

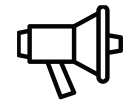
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CONTENTS

FINANCING OF SMALL BUSINESSES THROUGH INVESTMENT LOANS BY COMMERCIAL BANKS.....	15
Yangiboyev F.B.	
INTEGRATION OF THE TRANSPORT SECTOR INTO THE GREEN ECONOMY AND IMPACT ON SUSTAINABLE DEVELOPMENT: ECOLOGICAL TRANSFORMATION AND INNOVATIVE SOLUTIONS	20
Narziyev Umidjon Bakhrillayevich	
FOREIGN EXPERIENCE IN INCREASING THE INVESTMENT ACTIVITY OF JOINT-STOCK COMPANIES	24
Begamov. S.X.	
AN ENHANCED FINANCING MODEL FOR STARTUP PROJECTS IN HIGHER EDUCATION INSTITUTIONS OF UZBEKISTAN	27
Kasimova Nargiza Sabitdjanovna	
STRATEGIES FOR ENHANCING INVESTMENT POTENTIAL.....	32
Tillayeva Barno Ramizitdinovna	
THE IMPORTANCE OF USING ARTIFICIAL INTELLIGENCE IN HOTEL MANAGEMENT.....	36
Husenova Madina Farkhodovna	
MARKETPLACES AND ECONOMIC SECURITY IN UZBEKISTAN: RISKS AND REGULATION	42
Umarkhodjayeva Zaynabkhon Nodirkhonovna	
TECHNOLOGICAL STRENGTH AND PROPERTIES OF METAL OF AUSTENITIC JOINTS DURING WELDING WITH VARIOUS FLUXES.....	47
Khudoykulov Nurilla Zikirillaevich, Khudoyorov Sardor Sadullaevich	
MODERN SYSTEMS OF PRODUCT COST CALCULATION: METHODOLOGICAL FOUNDATIONS AND DIRECTIONS OF PRACTICAL TRANSFORMATION	51
Abdumalik Abdiraximovich Tulyaganov	
SUPPORTING ECONOMIC EXPANSION AND MAXIMIZING PRODUCTION EFFICIENCY WITHIN A MARKET ECONOMY.....	56
Aytmuratov Qutlimurat Jalgasovich	
SUCCESS FACTORS OF DIFFERENTIATION STRATEGY IN A MARKET ECONOMY.....	62
Sodiqov Miraxror Abbos ugli	
THE “MISSING MIDDLE” PROBLEM IN SOCIAL PROTECTION SYSTEMS AND MECHANISMS FOR ADDRESSING IT	67
Farrukh Juraqulovich Bafoev	
IMPROVING POPULATION INVESTMENT ACTIVITY THROUGH THE DEVELOPMENT OF BANK BROKERAGE SERVICES AND FINANCIAL LITERACY IN FORMING A SECURITIES PORTFOLIO IN THE KHOREZM REGION	72
Bakhtiyorov Khudaybergan Hamdam ugli	
DEVELOPMENT OF THE SERVICE SECTOR AND ITS IMPACT ON POVERTY REDUCTION.....	79
Dauletmuratov Adilbay Mirzabaeovich	
THE ROLE AND IMPORTANCE OF A SYNERGETIC APPROACH IN DEVELOPING THE MANAGEMENT SKILLS OF SCHOOL DIRECTORS.....	84
Yusupova Dilnoza Fayzullayevna	
REGIONAL INNOVATION DEVELOPMENT INDICATORS AND THEIR EVALUATION SYSTEM	89
Xamrayev Quvvat Iskandarovich	
GADGETS AND VALUES: HOW DOES THE VIRTUAL WORLD IMPACT THE EDUCATION OF YOUTH?	97
Makhmudova Sohiba Ravshan kizi, Mirzaliyev Sanjar Makhamatjon ugli	
WAYS TO IMPROVE SERVICE QUALITY AND SAFETY IN THE HOSPITALITY INDUSTRY THROUGH DIGITAL TECHNOLOGIES	101
Musayeva Shoira Azimovna	
DIRECTIONS FOR INCREASING HOUSEHOLD INCOMES BASED ON FOREIGN EXPERIENCE.....	104
Eshbaeva Shahnoza Faxriddinovna	

IMPROVING METHODS FOR DETECTING FRAUD CASES IN CURRENT ASSET AUDITS.....	108
Mavlyanova Dilobar Makhkamovna	
GLOBAL TRENDS IN WORLD MARKETS AND THEIR IMPACT ON THE DEVELOPMENT OF INTERNATIONAL TRADE	113
Meliqulov Abduhalil Norinovich	
THEORETICAL ASPECTS OF FORMING AND APPLYING THE INTEGRATION MECHANISM OF SMALL BUSINESS	119
Rustambek Ibragimovich Israilov	
THE IMPORTANCE OF USING PERFORMANCE INDICATORS IN IMPROVING ROAD MANAGEMENT METHODS.....	125
Sirojiddin Yadgarov	

THE IMPORTANCE OF USING PERFORMANCE INDICATORS IN IMPROVING ROAD MANAGEMENT METHODS

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Abstract: In traditional highway management practices, information about road conditions is obtained by measuring traffic-operational indicators. Measuring each of these indicators requires considerable time, and integrating all measurement results into a unified assessment may create additional challenges. In evaluating the traffic and operational condition of highways, the IRI (International Roughness Index) is widely recognized as an effective and internationally accepted indicator.

Various software solutions are used worldwide to measure road surface smoothness. Among them, the GLOCAL-EYEZ program, developed by Japanese specialists, has significant potential for practical application. This article examines the effectiveness and reliability of technical devices and technologies used to measure road surface smoothness. The data obtained using the GLOCAL-EYEZ program are also compared with the results of other measurement programs to evaluate their accuracy and efficiency.

Key words: road management, accelerometer, IRI (International Roughness Index), road surface smoothness measurement, GLOCAL-EYEZ program.

INTRODUCTION

GLOCAL-EYEZ is an advanced digital (DX) technology developed for pavement inspection using smartphones. This technology integrates Nichireki's pavement monitoring and pavement maintenance solutions with a fundamental road profile assessment system based on artificial intelligence (AI). The system was developed under the scientific leadership of Dr. Tomonori Nagayama, Professor at the School of Engineering of the University of Tokyo, together with AI and system development specialists from Smart City Research Institute Co., Ltd., a venture company established on the basis of Dr. Nagayama's research laboratory [1].

The Japanese GLOCAL-EYEZ program applies artificial intelligence technologies to comprehensively assess the condition of highways at a national scale. The system enables digital evaluation of road surface profiles using the IRI (International Roughness Index), supports photo-based reporting, and provides remote online monitoring through a unified digital interface. These capabilities contribute to improving the efficiency of road condition monitoring and supporting service providers in enhancing the quality of pavement maintenance and repair activities [2].

LITERATURE REVIEW

In recent years, numerous studies have been conducted on the issue of the informal economy. In particular, international experts such as F. Schneider, D. Enste, L. Medina, and C. Williams have extensively investigated this topic and provided significant scientific conclusions regarding the factors contributing to the formation of the informal economy, its development trends, and its impact on the overall economic system. Their research comprehensively analyzes economic and institutional mechanisms aimed at combating and reducing the scale of the informal economy.

According to J. Thomas, the informal economy refers to economic activities and the income generated from them that remain outside government regulation, taxation, and official control. This definition highlights the main characteristics of the informal economy, namely that economic activities are carried out beyond the formal institutional framework.

Among Uzbek researchers, Ortiqov and others, in their work entitled "Informal Economy," interpret this concept more broadly, describing it not only as an economic and social structure but also as a complex socio-economic phenomenon encompassing economic relations within society. According to their interpretation, the informal economy often includes activities conducted outside the supervision of state institutions, where economic resources may be used in hidden forms to obtain additional income.

According to M. A. Qurbonov, the consequences of informal economic activity cannot be evaluated uniformly. In certain circumstances, especially in the form of the so-called "grey economy," it may not necessarily hinder

the development of the formal economy and, in some cases, may even support it to a certain extent. The Swiss economist Dieter Cassel identified three positive functions of the informal economy within a market economy:

- “Economic lubrication” – the redistribution of resources between the formal and informal sectors, which helps smooth fluctuations in economic conditions. For example, during periods of crisis in the formal sector, production resources do not disappear completely but temporarily move to the informal sector and later return to the formal economy once economic stability is restored.
- “Social shock absorber” – the mitigation of social tensions. In particular, informal employment can provide an additional source of income for low-income groups of the population.
- “Built-in stabilizer” – the informal economy can indirectly support the formal economy by supplying resources and maintaining economic circulation. For instance, income generated in the informal sector is often spent on goods and services produced in the formal sector, thereby sustaining overall economic activity.

At the same time, many researchers emphasize that the expansion of the informal economy may negatively affect the development of a healthy competitive environment and the activities of legitimate business entities. As the scale of informal economic activity increases, it may create risks for enterprises operating legally and transparently. Therefore, the growth of the informal economy can also be regarded as a potential threat to economic security and fair market competition.

RESEARCH METHODOLOGY

This study is based on a systematic and comparative research approach. Scientific literature, international experience, and analytical reports on tax administration and the informal economy were examined. Methods such as comparative analysis, statistical analysis, and generalization were used to evaluate foreign practices and determine their applicability to the national context. The research also analyzes existing tax administration mechanisms and identifies factors influencing their effectiveness.

ANALYSIS AND RESULTS

The IRI (International Roughness Index) is one of the first and most widely applied indices used to analyze road surface profiles. This indicator is based on the so-called “quarter-car” model, which was developed to achieve the highest possible correlation with road surface measurement systems. The model represents a theoretical simulation of vehicle–road interaction and enables an objective assessment of pavement roughness.

Data collection for the present study was carried out between October 2020 and July 2021 in Tashkent and the Tashkent Region. During this period, the total monitored distance reached 3,615 km, covering 266 trips. The obtained evaluation results were visualized using the Mapbox mapping platform [3].

The experimental study conducted in Tashkent city and the Tashkent region during 2020–2021 involved assessing road conditions using a Chevrolet Cobalt test vehicle equipped with a smartphone. The GLOCAL-EYEZ measurement application collects vehicle vibration data through smartphone sensors and simultaneously records visual information through the camera. These data are automatically transmitted to the GLOCAL-EYEZ cloud service, where they are processed using the DRIMS algorithm, enabling an efficient and reliable assessment of road surface conditions (figure 1).

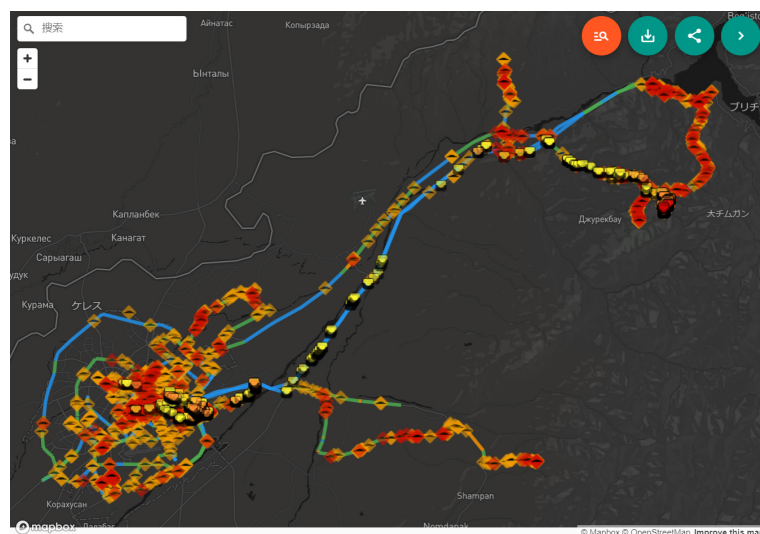


Figure. 1. Research results in Tashkent city and Tashkent region

Wheelbase — the horizontal distance (“L” in Fig. 2) between the axle of the front wheel and the axle of the rear wheel of the vehicle.

Device position — the horizontal distance (“d” in Fig. 2) from the axle of the front wheels of the vehicle to the installation location of the smartphone (device). Depending on the type and configuration of the vehicle, this value may be negative (indicated by the “-” symbol). For example, in the case shown in Fig. 2, the value “-15” should be entered as the device position parameter.

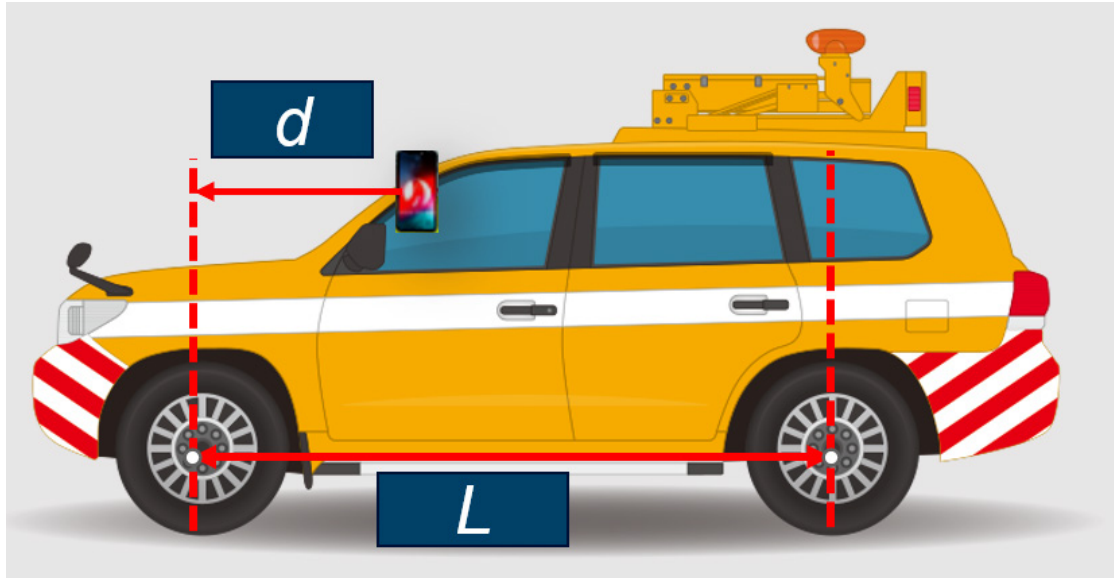


Figure 2. The case of a positive device position

Before starting the measurement process, it is necessary to ensure that the smartphone holder and the smartphone itself are securely fixed. The position and angle of the smartphone, which were determined during the initial installation, should not be changed during the measurement process [4].

To minimize the reflection of the vehicle interior on the windshield, it is recommended to cover the dashboard with a black cloth while maintaining appropriate safety conditions. During measurements, the vehicle speed should not exceed the established speed limits: on regular roads it should correspond to the permitted speed, while on expressways it should not exceed 80 km/h. Measurement data collected during rain, snowfall, or nighttime conditions cannot be effectively processed by artificial intelligence systems and therefore are not recommended for analysis [5].

The continuous measurement duration (from pressing the start measurement button to pressing the end measurement button) should not exceed two hours. If the measurement time exceeds this limit, the measurement should be stopped and restarted in order to divide the data into separate segments. If the application displays an overheating warning, the measurement should be stopped immediately so that the smartphone can cool down properly [6].

After the data transfer process is completed, the recorded measurement video will be automatically deleted and image frames will be displayed at intervals of every 10 meters in front of the vehicle. If it is necessary to retain the original video recording, the smartphone should be connected to a personal computer before transferring the data, and the measurement files should be saved to the computer. Additional information about saving data to a computer can be found in the Help section of the application.

To prevent the smartphone memory from becoming overloaded, unnecessary or previously transferred measurement data should be deleted regularly. To delete selected measurement files, open the File screen, press the Delete button, select the required files using the checkboxes, and confirm deletion using the Delete button at the bottom of the screen. To remove all measurement data from the device, press the Delete button and then select Delete All at the bottom of the screen [7].

A 4K (MP4) video recorded during measurements typically requires approximately 10 Gbit/s of storage capacity. However, during data transmission the video is converted into image files (JPG format), and the resulting data volume usually does not exceed 2 GB per 100 km.

The artificial intelligence-based road diagnostics program evaluates the condition and smoothness of highway pavement. Based on the collected data, the system identifies road surface defects and classifies them into specific categories and condition levels, as illustrated in Figure 3.

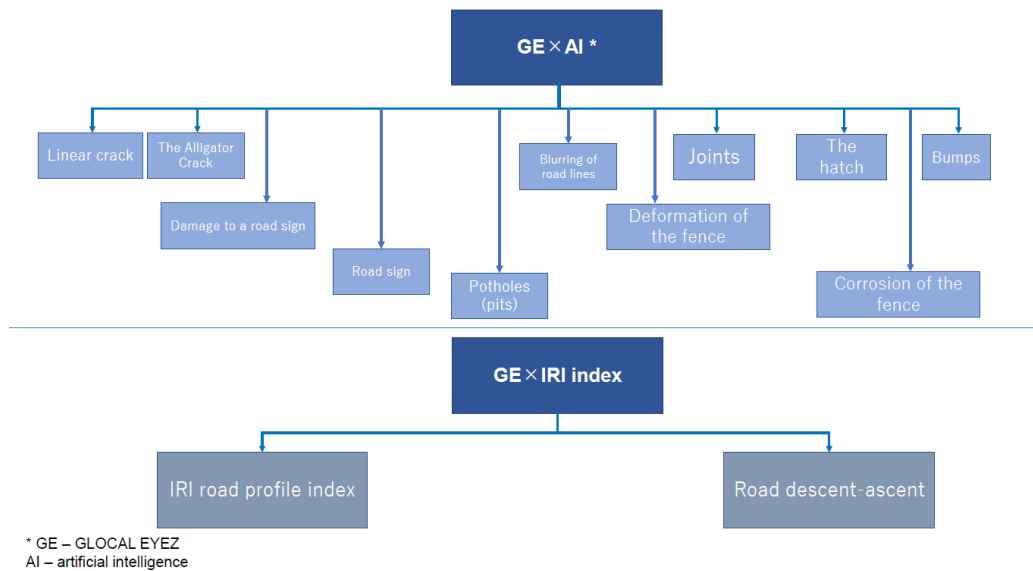


Figure 3. Classification of defects observed on road surfaces using artificial intelligence

The following driving modes may affect the IRI/elevation analysis, and the analysis may be unsuccessful [8]:

1. Driving in conditions where the speed of movement may be unstable (for example, during traffic jams);
2. Driving with sudden acceleration and sudden braking;
3. High-speed driving at a speed equal to or greater than 80 km/h;
4. Continuous driving at low speed at a speed equal to or less than 20 km/h, A temporary reduction in speed to 20 km/h or lower to comply with a red light or stop sign is acceptable;
5. Continuous driving around high-rise buildings and under elevated railway tracks (due to difficulties in receiving GPS signal);
6. Prolonged driving inside tunnels (due to GPS signal reception failure), GPS signals can be adjusted if driving in the tunnel is temporary (fig. 4) [9].

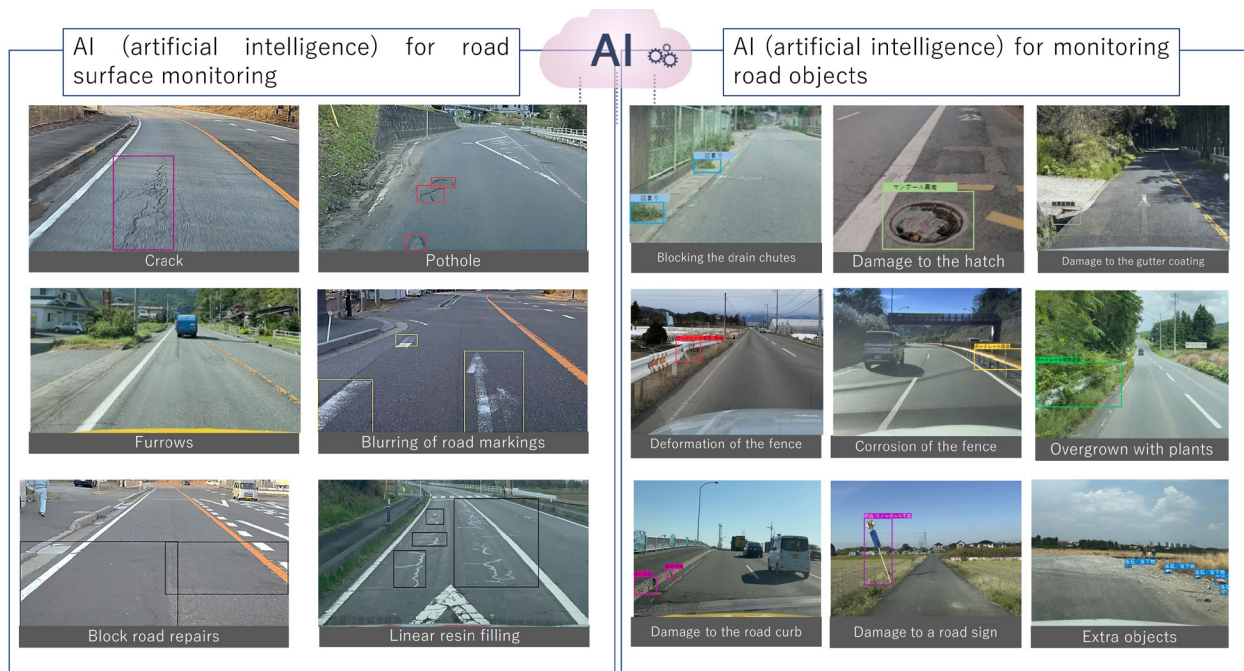


Figure 4. Types of road surface by condition

During IRI or elevation analysis, device orientation adjustment and vehicle model calibration (collectively referred to as “Calibration”) must be performed using the measurement data uploaded to the server. For this

process, the uploaded data must satisfy specific conditions. If the calibration procedure is not successfully completed, the IRI/elevation analysis cannot be carried out. In general, the availability of a larger amount of measurement data increases the likelihood of successful calibration.

Minimum conditions required for calibration:

- The vehicle must travel at least 250 meters at a constant speed within the following two speed ranges (at least once in each range):

1. 30–40 km/h
2. 50–60 km/h

- During the measurement process, the vehicle should perform at least ten turns in total, including both left and right turns.

- The total measurement duration, excluding stop time, must be no less than 20 minutes [10].

Continuous measurement over a distance of approximately 20 km at a speed of 40–50 km/h generally allows the collected measurement data to meet the calibration conditions described above. In such cases, additional trips for calibration are usually not required, since the required parameters can be obtained from several segments of the collected measurement data. Once the vehicle calibration has been successfully completed, repeated calibration is typically unnecessary, provided that the device position and the smartphone tilt angle set during the initial configuration of the application remain unchanged.

1. Measurement Notification Function. The system includes several notification mechanisms that inform the user about important operational conditions during the measurement process:

2. GPS signal warning. If GPS signals are not detected at the beginning of the measurement, an alert sound is generated and a warning message is displayed. In such cases, it is recommended to restart the application or the smartphone.

- The warning sound usually lasts for approximately three seconds.

- If GPS signals are lost during the measurement process, the warning message may not be displayed.

3. Smartphone temperature warning. When the smartphone temperature increases during measurement, a sound signal is generated and a warning message appears on the screen.

Situation 1: High temperature. A warning message is displayed. It is recommended to temporarily stop the measurement to allow the device to cool down, although continuing the measurement generally does not cause significant problems.

Situation 2: Very high temperature. In this case, the warning signal sounds for approximately three seconds. Measurement should be stopped immediately because the smartphone may automatically shut down due to overheating. The measurement can be resumed once the device temperature returns to a normal level.

4. Storage capacity warning. If a message indicating insufficient storage capacity appears, it is necessary to delete measurement data that has already been uploaded to the server in order to free memory on the smartphone.

CONCLUSIONS AND RECOMMENDATIONS

An automatic detection function is available to determine whether the camera is correctly focused on the road surface in front of the vehicle. If the camera is not properly directed toward the road surface, a warning message will appear. This message may occur when the road surface cannot be clearly captured due to various reasons, such as contamination on the windshield or camera lens, or reflections from objects that are not part of the road surface. In such cases, appropriate measures should be taken, including cleaning the windshield or the camera lens to ensure accurate data collection.

The platform is capable of accurately estimating the road profile, including IRI (International Roughness Index) and surface smoothness, based on vehicle vibrations measured through a smartphone. Advanced algorithms automatically calibrate vehicle parameters and filter out vehicle-induced vibrations. As a result, the accuracy of the road profile estimation becomes comparable to that achieved by specialized laser-based road profiling systems.

In addition, road surface anomalies can be automatically detected using deep learning algorithms applied to images recorded by the smartphone camera (also compatible with drive recorders). Common defects such as cracks and potholes are classified into several levels according to the severity of damage, allowing the platform to systematically analyze and group these defects by road sections.

The analysis results are displayed on digital maps almost in real time, allowing road condition information to be easily visualized through a web interface. At the same time, the system provides statistical information, including temporal changes and histograms of collected pavement condition data, which can also be viewed directly on the map. These capabilities support efficient road monitoring and contribute to improving the quality and timeliness of pavement maintenance and management decisions.

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