurance company under this policy will pay compensation only to the owner of the injured car. The CASCO policy protects the car itself. In this case, the insurance company will pay compensation to the policyholder himself.

Even considering that the tariffs for optional car insurance in Kazakhstan are quite low, the demand for it is not growing. This is due to the large number of fraud cases in this area. Here we can assume that citizens are not interested in getting a casco, based on the number of payments of a similar mandatory product. CASCO is mainly formed at the expense of legal entities and collateral agreements for car loans to individuals. If we consider the absolute figures for the market, then according to the data of National Bank for the first of April insurance companies collected 31 billion tenge of premiums for mandatory products. CASCO collected 21 billion premiums.

According to the Statistics Committee, about 15 thousand traffic accidents occurred in Kazakhstan in 2022. This is 9% more than in 2021 (Figure 1).

It is interesting to note that 30% of all traffic accidents in 2022 occurred in the city of Almaty. And almost 50% of the accidents occurred in the entire Almaty region.

Apparently vehicle insurance commonly offers 3 categories of coverage. There is collision coverage, comprehensive coverage and liability coverage.

However, this coverage has several limitations. First, car insurance may exclude coverage of prior damage or fraying of the vehicle. This implies that if the car has already been damaged before the purchase of the insurance policy, the insurer may not cover the repair costs. Second, there may be restrictions, limits on the amount of compensation for repair or replacement costs.

Unfortunately, according to the unfavorable feedback of Kazakhstani policyholders in the official social networks of insurance companies and on other websites, the amount of insurance payments often does not cover real losses. Companies use the conditions and exceptions in the policy agreements in their favor, and make complaints against the documents provided in order to reduce the amount of payments. Nevertheless, insurance companies can also reduce the amount of the payment if they suspect the policyholder of fraud due to disputed circumstances and incorrect documents provided.

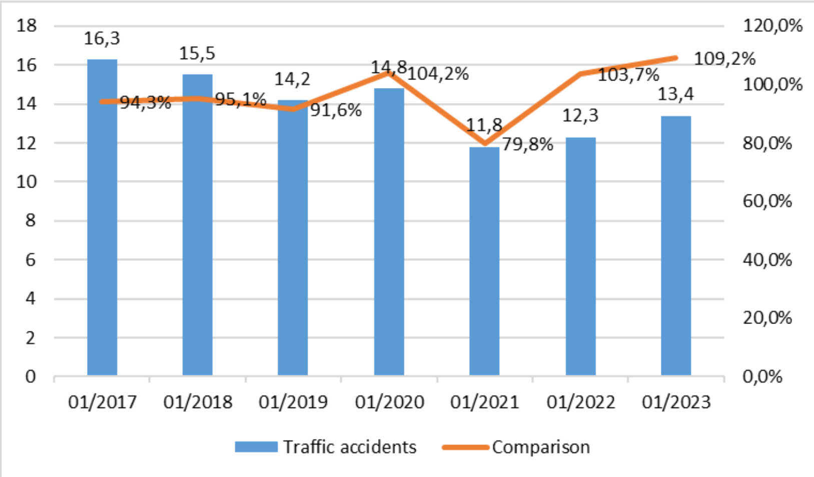

Figure 1 – Traffic accidents in Kazakhstan

However, in the case when the inspection and evaluation of the vehicle is carried out by an insurance company, the policyholder must be aware of the rules for calculating the cost of restoration work. Otherwise, the tricks described above by unscrupulous companies can bring the policyholder, the driver, to large unnecessary costs.

Large insurance benefits provide individuals with financial security and protection against unforeseen events and against overpayments from their own pocket. Increased insurance benefits can stimulate economic growth and development, as they create a demand for insurance products and services. This demand can lead to the growth of industries such as healthcare, finance, and insurance. For instance, if we consider life insurance, the healthcare industry benefits from increased insurance benefits, as it allows for more people to access medical services and treatments, leading to increased demand for healthcare providers and facilities. Similarly in CASCO and CTP. The turnover and demand for repair services will result in an increase in insurance benefits. Because on the roads of the country we can notice a lot of old and worn-out cars with broken, dented and missing car body elements.

While increased insurance benefits can have a positive impact, there are also potential drawbacks and barriers to achieving widespread insurance coverage. One potential drawback is the increased cost of insurance premiums, which can make it difficult for some individuals to afford insurance coverage. According to the statistics of active policies, as of March 1, 2023, the average insurance premium for passenger vehicles is 13,166 tenge. In addition, barriers to entry may exist, such as limited availability of insurers in some areas or limited coverage for pre-existing conditions.

There are some statistics that allow us to review the situation.

There is Table 1 on the accepted insurance premiums of Kazakhstani companies according to the reports of general insurance companies (not life insurance) for the first day of the year.

And Table 2 is a similar table on insurance payments of Kazakhstani companies according to the reports of general insurance companies (not life insurance) for the first day of the year. By a simple visualization, we can understand that Eurasia is a company with a large turnover. In four companies, such as Centras Insurance, Victoria, Commesk, NOMAD, there is a decrease, presumably due to the number of policyholders.The rapid growth is shown by Zhusan, Freedom Finance, supposedly thanks to convenient online services. The data source is the National Bank. (Values in thousands of tenge).

Table 1 – CTP insurance premiums (in billions of KZT)

Insurance companies	01.01.2021	01.01.2022	01.01.2023
JSC "Subsidiary of Halyk Bank of Kazakhstan "Insurance Company "Halyk"	16,7	22,6	14,5
JSC "Grain Insurance Company"	0,1		
JSC "KH&MIC INTERTEACH"	0,6	0,4	1,7
JSC "Oil Insurance Company"	5,3	5,3	5,6
JSC "Amanat Insurance Company"	3,7	4,8	5,6
JSC "Centras Insurance Company"	3,0	1,9	3,3
JSC "Freedom Finance Insurance Company"	2,0	4,4	4,9
JSC "Jysan Garant Insurance Company"	3,8	9,5	16,8
JSC "ASKO Insurance Company"	5,3	5,9	7,5
JSC "Victoria Insurance Company"	0,6	0,6	0,6
JSC "Eurasia Insurance Company"	21,2	28,1	34,4
JSC "Kazakhmys Insurance Company"	0,2	0,2	0,3
JSC "Kommesk-Omir Insurance Company"	4,7	3,6	2,7
JSC "London-Almaty Insurance Company"	2,6	1,9	
JSC "NOMAD Insurance Company"	10,5	9,4	9,4
JSC "TransOil Insurance Company"	0,7	0,5	0,5
JSC "Basel Insurance Company"	0,0	1,4	4,4

Table 2 – CTP insurance payments (in billions of KZT)

Insurance companies	01.01.2021	01.01.2022	01.01.2023
JSC "Subsidiary of Halyk Bank of Kazakhstan "Insurance Company "Halyk"	5,4	9,0	9,3
JSC "Grain Insurance Company"	0,2	-	-
JSC "KH&MIC INTERTEACH"	0,2	0,1	0,2
JSC "Oil Insurance Company"	2,4	2,4	2,8
JSC "Amanat Insurance Company"	1,6	1,2	1,7
JSC "Centras Insurance Company"	1,5	1,0	1,0
JSC "Freedom Finance Insurance Company"	0,6	2,4	4,3
JSC "Jysan Garant Insurance Company"	0,8	2,2	5,8
JSC "ASKO Insurance Company"	1,7	1,5	1,8
JSC "Victoria Insurance Company"	0,4	0,3	0,3
JSC "Eurasia Insurance Company"	7,2	11,4	16,4
JSC "Kazakhmys Insurance Company"	0,1	0,1	0,1
JSC "Kommesk-Omir Insurance Company"	2,5	1,8	1,3
JSC "London-Almaty Insurance Company"	0,8	0,9	-
JSC "NOMAD Insurance Company"	3,4	2,8	2,3
JSC "TransOil Insurance Company"	0,4	0,6	0,4
JSC "Basel Insurance Company"	0,1	0,3	1,4

CTP – civil liability insurance for drivers of vehicles - is mandatory. And there is a table of active policies, considering all types of vehicle. The Figure 4 shows the distribution of policies. By a simple visualization, it becomes obvious that in the city of Almaty, in the Almaty region (and in the Turkestan region) there is the largest number of active insurance policies. The entire Almaty region, including the megalopolis, accounts for 25.3% percent of the total number of policies. Whereas in the Akmola region and in the city of Astana, in total, only 12% percent of this parameter.

There is a big gap in the next column. The value of the overall insurance premium only in the city of Almaty is 24.3% of the total.

Table 3 – Active policies by regions

Regions	Number of policies	Insurance premium	Average insurance premium
Astana City	299 120	6 232 377 201	20 836
Almaty City	492 130	13 996 232 524	28 440
Akmola Region	159 937	1 793 394 429	11 213
Aktobe Region	129 761	1 637 270 206	12 618
Almaty Region	458 895	6 331 832 516	13 798
Atyrau Region	98 393	2 523 546 321	25 648
Other	2 102 269	24 987 555 482	11 886
ALL	3 740 505	57 502 208 676	15 373

Now consider the other side. Obviously, the number of active insurance policies in the Almaty region is much higher than in other regions. And this number is growing every month, and the probability of accidents is also increasing. Very frequently we witness traffic accidents on the roads of the city. And most probably, passenger cars will become participants in a traffic accident.

According to reports for the first of March 2023 in Figure 2, there are about 3.74 million active insurance policies in the country, and 88.62% are passenger cars. For this type of vehicle, the average insurance premium is 13,166 tenge. And our calculator considers the costs of only passenger cars from all types of transport.

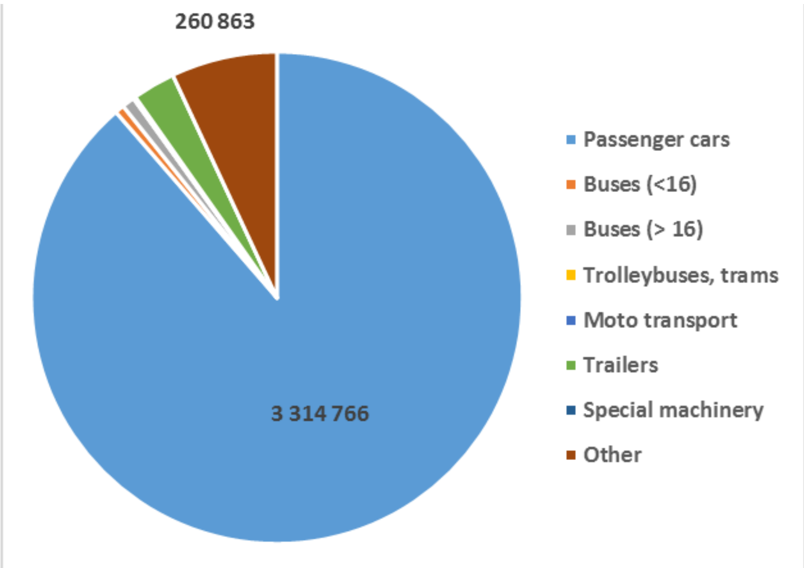

Figure 2 – Number of active policies by types of vehicle

Methodology

To do a car inspection, you will need a camera and, if necessary, a simple measuring device. If the vehicle is in poor condition, the inspection takes place at the depot. The inspection can also be carried out by a specialized technical center (service station), when these conditions are initiated by the individual who ordered the expert report. The vehicle must be presented for inspection in order and cleanliness that ensure the safety and maneuverability of high-quality control. There must be access to the engine compartment, cab, trunk, etc. Whoever is assigned the examination, or the owner of the vehicle must provide documents proving the right to use the vehicle. If the vehicle is damaged because of a traffic accident, it is also necessary to provide documents about the accident, such as B. Post-accident report, Vehicle technical condition inspection report with a description of damages, accident diagram, declarations, etc.

During the inspection of the vehicle, we need the necessary data for the inspection:

- Identification data of the vehicle, with a check of their correspondence to the identification data specified in the documents;
- Mileage of the vehicle according to the odometer reading, with an assessment of the reliability of the displayed value;
- Completeness and equipment of the vehicle, the presence of additional equipment;
- List and volume of defects and damages that exist at the time of the inspection, caused by the specific road accident;
- Signs of previously conducted repairs of the vehicle, replacement of units, assemblies, and expensive components.
- The list of restorative work, methods and volumes of its implementation in accordance with the standards for technical maintenance and repair recommended by the manufacturer of the vehicle.

The data recorded because of the vehicle inspection allows the expert to proceed with calculations in accordance with the objectives of the study.

Calculation of vehicle wear and tear

When determining the replacement cost of a vehicle, wear and tear should be understood as a quantitative measure of the physical aging of the vehicle under the influence of external and internal factors, obtained during operation and characterizing the condition of the vehicle as a whole and its individual elements (assemblies, parts).

The amount of physical wear and tear of component parts (parts, units and assemblies) of the vehicle of foreign and CIS production is calculated according to Formula (1).

$$D_{phys} = 100 * (1 - e^{-\Omega}) \tag{1}$$

where:

e – is the base of natural logarithms;

Ω – is a function depending on the age and actual mileage of the vehicle since the beginning of operation.

The function Ω, which depends on the age and mileage of the vehicle, is determined by Formula (2).

$$\Omega = (a * A + b * L) \tag{2}$$

where:

A – is the service life of the vehicle (years), with an accuracy of one decimal place. The countdown of the service life begins from the moment the vehicle is put into operation;

L – is the mileage of the vehicle. The actual mileage of the vehicle is determined by the readings of the vehicle's serviceable odometer, and in case of doubt about their reliability – by the estimated mileage;

a, b – are parameters depending on the type of vehicles, determined in accordance with Table 4.

Indicators for calculating the function depending on the age and mileage of the vehicle.

Table 4 – Table of coefficients a, b

Category (type)	Vehicle brand	a	b
Passenger cars	ВАЗ (Lada), ГАЗ, ЗАЗ	0,057	0,003
	Brilliance, BYD, Chery, Derways, FAW, Geely, Great Wall, Hafei, Haima, Lifan, Luxgen, Xin Kai	0,057	0,0029
	Aston Martin, Bentley, Bugatti, Ferrari, Jaguar, Maserati, Porsche, Audi, BMW, Mercedes-Benz, Mini, Rover, Alfa Romeo, Citroen, Fiat, Ford, Opel, Peugeot, Renault, Saab, SEAT, Skoda, Volkswagen, Volvo	0,042	0,0023
	Acura, Buick, Cadillac, Chevrolet, Chrysler, Dodge, Hummer, Infiniti, Jeep, Lexus, Lincoln, Mercury, Pontiac	0,045	0,0024
	Hyundai, Kia, Ssang Yong, Daewoo	0,052	0,0026
	Daihatsu, Honda, Isuzu, Mazda, Mitsubishi, Nissan, Subaru, Suzuki, Toyota	0,049	0,0025
Trucks - flatbed trucks, box trucks, dump trucks, tipper trucks, tractor trucks		0,077	0,0023
Buses		0,113	0,0008
Trolleybuses and tramcars		0,098	0,0008
Trailers and semi-trailers for trucks		0,09	0
Trailers for passenger cars and residential vehicles (car-house type)		0,06	0
Motorcycles		0,07	0
Scooters, mopeds, scooters		0,09	0
Agricultural tractors, self-propelled agricultural, firefighting, municipal, loading, construction, road, earthmoving and other equipment based on automobiles and other self-propelled bases		0,15	0
Bicycles		0,04	0

Determination of vehicle mileage

To determine the mileage of a vehicle (vehicle), the value taken from a serviceable odometer or specified in the accounting documents on the vehicle is used. In cases where there are doubts about the reliability of the specified mileage, the calculated path is used.

The estimated mileage of the vehicle is determined in the following cases:

- if the readings of a serviceable odometer differ from the value of the calculated mileage of a similar vehicle by more than 25% downwards;
- when replacing the odometer, including the replacement of the body (cab) assembly or the chassis of the vehicle during operation;
- if the odometer malfunctions;
- if a part of the odometer drive is damaged;
- if the vehicle has a five-digit odometer with a service life that allows us to assume that the value of the odometer will be reset when its maximum value reaches 99,999 km (miles);
- if there is no technical possibility of indicating the readings of the electronic odometer at the time of inspection of the damaged car.

The estimated mileage is determined by calculating the average annual mileage of the same type of vehicle and the duration of its operation, using the Formula (3).

$$L_T = L_0 * A^{M(L)} \quad (3)$$

where:

A – is the service life of the vehicle;

$M(L)$ – is the braking coefficient, considering the decrease in the average annual mileage as the vehicle is operated, determined in accordance with Table 5;

L_0 – is the average annual mileage, determined in accordance with Table 5.

Table 5 – Table of coefficients L_0 and $M(L)$

Type of vehicle	L_0, 10^3 km	$M(L)$
CIS passenger cars	15	0,86
European, Turkish passenger cars	15	0,9
American passenger cars	15	0,9
Asian cars (without Japan)	15	0,87
Japanese passenger cars	15	0,92

Two basic approaches can be used to determine the value of a vehicle:

- comparative, based on an analysis of the primary and secondary markets for sales of vehicles;
- cost approach, based on determining the costs required to restore or replace the object under study, taking into account its depreciation.

The income approach in determining the cost of vehicles is not applied. This is since this approach is effective mainly for the valuation of revenue generating objects – enterprises, industrial complexes, and other businesses. Vehicles, as a rule, are the elements of a system that generates income.

Initial data to determine the market value of vehicles are the data established during the inspection of vehicles, the study of documents on the vehicle, reference literature, study of case files, and other submitted documents:

- brand, model, modification;
- body type;
- date of issue;
- mileage;
- equipment and completeness;
- the technical condition of the vehicle;
- volume and quality of previously performed repair effects, including replacement of major assemblies and units.

Determination of the market value using the market information method

The market value of the vehicle denotes the estimated amount of money for which the vehicle can be sold in a competitive transaction when the parties to the transaction have all available information about the subject of the valuation and the price of the transaction and there are no exceptional circumstances affecting out if:

- one of the parties to the transaction is not obliged to sell the object of valuation, and the other party is not obliged to buy it;
- the parties to the transaction are well informed about the subject matter of the transaction and act in their interests;
- the price of the transaction corresponds to the cash consideration of the subject of the valuation and there was no compulsion on the part of the transaction parties.

The market value of is determined according to the following scheme:

The expert analyzes the available price information from the following sources:

- price lists of organizations selling new and used cars;
- information on the prices of new and used vehicles published in regional magazines;
- information on regional market prices for new and used cars, posted on thematic sites.

The research part of the question should list the price information sources from which the market value of vehicles is determined.

When selecting an information source, it should be noted that it must meet the following requirements:

- have the status of an official publication or a reference to the publisher (organization) that provided the information;
- contain information about the properties of the object (eg., object, type, brand, model, identifying elements, main characteristics) in order to establish an unambiguous match of the information provided with the object of investigation;
- providing reliable and timely information;
- have the efficiency to convey new information.

The method of market information is recommended for new cars, or for cars with mileage up to 1000 km and with a period of operation up to 1 year.

The market value of the vehicle is determined using Formula (4).

$$C_m = \frac{\sum_{i=1}^{n} P_i}{i} \tag{4}$$

where:

P_i – price of the i-th analogue of vehicle in currency of tenge;

i – number of offers, i > 3.

The concept of repair of the vehicle

Restorative repair is a set of works necessary to restore the technical characteristics of the vehicle and its consumer properties, to the condition that the vehicle had immediately before the damage.

The cost of restorative repair of the vehicle means the most probable amount of costs, sufficient to restore the vehicle to its original, before the accident, condition.

Calculation of the cost of restoration of the damaged vehicle is determined at the time of the study, according to the Formula (5).

$$C_r = C_w + C_m + C_d \tag{5}$$

where:

C_w – the cost of repair work;

C_m – the cost of materials used in the restoration process;

C_d – the cost of details, units, and assemblies to be replaced (replaced).

Volume, methods, types, technology, and labor intensity of repair works are determined depending on the nature and extent of damage, and condition (corrosion damage) of parts and assemblies, taking into account the need for disassembly/assembly, adjustment, adjustment, painting, anti-corrosion, anti-noise treatment, etc., in accordance with the technology established by the vehicle manufacturer, and in the absence of the required repair technology from the manufacturer - by expert evaluation according to available analogs and data from the official representative offices of the manufacturers.

The labor requirements for the replacement of body parts include the following work:

- disconnection and removal of the old part with the removal of metal residues, loose formation rust (corrosion);
- straightening the mating edges;
- fitting and welding a new part with cleaning of welding spots and welds;
- smoothing the surfaces with the filler, with grinding the defective places sanding the defective places.

Replacement of the body or frame of a passenger car, minibus, bus, cab or truck frame can be assigned when they do not meet the established requirements for their acceptance for repair.

Determine the cost of spare parts and materials

The reliable market value of spare parts are the prices of sellers who sell spare parts as their main business. The expert must indicate at least two sources of information about the value of the spare parts (name, telephone number, address, website address) applying the principle, economic feasibility.

1. For vehicles under warranty as well as for vehicles up to 7 years of operation it is recommended that the cost of original spare parts and components be taken on the basis of data from an official dealer or on the basis of data from a specialist store officially representing the trademark in question.

2. For vehicles with the service life exceeding 7 years, the cost of spare parts and components should be taken based on data on the cost of spare parts corresponding to the requirements established by the vehicle manufacturer, considering the principle of economic feasibility.

3. In the course of estimating the cost of components, sub-assemblies, assembly units it is necessary to indicate their full names in accordance with the catalog of spare parts for the concrete brand (model, variation) of the transport means, drawn up by the transport means manufacturer, or in the electronic database of cost information in relation to components (components, sub-assemblies, assembly units, materials), in the absence of such sources - in a program calculating complex or a price-list of the corresponding component parts (components, sub-assembly, assembly units, materials) supplier.

4. When choosing components (parts, units, assemblies, aggregates, materials) it is recommended that the delivery time of the required products should not exceed 45 calendar days.

5. In cases stipulated by the technological documentation, when replacing individual component parts (parts, units, assemblies, aggregates, materials), the need for their replacement is considered, considering the repair kit, which includes not only the component parts (parts, units, aggregates, materials) being replaced, but also products, which fully ensure elimination of damage.

6. It is necessary to indicate both the full cost of restoration (real damage: without considering the fall in value of the replaced parts due to their wear and tear) and the cost of restoration (direct damage: considering the fall in value of the replaced parts due to their wear and tear).

7. In exceptional cases (for example, if the delivery period of new parts (units, aggregates) exceeds 45 days, if there is no guaranteed delivery or if the production of new parts is stopped), if there is a market of used parts, it is reasonable to use such parts (units, aggregates) when calculating the cost of repair parts, their market value is used. In this case, the cost of used component parts (parts, units, assemblies) cannot exceed the cost of new component parts (parts, units, assemblies), considering their wear and tear.

Depreciation of component parts (parts, units, aggregates) to be replaced in these cases is not considered. The cost of spare parts is determined based on reliable data on the market value of new spare parts, existing in the region at the time of the study.

The cost of spare parts, taking into account physical wear and tear, is determined using Formula (6).

$$C_d = C_d^{new} * \left[1 - \frac{D_{phys}}{100\%}\right] \tag{6}$$

where:

C_d^{new} – the cost of a new part, the tenge.

The cost of materials for the restoration of the vehicle is calculated using Formula (7).

$$C_m = \sum_{i=1}^{n} P_i^m * N_i^m * K_i^e \tag{7}$$

where:

C_m – the cost of materials for the restoration of the vehicle (tenge);

n – number of types of materials needed for repair;

P_i^m – cost of one unit of i-th kind of material (tenge);

N_i^m – specific rate of consumption of the material of the i-th kind (units of i-th rate of consumption of the material of the i-th kind (units of material/repair units);

K_i^e – number of repaired units (number of parts, units, assemblies, kilograms, meters, square meters, etc.), for the restoration of which the material of the i-th kind is necessary.

The specific rate of consumption of the material of the i-th type is calculated as the average value determined according to the data of producers of such material, presented in the commodity market of this material.

In the absence of such data, the specific rate of consumption of the material of the i-th kind is taken according to the reference books issued by the manufacturers of the vehicle.

The number of repair units (for example, the number of parts, units, assemblies, kilograms, meters, square meters) subjected to restoration repair using the material of the i-th kind, is determined by the results of the inspection of the vehicle as in example Table 6.

Table 6 – Example of calculating painting works cost

Part: Hood	Area	1,4 m^2	
Material designation	Consumption, kg	Cost per unit, tenge	Total cost of the unit, tenge
Primer	0,392	8 698,2	3 409,69
Primer remover	0,1176	3 290,0	386,90
Enamel	0,336	9 100,0	3 057,60
Enamel remover	0,1008	4 585,0	462,17
Polyester putty	0,14	3 761,5	526,62
Total:			7 842,98

The cost of repair work is determined based on the manufacturer's standards of labor intensity of maintenance and repair of vehicles, and the cost of one standard hour of maintenance and repair of the vehicle type. The total cost of repair work is determined using Formula (8).

$$C_w = C_{normhour} \sum T_{ri} \tag{8}$$

where:

$C_{normhour}$ – the cost of a standard hour, tenge.

T_{ri} – the standard time required to complete a specific repair task, measured in norm-hours. It varies depending on the complexity of the repair and is provided by the manufacturer or standard repair guidelines.

In determining the labor intensity of vehicle repair, you must use the standards of the labor intensity of maintenance and repair work, developed and approved by the manufacturer of the vehicle or authorized organizations, and if you use a software product, in conclusion, must specify its license data (license number or a few of the electronic key).

Technical impacts, such as: painting, removal / installation, disassembly / assembly, and replacement, must be taken in priority from the same brand, model as the examined vehicle. If there are no standards provided by the manufacturer of the vehicle, it is necessary to use the known standards of labor intensity for the vehicle of a similar brand, but model, for which this type of technical action is provided.

Labor inputs for repair of body parts are taken according to the data of the vehicle manufacturer if such are provided by it. If there is no information about the standards of labor inputs for the repair of body parts for passenger cars, trucks and buses established by the vehicle manufacturer (published in reference books or implemented in software products), these standards shall be determined:

- with the use of formulas determining the labor intensity of repair work on the body part, depending on the damaged area, nature of damage, and the constructive nature of the part both established within the software packages and given in the special literature;
- with the use of integrated labor-intensiveness indicators, depending on the area of the part and the category of deformation complexity;
- according to the labor-intensiveness standards for similar technical equipment without regard to their country of origin; in doing so, it is necessary to consider the recommendations set forth.

Labor costs of technical actions to eliminate body distortions are taken for vehicles made in the CIS countries and other manufacturers according to the vehicle manufacturer's data.

Data-Based Estimation Model Development

Accurate information about the vehicle is required for the calculator to operate. The brand and model of the car allow you to determine not only tabular data for various calculations, but also to find an analogue in online services for the selling of automotive products. Thus, the calculator computes the average market value for a given model. The insurance benefit may not exceed this amount. The user can find some of input data on the back of the certificate matriculation.

The service life and mileage of the vehicle determine the age of the machine. The service life is the difference between the current year (using datetime in python) and the year of manufacture of the vehicle, which is also on the back of the certificate matriculation. Mileage measured in kilometers is an optional input if there is a possibility of malfunction of the odometer. In this case, the user enters 0. In this case, the user enters 0. For more information about the conditions, see Table 5.

We have parsed a complete list of brands and models, generations and years of manufacture from one of the web services. This makes it easier for the user to enter data, i.e. select data.

To determine the average market value of a vehicle, we need accurate data that will allow us to find analogues among the ads of online services. To do this, user needs to enter the following data:

- Brand and model of car;
- Year of manufacture of the vehicle;
- Engine capacity;
- Type of fuel (gasoline, gas, diesel, hybrid, electricity);
- Transmission (manual, automatic);
- Wheel drive (front, back, full);
- The location of the steering wheel (right, left).

The norm-hours is the cost of the master's work for one hour. The value of the norm-hours is defined by the manufacturer's company, the car dealer, if the warranty is valid. For cars with an expired warranty period and for cars without a warranty (depending on the service life), a special Table 7 with values is given. To determine the cost of a norm-hour, the tabular values are multiplied by the current size of the MCI (monthly calculation index). Now 1 MCI is 3 450 tenge. The working hours of the master selected to repair the car are also entered.

Table 7 – Table of costs of the norma hour

Vehicle class	Cost of the norma hour, MCI	
	Up to 5 years	Over 5 years
“A”, especially small (mini)	2,2	2
“B”, small	2,2	2
“C”, lowest average	2,2	2
“D”, medium	2,2	2
“E”, upper medium (large)	2,2	2
Compact SUVs, pickup trucks (curb weight < 2100kg)	2,2	2
“M”, multi-purpose (minivans, minibuses)	2,2	2
All-terrain vehicles	2,2	2
Mid-size SUVs (unladen weight < 2100kg)	2,2	2
Full-size SUVs (unladen weight > 2100kg)	2,4	2,2
Pickup trucks (unladen weight > 2100kg)	2,4	2,2
“S”, sport (sports cars, coupes, convertibles)	2,6	2,4
“F”, representative	2,6	2,4
CIS cars	2,2	1,5

When choosing painting works, it becomes necessary to enter the area of the damaged part of the body. There are several mandatory materials in this type of work. The average costs and consumption rates of materials are presented in Table 8.

Table 8 – The average costs and consumption rates of materials

Materials	Average price per 1kg / 1 liter	Consumption rate
Putty	3 761,5	0,100
Acrylic clear varnish	10 969,5	0,120
Primer	8 698,2	0,280
Thinner	7 020,0	0,080
Enamel	9 100,0	0,240
Enamel remover	4 585,0	0,072
Primer remover	3 290,0	0,084

In addition to data about the policyholder's car, tabular data from the methodology is needed for calculation. We get these coefficients from excel tables via openpyxl. There are few types of coefficients, the cost of norm-hours for cars without warranty, the consumption rates of repair materials, elements of a passenger car. We have merged the tabular values for determining mileage and physical wear with the full table of models for a quick and convenient search.

Structure of the code and Application

We used the Tkinter library for the graphical user interface. The first function uses Tkinter settings as Notebook for window, Frame for tabs. The main window, 650x300 in size, consists of three labeled tabs for calculated output data. There is a tab of physical wear, a tab of the average cost of the vehicle, a tab of the cost of restorative repairs. Further, we use classes - a code template for creating objects - for each tab.

At the very bottom of the window there is a button that completes and saves the history of the entire operation.

In the first tab, first, we need to initialize a list of brands and a list of detailed descriptions of models. Then we work with the “tkinter” tab using the “start(self)” function. Labels are used to indicate the input data. For choosing the brand and the model of car it's convenient to use “Tkinter Combobox” widget that makes a drop-down. Based on the choice of a combobox with car brands, the dropdown of the second combobox with car models changes. It's “Combobox(postcommand)” that updates the list of models based on clicked brand.

For the year of production and mileage, we use Entry widgets. The user clicks on the button to get the result of calculating physical wear. It runs next function.

The calculation itself is in the “calculate iznos()” function. Additional data (a, b, L_0, M(L)) and two formulas described earlier in this article. The second formula is for the case if the user does not enter the mileage of the car. The math library is used to find the exponent. The result is displayed on the window. “Widget.configure” outputs, shows the result on the window.

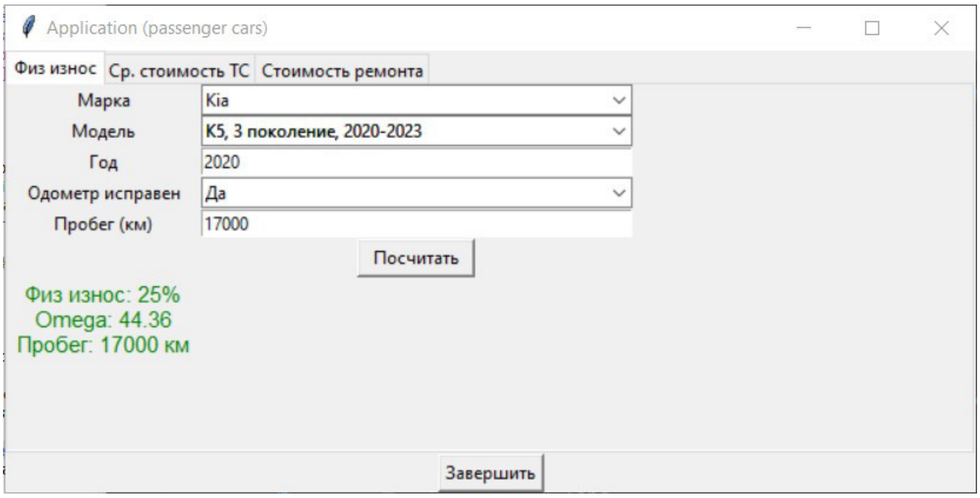

Figure 3 – Application 1

In the second tab, the user must specify the exact data to search for analogues of the car. At the beginning, we initialize the data that we will work with in this tab. The list of data is given above in Figure 3.

The brand and model in the second tab are selected in the same way as in the first tab. Such input data as year, engine capacity, mileage are recorded through the Entry widget. And the rest of the input data, such as engine type, transmission, steering wheel location, wheel drive, are recorded through the Combobox widget. The button runs the following functions.

Beautiful soup is the package for data scraping from HTML and XML source code using Python programs. To parse market prices for analogues from three online services, three functions are used according to the names. These are such well-known online services as Kolesa.kz, Aster.kz, MyCar.kz.

The principle of searching for ads by a certain filter is the same everywhere. The main task in each function is to get the correct URL link and get request to “html.parser content”. In the soup obtained through the request, we find the right part and collect the prices in the list by using “find all” method. In case of “ConnectionError”, try except method of blocking is used. All three functions supplement the list with the prices of analogues as in Figure 4.

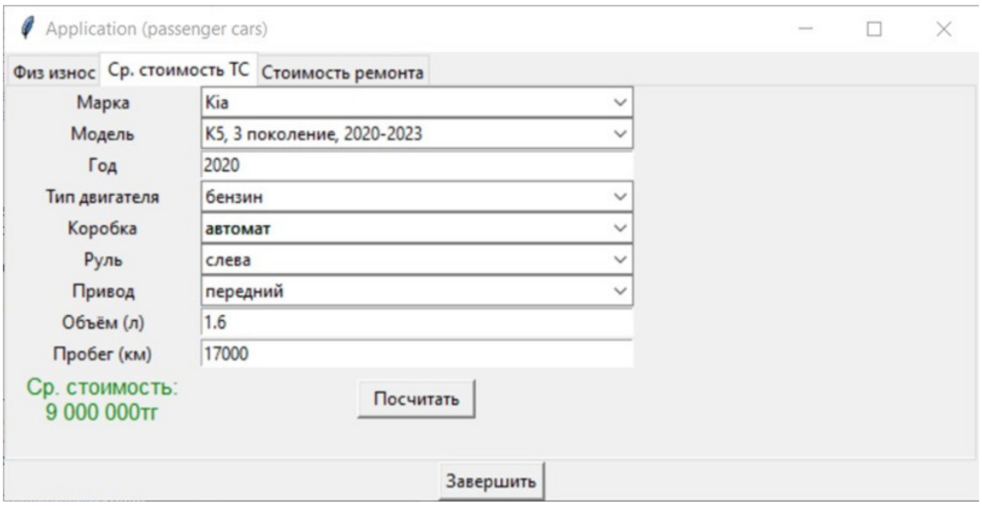

Figure 4 – Application 2

In the third tab, the main part of the calculator's work is carried out. The user selects the brand, model and class of the car (like the previous tabs), enters the year of manufacture, and then selects the car unit and part from the dropdowns (Combo Box widgets). Similarly, to changing the list of models from the selection of the brand, the list of parts also changes from the selection of the unit - in the function “updtcblist v2()”. The type of work relative to this part is also selected.

There are four types of repair work:

- Painting work on the body;
- Removing and mounting the part;
- Disassembly and assembly;
- Replacement of a part.

If painting works are selected, the user enters the damage area for calculation.

If there is a warranty and its term has not expired, the user must specify the value of the norm-hour. Also, the working time is entered there. Commonly, it counts in hours in Figure 5.

The operation of this tab does not end after clicking the calculation button. After calculating the cost of repairs for one job, the user can make changes to calculate the cost of another type of work on another part, and so on. With each click of the calculation button, the data is saved. And to display a complete list of identified works, at the end of using the calculator, you need to click on the button at the very bottom in Figure 6.

Recent advancements in machine learning and deep learning have significantly improved the accuracy and efficiency of vehicle repair cost estimation models. Narayana et al. [15] demonstrated the effectiveness of predictive analytics in the automotive retail sector, which is highly relevant for predicting repair costs. Their use of machine learning algorithms highlights the potential for accurate cost estimation models tailored to specific markets.

Similarly, Amik et al. [16] focused on the Bangladeshi market, employing machine learning models to predict pre-owned car prices. This study emphasizes the importance of regional data in customizing prediction models, a principle that can be applied to repair cost estimation to enhance model accuracy across different geographic areas.

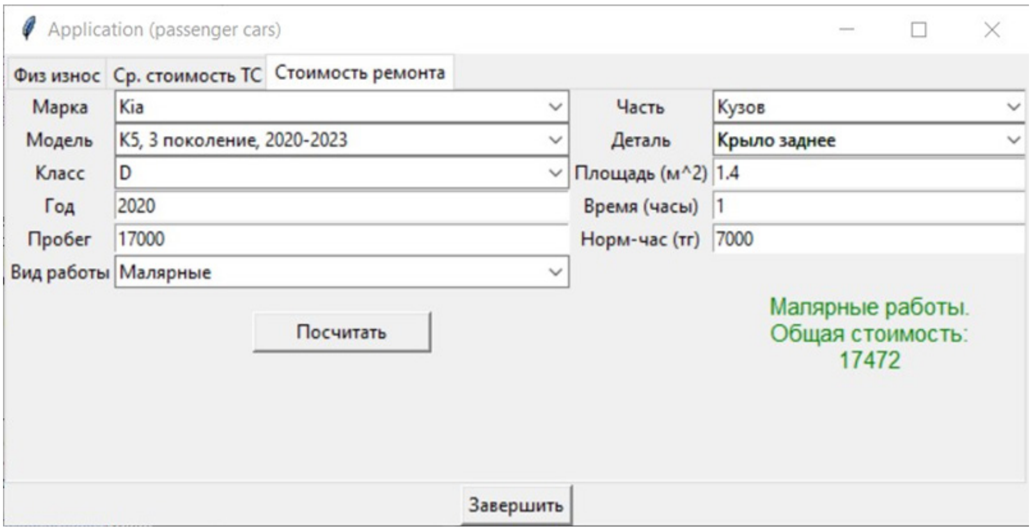

Figure 5 – Application 3

Jagannathan et al. [17] utilized a combination of Gaussian mixture models and deep learning techniques for vehicle detection and classification. Their approach improves the precision of vehicle damage assessments, which is crucial for developing reliable repair cost estimation models. This research highlights the potential of integrating advanced machine learning techniques to enhance damage detection accuracy.

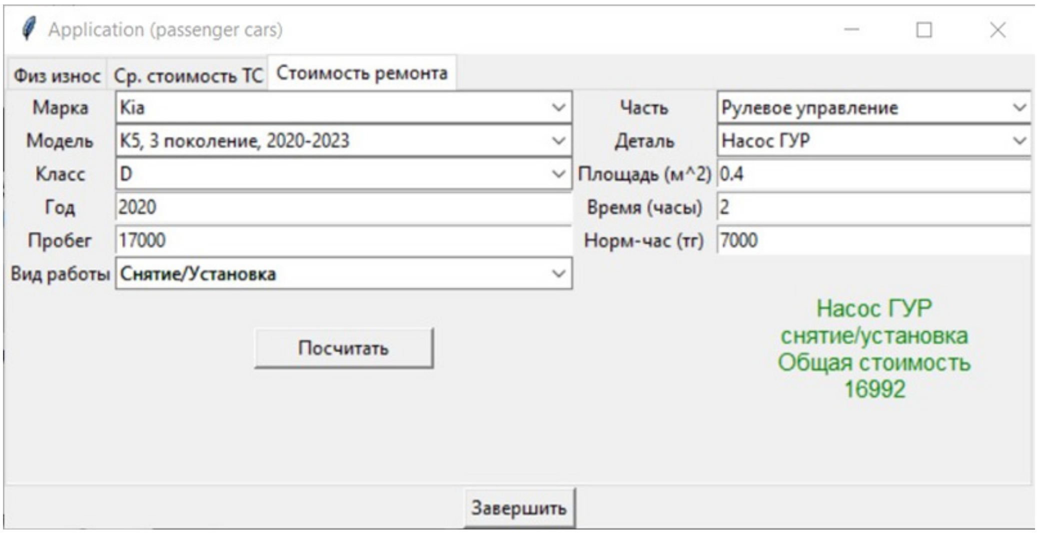

Figure 6 – Application 4

Jamiya and Esther Rani [18] introduced the LittleYOLO-SPP algorithm for real-time vehicle detection. This algorithm's speed and accuracy are vital for timely damage assessments, demonstrating the application of advanced convolutional neural networks in automating the repair cost estimation process. The research shows the importance of real-time detection in improving the efficiency of insurance claim processing.

Gao and Lee [19] employed an ensemble of deep learning models to detect vehicles and estimate traffic density. Their findings are significant for vehicle damage detection and repair cost estimation, as accurate vehicle detection is a critical step in assessing damage. The ensemble approach enhances detection robustness and accuracy, providing reliable data for cost estimation models.

The study by Singh Saini and Rani [20] evaluates various machine learning models for predicting used car prices, identifying the most effective algorithms that can also be applied to vehicle repair cost estimation. Similarly, the research by Elmousalami and colleagues [21] demonstrates the application of dynamic cost estimation models in construction projects, using neural networks and regression techniques.

These recent studies collectively underscore the advancements in machine learning applications for vehicle damage detection and repair cost estimation, highlighting the integration of diverse algorithms and regional customization to improve model accuracy and efficiency. The code for this quantitative model for estimating vehicle repair costs in insurance claims is available as open source and can be accessed at: https://github.com/Bignatsu/Quantitative-Model-for-Estimating-Vehicle-Repair-Costs-in-Insurance-Claims

Results and Discussion

The primary objective of this research was to develop a robust and reliable model for estimating vehicle repair costs in the context of insurance claims. The model integrates various factors including parts pricing, labor costs, and specific insurance policy conditions to ensure accurate cost predictions. This comprehensive approach is designed to enhance the fairness and efficiency of the insurance claims process.

When the user finishes using the calculator, he clicks on the button at the very bottom of the window. The calculator will close and the excel will open. This is a file with all the records, with the history of using the calculator. Therefore, the user may make mistakes when using the calculator, as it is possible to delete it in the file later. The user can also edit the file if he does additional research on the auto goods market. The excel file is a draft that the user will use during the process, or for the purpose of training.

The developed model utilized machine learning techniques to analyze a diverse dataset comprising vehicle repair costs, insurance policy details, and vehicle specifications.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Марка	Модель	Класс	Год	Пробег	Вид работы	Часть	Деталь	Площадь	Время	Норм часы	Стоимость	
2	Kia	Rio, 4 пок	B	2020	1020	Малярные	Кузов	Бампер передний	0,6	1	7500	11988,0393	
3	Kia	Rio, 4 пок	B	2020	1020	Замена	Электрооборудование	Фары	0	2	7500	54996,66667	с учетом детали
4													

	A	B	C	D	E	F	G	H	I	J	K
1	Марка	Модель	Год	Тип двигателя	Коробка	Руль	Привод	Объём	Пробег до	Ср. стоимость	
2	Kia	Rio, 4 пок	2020	бензин	автомат	слева	передний	1,6	1020	8185218,119	
3											
4											

	A	B	C	D	E
1	Марка	Модель	Год	Пробег	Физ износ
2	Kia	Rio, 4 пок	2020	1020	16,55841417
3					

Figure 7 – Excel file after closing application

Both obtaining the data necessary for the calculation and the output of the results is done through excel files. And in working with them, we used the openpyxl library.

Validation of the model was conducted using a subset of the data, resulting in high predictive accuracy. The model's estimates closely matched the actual repair costs, with a minimal margin of error.

The key findings, among others, is the inclusion of multiple variables, such as parts pricing, labor costs, and policy conditions, significantly improved the accuracy of cost estimations. Also, it is crucial to note that advanced algorithms, including regression analysis and neural networks, were employed, demonstrating high efficacy in predictive accuracy. At the end we got the user-friendly application, whose model was implemented into a user-friendly application, allowing insurers and policyholders to input relevant data and receive reliable cost estimates quickly.

The results indicate that the comprehensive approach of integrating various factors into the model leads to more accurate and reliable vehicle repair cost estimates. This aligns with findings from similar studies, such as those by Katreddi S. et al. [5] and Zhang et al. [6], who also reported significant improvements in predictive accuracy using machine learning techniques.

Katreddi's S. [5] et al. study focused on maintenance cost estimation using machine learning for delivery trucks. Our research extends this approach by including comprehensive vehicle repair cost estimation, integrating a broader range of variables. While Zhang’s et al. [6] work emphasized damage detection using deep learning, our model builds on this by incorporating cost estimation, providing a holistic solution for the insurance claims process.

The research successfully developed an accurate and reliable model for vehicle repair cost estimation in insurance claims. The integration of multiple variables and advanced machine learning techniques significantly enhanced the model's accuracy. The user-friendly application derived from this model facilitates practical use by insurers and policyholders, promoting transparency and fairness in the insurance claims process.

This study bridges important gaps in previous research by offering a comprehensive tool that not only predicts repair costs accurately but also supports better financial risk management in the insurance industry. Future research could explore the incorporation of real-time data and further refinement of the model to cover a wider range of vehicle types and repair scenarios.

Conclusion

The primary objective of this study was to develop a reliable and effective model for estimating vehicle repair costs in the context of insurance claims. To achieve this, the research employed a comprehensive approach integrating multiple variables such as parts pricing, labor costs, and specific insurance policy conditions. Advanced machine learning techniques, including regression analysis and neural networks, were utilized to analyze the data and develop the predictive model. A user-friendly application was created to facilitate practical use by insurers and policyholders.

The developed model demonstrated high accuracy and reliability in predicting vehicle repair costs. Validation tests showed that the model's estimates closely matched actual repair costs, with a minimal margin of error. The integration of diverse variables and the application of advanced machine learning algorithms significantly enhanced the model's predictive capabilities. The resulting tool not only provides precise cost estimates but also promotes transparency and fairness in the insurance claims process.

The study confirms the validity of the author's statement that a comprehensive model integrating various factors can accurately estimate vehicle repair costs. The research contributes to the scientific knowledge in the field of insurance and vehicle repair by offering a robust tool that bridges the gap in existing estimation methods. The model's accuracy and practical applicability make it a valuable asset for the insurance industry, supporting better financial risk management and improved customer satisfaction.

The successful development of this model opens up several prospects for its implementation and further development. The model can be integrated into insurance company systems to streamline the claims process, reduce processing times, and enhance customer experience. Additionally, the model's framework can be adapted to include real-time data, improving its accuracy and responsiveness to changing market conditions. Future research could explore expanding the model to cover a broader range of vehicle types and repair scenarios, as well as integrating additional variables such as geographical location and market trends.

In summary, this research provides a significant advancement in vehicle repair cost estimation, offering a practical and scientifically validated tool that can be widely implemented in the insurance industry. The model's development and successful application demonstrate its potential to improve the efficiency and fairness of the insurance claims process, making it a valuable contribution to both the academic field and industry practice.

Information on funding

This research can be funded by the personal funds of Sagidolla Bizhigit.

Acknowledgments

Sagidolla B. is a PhD student at SDU University and served as the supervisor for Ali S., Aibolat D., and Shayakhmetov N., who are graduates of the Bachelor program in the Mathematical Department at SDU University, and this work was conducted for their Bachelor thesis defense. As part of bachelor studies, Ali S., Aibolat D., and Shayakhmetov N. have been actively involved in specific tasks, methodologies, and research aspects relevant to this paper.

REFERENCES

1 Outreville J. F. Risk Management and Insurance Review, 2013, vol. 16, pp. 71–122.
2 Nair V.G. Packt Publishing Ltd, 2014.
3 Moore A.D. Packt Publishing Ltd, 2018.
4 Hunt J. Springer, 2019. pp. 35–42.
5 Katreddi S. et al. Frontiers in Mechanical Engineering, 2023, vol. 9, p. 1201068.

6 Zhang Q., Chang X., Bian S. B. IEEE Access, 2020, vol. 8, pp. 6997–7004.
7 Dorathi Jayaseeli J.D. et al. Proceedings of ICTIDS 2021, Springer Singapore, 2021, pp. 279–288.
8 Harshani W.A.R., Vidanage K. IEEE 2017, pp. 18–21.
9 Dhieb N. et al. Proceedings of 31st ICM, IEEE, 2019, pp. 158–161.
10 Patil K. et al. Proceedings of 16th ICMLA, IEEE, 2017, pp. 50–54.
11 Dwivedi M. et al. Proceedings of AIDE 2019, Springer Singapore, 2021, pp. 207–221.
12 Elbhrawy A.S., Belal M.A.F., Hassanein M.S. Journal of Computing and Communication, 2024, no. 3, pp. 55–69.
13 Gaukhar K., Zagira I., Aibota R. Vestnik NAN RK, 2020, no. 4, pp. 339–347.
14 Sartova R.B. Izvestiya VUZov Kyrgyzstana, 2018, no. 9, pp. 45–51.
15 Narayana C.V. et al. Proceedings of 2021 ICESC, IEEE, 2021, pp. 1680–1687.
16 Amik F.R. et al. Information, 2021, no. 12, p. 514.
17 Jagannathan P. et al. Wireless Communications and Mobile Computing 2021, p. 5590894.
18 Rani E. et al. Optik, 2021, 225, p. 165818.
19 Mittal U., Chawla P., Multimedia Tools and Applications, 2023, vol. 82, pp. 10397–10419.
20 Singh Saini P., Rani L. Proceedings of International Conference on Data Analytics and Insights, Springer Nature Singapore, 2023, pp. 577–588.
21 Shah S., Gopinath S. Proceedings of International Conference on Civil Engineering Innovative Development in Engineering Advances, Springer Nature Singapore, 2023, pp. 625–633.

[1]*Сағидолла Б.,
магистр, ORCID ID: 0009-0009-3846-4701,
*e-mail: bizhigit.sagidolla@sdu.edu.kz
[1]Али С.,
бакалавр, ORCID ID: 0009-0008-6990-3546,
e-mail: 190103355@stu.sdu.edu.kz
[1]Айболат Д.,
бакалавр, ORCID ID: 0009-0009-8215-8066,
e-mail: 190109006@stu.sdu.edu.kz
[1]Шаяхметов Н.,
бакалавр, ORCID ID: 0009-0007-7283-1275,
e-mail: 190107095@stu.sdu.edu.kz

[1]SDU Университеті, Қаскелең қ., Қазақстан

САҚТАНДЫРУ ТАЛАПТАРЫ БОЙЫНША АВТОКӨЛІКТІ ЖӨНДЕУ ҚҰНЫН БАҒАЛАУДЫҢ САНДЫҚ ҮЛГІСІ

Аңдатпа

Бұл мақалада сақтандыру талаптары контекстінде көлік құралдарын жөндеуге жұмсалған шығындар сметасы дәлдігін жақсартуға арналған сандық үлгіні ұсынады. Автокөліктердің кең таралғандығы және жиі зақымдануы себеп болған біздің зерттеуіміз жөндеу шығындарына әсер ететін көптеген айнымалыларды біріктіретін сенімді жүйені жасауға бағытталған. Оларға қосалқы бөлшектер бағасы, еңбек шығындары және сақтандыру полисінің мүмкіндіктері кіреді. Ұсынылған модель жөндеу құнының әділ және дәл болжамын қамтамасыз етуге бағытталған болжау құралына осы элементтерді синтездеу үшін математикалық және компьютерлік модельдеу әдістерін пайдаланады. Бұл құрал өтемақылардың нақты жөндеу шығындарына сәйкес келуін қамтамасыз ету арқылы сақтандырушылар мен сақтанушылар арасындағы әділ әрекеттесуді жеңілдетуге арналған. Бұл модельдің пайдалылығы сақтандыру талаптарын өңдеудің ашықтығы мен тиімділігін арттыруда, осылайша қаржылық тәуекелдерді басқаруды жақсартуда және сақтандыру секторының тұрақтылығына ықпал етуде ерекше маңызды.

Тірек сөздер: автокөлікті жөндеу құнын бағалау, сақтандыру жағдайлары, математикалық модельдеу, сандық талдау.

[1]***Сагидолла Б.,**
магистр, ORCID ID: 0009-0009-3846-4701,
*e-mail: bizhigit.sagidolla@sdu.edu.kz
[1]**Али С.,**
бакалавр, ORCID ID: 0009-0008-6990-3546,
e-mail: 190103355@stu.sdu.edu.kz
[1]**Айболат Д.,**
бакалавр, ORCID ID: 0009-0009-8215-8066,
e-mail: 190109006@stu.sdu.edu.kz
[1]**Шаяхметов Н.,**
бакалавр, ORCID ID: 0009-0007-7283-1275,
e-mail: 190107095@stu.sdu.edu.kz

[1]SDU Университет, г. Каскелен, Казахстан

КОЛИЧЕСТВЕННАЯ МОДЕЛЬ ДЛЯ ОЦЕНКИ СТОИМОСТИ РЕМОНТА АВТОМОБИЛЯ ПРИ СТРАХОВЫХ ВЫПЛАТАХ

Аннотация

В данной статье представлена количественная модель, разработанная для повышения точности оценки стоимости ремонта автомобиля в контексте страховых выплат. Мотивированное повсеместным распространением автомобилей и частым возникновением повреждений, наше исследование сосредоточено на разработке надежной системы, которая объединяет множество переменных, влияющих на стоимость ремонта. К ним относятся цены на запчасти, трудозатраты и особенности страхового полиса. Предлагаемая модель использует математические и компьютерные методы моделирования для синтеза этих элементов в инструмент прогнозирования, который призван обеспечить справедливые и точные прогнозы стоимости ремонта. Этот инструмент призван облегчить справедливое взаимодействие между страховщиками и страхователями, обеспечивая соответствие компенсации фактическим затратам на ремонт. Полезность этой модели особенно важна для повышения прозрачности и эффективности рассмотрения страховых претензий, тем самым поддерживая лучшее управление финансовыми рисками и способствуя стабильности страхового сектора.

Ключевые слова: оценка стоимости ремонта автомобиля, страховые случаи, математическое моделирование, количественный анализ.

Article submission date: 27. 07. 2024