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AI-BASED PAVEMENT CONDITION ASSESSMENT AND AUTOMATED REPORTING USING AN OFFLINE ANDROID APPLICATION

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Keywords
Pavement condition survey, road defect detection, Android application, GPS tracking, geotagging, offline data storage, CSV/Excel export.

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Abstract
Pavement condition surveys are essential for infrastructure maintenance planning, yet they are still conducted manually in many regions. Conventional practice relies on vehicle odometers for distance measurement, visual identification of surface distress, and separate GPS devicecoordinate logging, followed by manual transcription of the data into spreadsheets. This workflow is time-consuming and prone to human error. It also delays decision-making and reduces the effectiveness of maintenance prioritization. This paper presents an AI-based mobile application for pavement condition surveying and reporting that integrates data acquisition, storage, and reporting into a single Android platform. The system uses the device's embedded GPS module for real-time location tracking and road-length measurement. Road surface images are captured through the onboard camera, and each image is automatically geotagged with latitude, longitude, and timestamp metadata. The system employs a to detect and classify pavement defects such as , achieving .All survey data are stored in local (offline) storage, which allows the system to operate in remote areas with limited or no network connectivity. On completion of a survey, the collected records can be exported to Excel formats with a single action, which eliminates manual data entry. The proposed system reduces survey time and human error, and it improves the accuracy, reliability, and cost-effectiveness of pavement data collection for maintenance engineers and supervisors.

INTRODUCTION

Road infrastructure is fundamental to a country's economic growth and public mobility. However, in many urban and rural areas of Pakistan, road maintenance is not carried out in a timely manner. Pavement distresses such as potholes, cracks, rutting, and [1], shown in Fig. 1, often go undetected until they have progressed, which

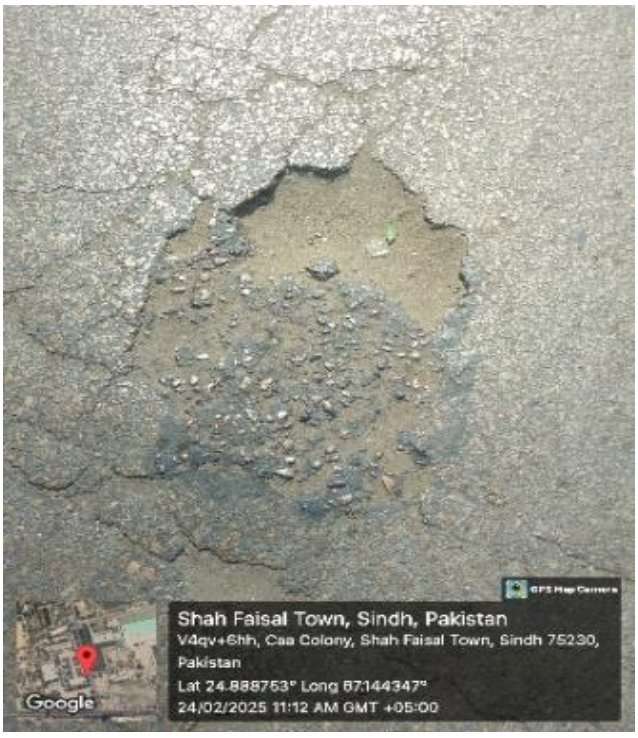
increases accident risk and vehicle operating and maintenance costs. In the conventional approach to pavement inspection, engineers visit the road section in person, record visible defects, photograph them with a handheld camera, and log coordinates using a separate GPS device. They then return to the office and manually transcribe the data into spreadsheets. This workflow is slow, labor-intensive, and prone to human error.

Rutting

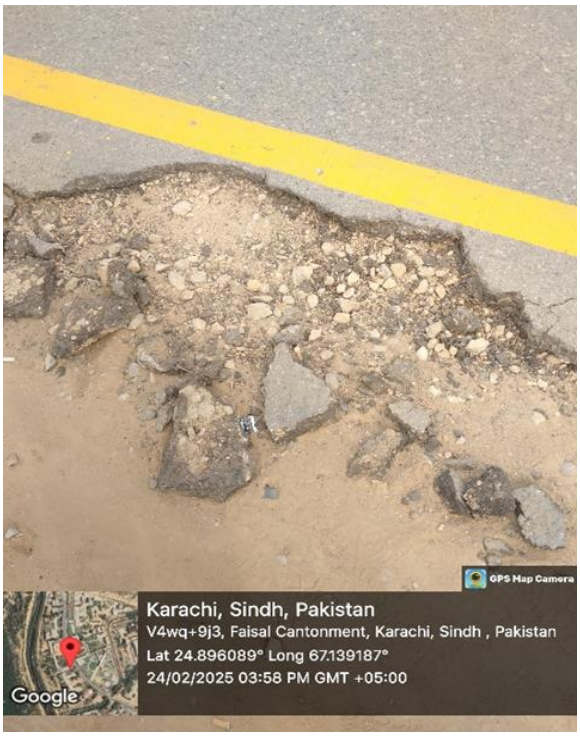


Alligator cracks

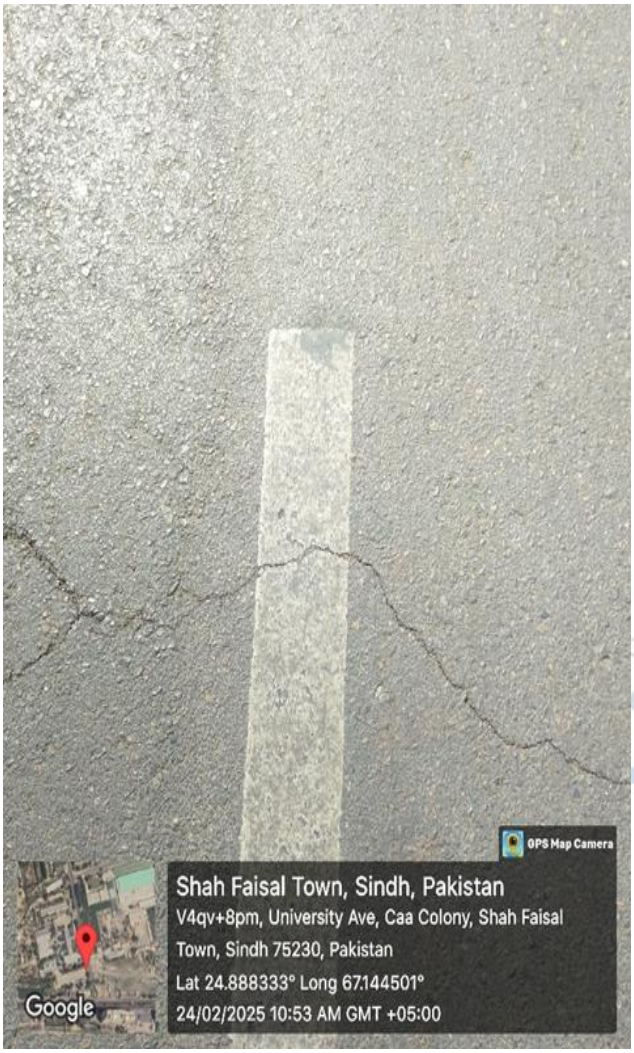




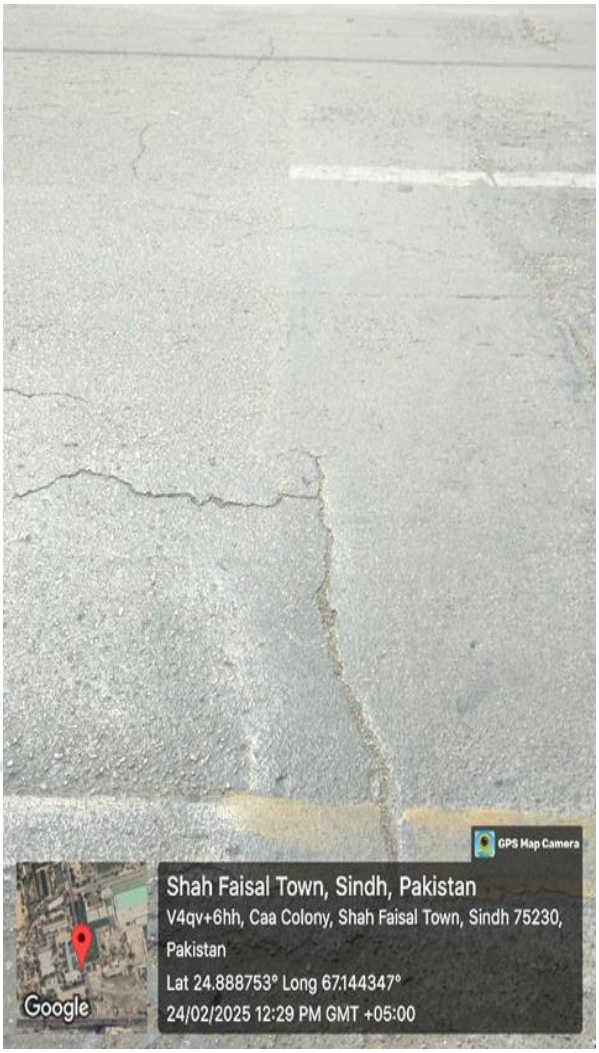
Pothole



Edge Cracking



Transverse Cracks



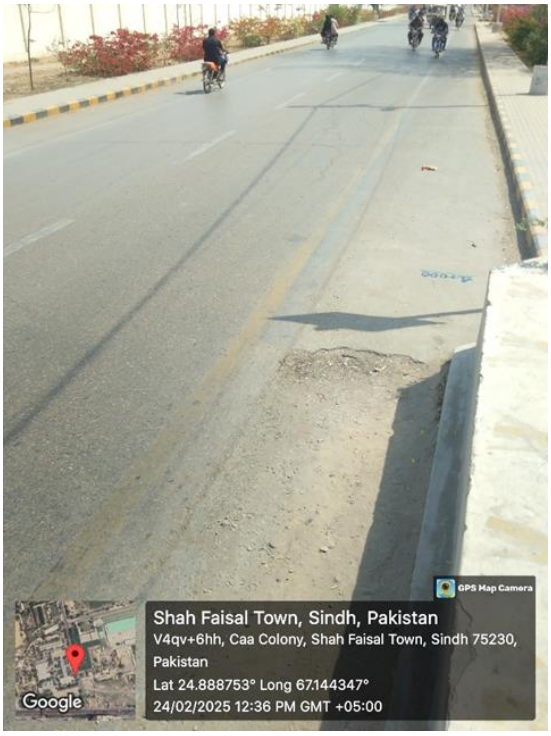
Block Cracks



Patches



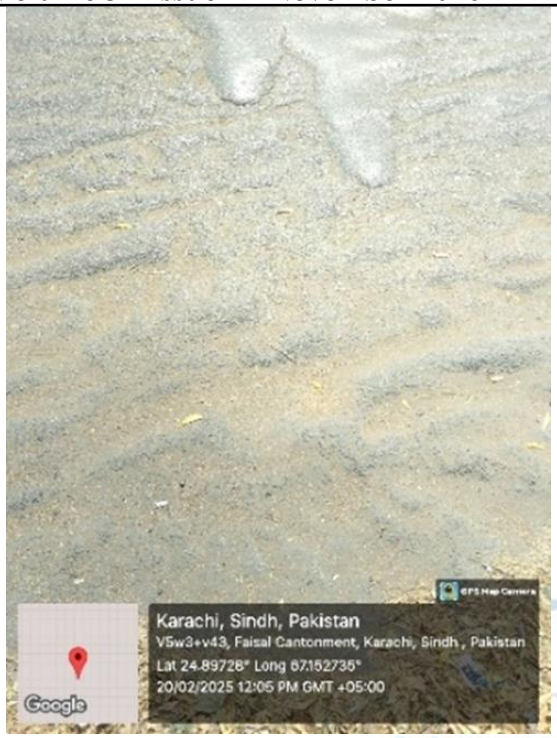
Potholes



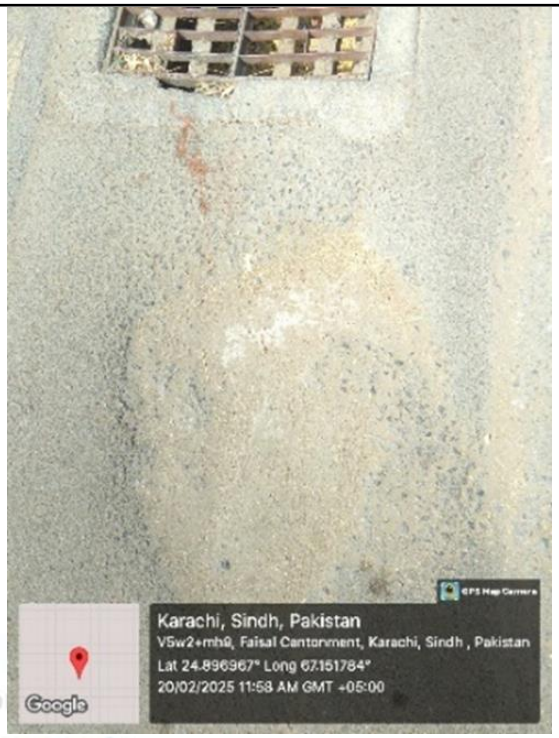
Edge Cracking



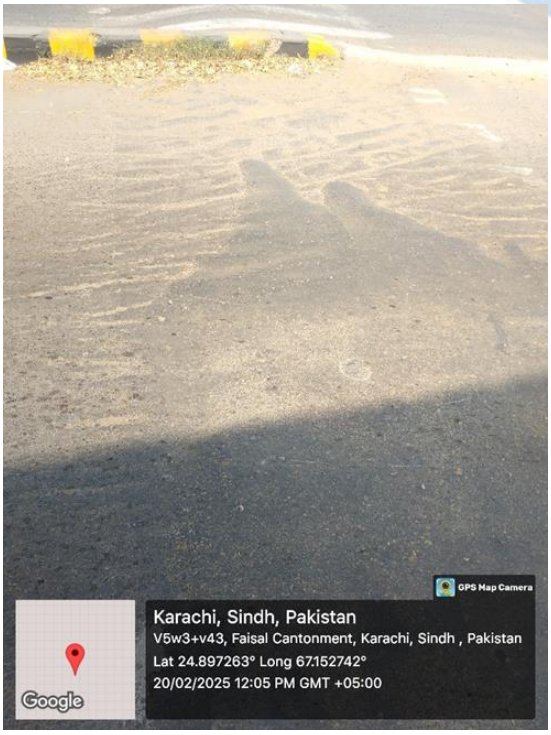
Longitudinal Cracks



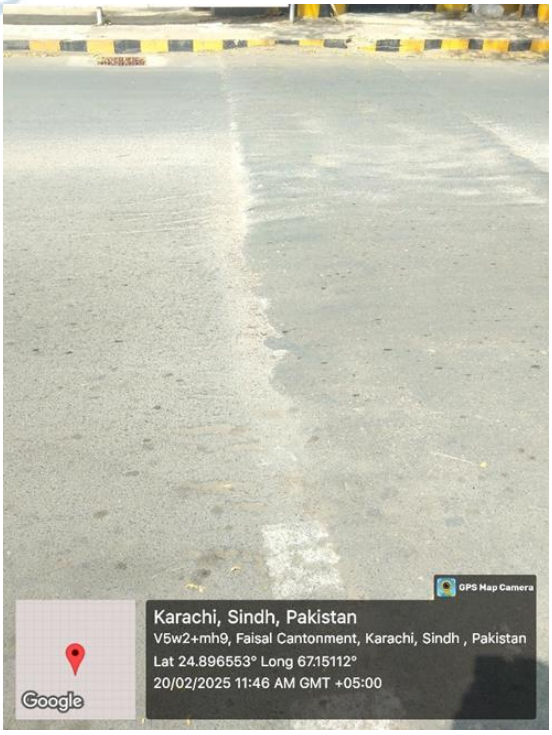
Rutting



Depression



Patches over the removed Speed Breaker



Patchwork

Figure Error! No text of specified style in document.**-1: Road Defects and Their Names**

Almost every field is undergoing digital transformation, yet the road maintenance sector still lacks modern, fast, and reliable digital tools. Mobile computing, GPS tracking, and offline-capable local databases such as Hive, a lightweight, high-performance key-value database that stores data on the device, can give field engineers a fast, structured way to collect data. However, the adoption of such technologies by road authorities in Pakistan remains limited. To address this gap, this work presents an AI-based mobile application for pavement condition surveying and reporting. The application enables surveyors to record road defects, capture images, geotag each record using GPS coordinates, and store all data locally without requiring an internet connection.

The objective of this work is to modernize the conventional manual road inspection process by providing a mobile application that is practical, easy to use, and reliable under field conditions. The application automatically structures the collected data, which accelerates report generation and supports engineers in maintenance decision-making.

The collected data can subsequently be exported to Excel or CSV formats and used directly by supervisors and relevant departments. This approach reduces survey time and also produces accurate, standardized data. The main contributions of this work are: (1) an integrated Android application that combines GPS tracking, image capture, and defect recording in one platform; (2) an offline-first storage architecture based on Hive for use in areas with limited connectivity; and (3) one-step export of survey data to Excel and CSV formats for reporting

1.1 Background

Pakistan has an extensive road network that is a key component of national development, yet road maintenance still relies largely on manual methods. Survey teams are typically dispatched to the field to identify road defects, photograph them (Fig. 2), and record their locations using handheld GPS devices. On returning to the office, the teams manually enter the collected data into spreadsheets. This process is time-consuming and prone to human error at every stage. If a defect's coordinates are recorded incorrectly or an image is not captured properly, the resulting report is inaccurate and maintenance can be delayed.

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Figure Error! No text of specified style in document.**-2: Visual Observation of Pavement Condition Survey**

Another major challenge facing infrastructure departments in Pakistan is the absence of an integrated digital solution that streamlines the survey process. Although smartphones are widely available to field engineers, structured mobile applications for road surveying are not. The built-in GPS, camera, and local storage capabilities of these devices remain largely unused in road surveying. This creates a critical need for a simple, cost-effective, and field-ready digital solution that enables accurate and efficient survey completion. Recent studies have reported significant improvements in road inspection using machine learning and digital tools [citation]. However, in developing countries such as Pakistan, deploying complex AI-based systems is often impractical because they require high computational resources, large annotated datasets, and specialized hardware. A more realistic solution is a mobile application that operates offline, provides a simple user interface, and performs essential functions locally on the device, namely automatic geotagging, image capture, and distance tracking.

1.2 Methodology

This section describes the proposed system architecture and its core modules, the functionality of each module, the hardware and software tools used for implementation, and the implementation process. It also presents the testing strategy and validation plan used to evaluate the accuracy, reliability, and practical applicability of the application under field conditions. An agile development methodology was adopted: a minimum viable product (MVP) was first developed and deployed in field trials, user feedback was collected, and the application was refined over successive iterations.

1.3 System Workflow

This subsection describes the step-by-step operation of the proposed application during a real field survey, showing how the user interface, the sensing components, and the local data layer interact.

Application launch. On launch, the application presents a dashboard with three options: start a

new survey, enter road details, and view previous records.

Survey initialization. When the user taps the "Start Survey" button, the system initializes the device's GPS module and begins measuring the distance traveled from the starting point (A) to the end point (B). GPS initialization runs in the background and continuously updates the real-time coordinates throughout image capture.

Road information entry. The surveyor then enters the road name. The interface is designed to minimize manual input, and most data fields are populated automatically.

Defect capture. When the user opens the defect capture screen, the application activates the camera. Each captured image is immediately geotagged, and the system automatically identifies the defect type (crack, pothole, rutting, or patching). Latitude, longitude, and timestamp are linked to each image.

Data storage. Each record is saved in a local database in a structured format containing the road name, defect type, coordinates, image, distance, remarks, and inspection time. Record identifiers (IDs) are assigned by auto-increment. Because all data are stored on the device, the application operates fully offline in areas without internet access.

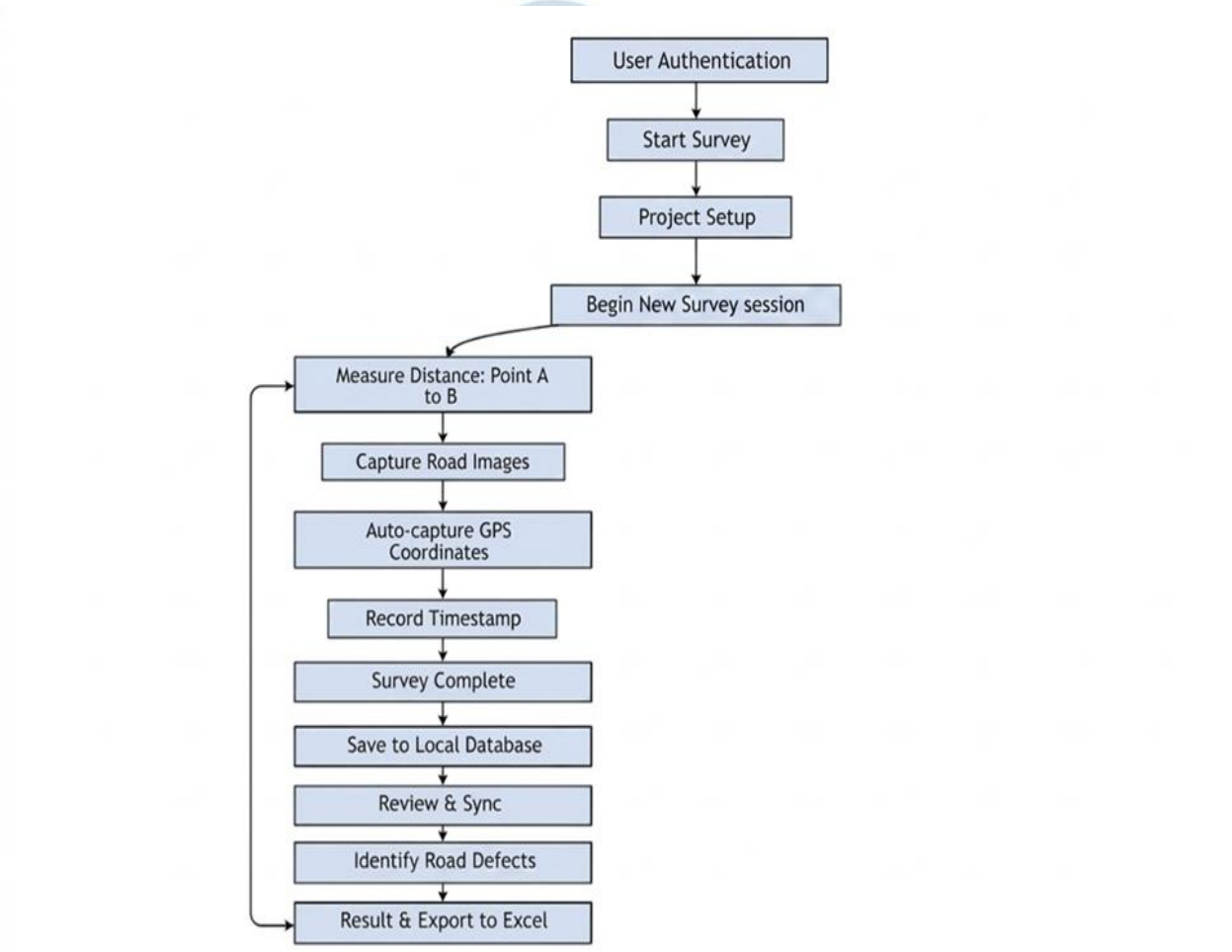


Figure 1.3: Work Flow Chart of AI Pavement Condition Survey & Report Mobile Application

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1.4 System Modules

The system is divided into six modules, each with a specific function. Together they form a complete pavement condition survey system.

Survey Initialization Module. The field engineer selects the road name and segment before the survey begins. This gives every dataset a unique identifier and prevents duplicate records.

GPS Tracking and Location Module. This module retrieves real-time GPS coordinates. When the engineer stops to capture a defect, it automatically records the latitude and longitude, which removes manual coordinate entry. It also supports road alignment mapping and distance measurement from point A to point B.

Image Capture Module. This module uses the device camera to capture an image of the defect and attaches it to the corresponding record. Each image is automatically tagged with a timestamp and location, so the survey data stay structured.

Local Data Storage Module. Survey data (images, GPS coordinates, date, distance, and remarks) are stored in structured tables in an on-device database. This allows surveys to continue without internet access and simplifies report generation.

Report Generation Module. After the survey, this module exports the records to Excel and CSV formats. Each report contains the defect image, coordinates, timestamp, remarks, and distance, which gives maintenance engineers accurate and timely information.

User Interface (UI) Module. This module manages user interaction through a simple, clean, field-friendly interface that engineers with limited digital literacy can use easily.

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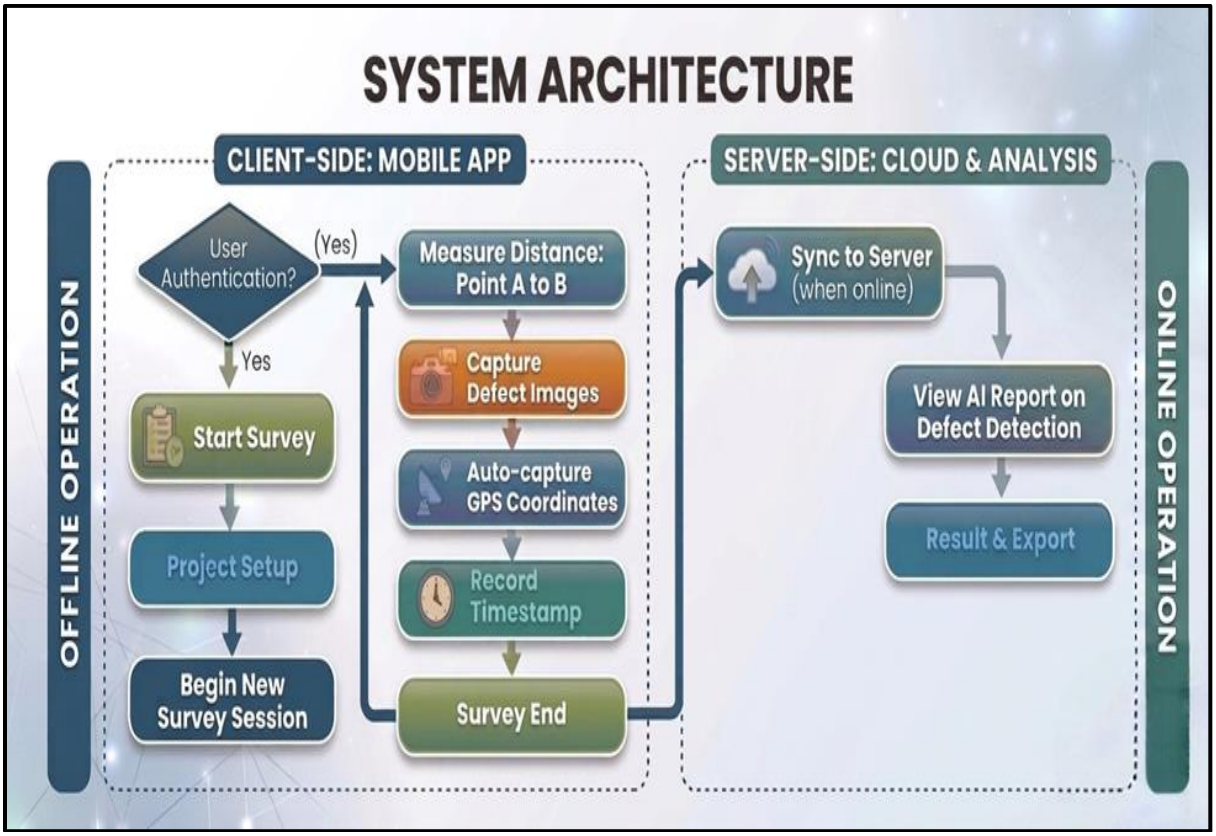


Figure 1-4: System Architecture

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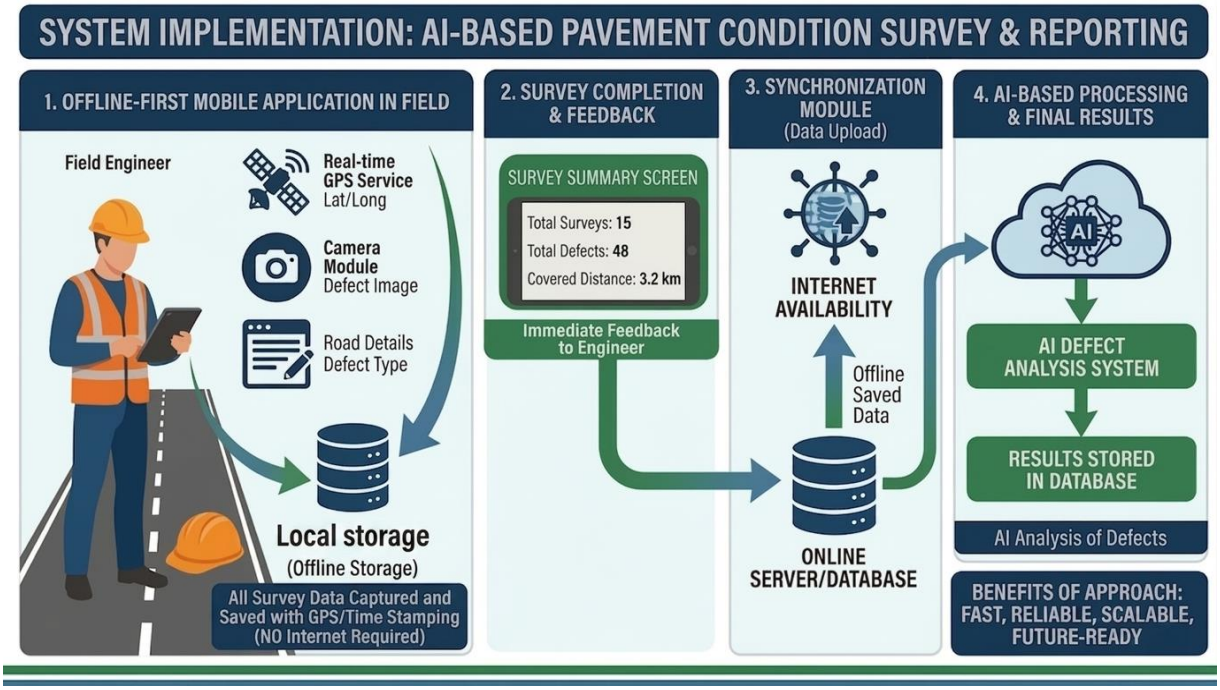
1.5 System Implementation and Results

This section describes the implementation of the proposed pavement condition survey and reporting application and presents the results of its field evaluation. Section 3 covered the system design, architecture, and methodology. Here we report how the system was implemented and what it achieved in practice.

The aim was to automate the road survey workflow, reduce data-entry errors, and support data-driven maintenance decisions. The section covers the implementation (development tools, offline data handling, and the local database), the graphical user interface (GUI), and the system testing and result analysis. It then compares the system with existing solutions and discusses its limitations and directions for future work.

The application was implemented for field conditions in which internet access is limited and data accuracy is critical. It follows an offline-first design: all functions, including data collection and storage, work without a network connection.

When the engineer starts a survey, the GPS service is activated and continuously records the device's latitude and longitude. All survey data (road name, defect type, image, remarks, timestamp, and distance) are stored in an on-device local database. When a defect is identified, the camera module is launched and the engineer captures an image. The application automatically attaches the GPS coordinates and timestamp to the image, which removes manual entry and reduces human error. When the survey is complete, a summary screen shows the number of defects recorded and the total distance covered.



1.6 Database Implementation

The role of database implementation is very important in this project because the entire pavement survey system is data-driven. The primary objective of the mobile application was to store the data collected from the field in a secure, structured and reliable manner so that later analysis and reporting on that data can be done easily. For this reason, local storage database was used in this project which is considered a lightweight and efficient solution for mobile application.

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Survey Defects

Survey ID	Road Name	Start Time	Distance	End Time	Polyline	Latitude	Longitude	AI Label	Confidence	Remarks
SURVEY_1972	mini	2026-04-09T21:00:33.297419	0.0000	2026-04-09T21:01:07.622844		24.8363	67.2243	AlligatorCrack	58.77%	
SURVEY_8229	road	2026-04-09T20:36:00.278250	0.0000	2026-04-09T20:36:13.841994		24.8363	67.2243	AlligatorCrack	57.01%	
SURVEY_2287	1	2026-04-07T20:40:41.279728	0.0000	2026-04-07T20:41:02.241835	24.8013483,67.1424552	24.8013	67.1424	Nonroad	98.75%	
SURVEY_2287	1	2026-04-07T20:40:41.279728	0.0000	2026-04-07T20:41:02.241835	24.8013483,67.1424552	24.8013	67.1425	TransverseCrack	81.68%	
SURVEY_7174	1	2026-04-07T20:35:41.783832	0.0000	2026-04-07T20:36:04.645649		24.8014	67.1425	Nonroad	88.98%	
SURVEY_7174	1	2026-04-07T20:35:41.783832	0.0000	2026-04-07T20:36:04.645649		24.8013	67.1425	TransverseCrack	59.4%	
SURVEY_8768	1	2026-04-07T20:33:19.548348	0.0000	2026-04-07T20:34:19.746097		24.8013	67.1424	TransverseCrack	89.59%	

The local storage has been specially implanted for offline data storage. When a field engineer conducts a road survey, all information such as road name, road defect type latitude longitude timestamp distance image and remarks is immediately saved in the local database. The advantage of this implementation is that even if the internet is not available there is no data loss and the survey continue smoothly.

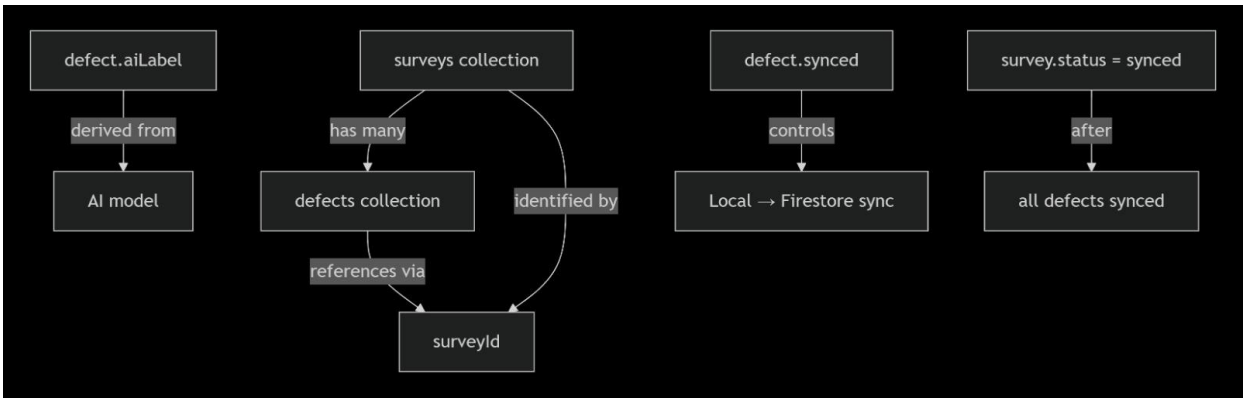


Figure 1-5: Entity Relation Diagram (ERD)

The database design is such that a survey record has a primary key (ID) that is unique. This ID is used to uniquely identify each entry that aids in data retrieval and update processes. Rather than storing them in the database, image is saved by their file path which makes the database size manageable and enhances performance of an application.Database queries are optimized to be able to filter survey records on a data-wise road-wise and defect-wise. This is a highly handy feature in reporting and analysis. The database synchronization mechanism is triggered when there is an internet connection. Offline records are mirrored to the online server database and

once it has been uploaded the records are considered as having been synced. The problem of duplicate entries is also avoided in this process.

1.7. Application Interface (GUI)

The graphical user interface (GUI) directly shapes the field engineer's experience. It was designed to be simple, clear, and usable, so that during a survey the engineer can concentrate on data collection rather than on operating the application. The interface is presented screen by screen, beginning with the User Authentication screen (Fig. 4.4).

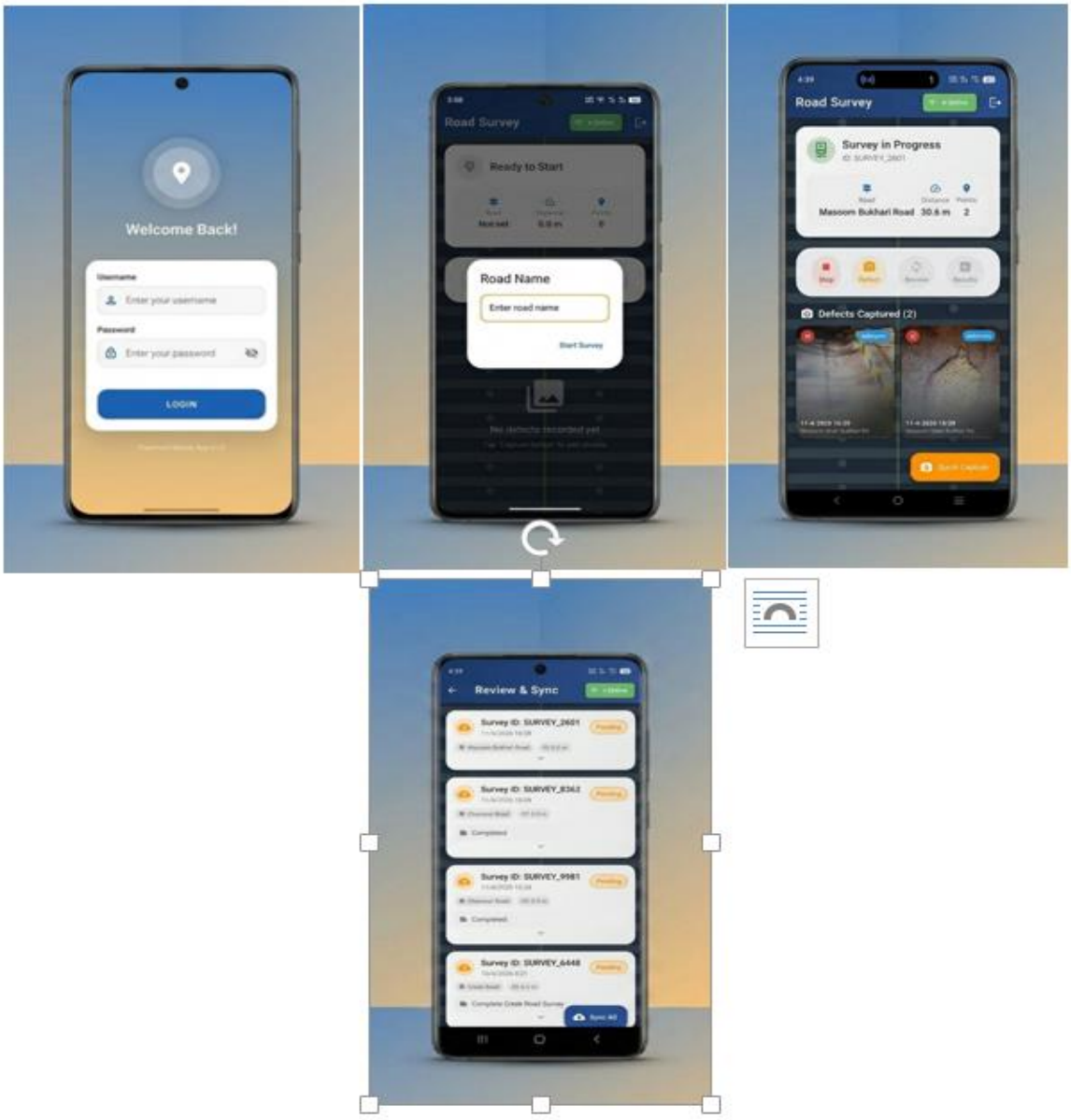


Figure 1-6: Review and Sync Screen

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Upon completion of the survey, a summary screen is displayed showing the total number of detected defects, the distance covered, and the overall survey duration. This screen provides the field engineer with immediate confirmation that the survey has been successfully completed. Subsequently, the collected data is synchronized with the database, as illustrated in Figure 4.9.

1.8 Result Analysis.

This section presents a detailed analysis of the result obtained from the AI-Based Pavement Condition Survey & Reporting Mobile Application. The primary aim of the result analysis was to determine the effectiveness, accuracy and efficiency of the proposed system in a real-life setting. This analysis also made a comparison of system performance against the traditional survey methods that were performed using manual methods.Field testing of the application was done on different sections of the road where real time survey data was taken and the results indicated that the mobile application rendered the data collection process very quick and systematic. Survey completion time was significantly reduced compared to manual survey as GPS capturing timestamping and image tagging were happening automatically.The results of the AI-based processing accurately identified and classified road defects. The system clearly detected cracks, potholes and surface irregularities which was very useful for reporting data analysis and also revealed that the system provided consistent results and there were no issues with duplicate or missing records which often occur in manual surveys.During the result analysis database records were analysed road-wise and data-wise. The excel export feature presented the results in an easily understandable format making it easier for decision makers to analyse the report (represented in Fig 4-6). Both field engineers and supervisors considered this feature very useful.Performance metrics show the system's excellent accuracy, reliability and speed. Offline data collection and subsequent online synchronization ensured reliable performance especially in areas with limited internet availability

	A	B	C	D	E	F	G	H	I	J	K
1	Defect ID	Survey ID	Road Name	Start Time	Distance	End Time	Latitude	Longitude	AI Label	Confidence	Remarks
2	DEF_1771155908447	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.8076793	67.120586	patholes	38.22	
3	DEF_1771155908442	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.8076772	67.120586	TransverseCrack	94.63	
4	DEF_1771155908436	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.807688	67.120297	patholes	88.26	
5	DEF_1771155908432	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.8077316	67.120329	Patches	40.76	
6	DEF_1771155908425	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.8077806	67.120347	Nonroad	93.6	
7	DEF_1771155908402	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.8077965	67.120365	patholes	43.54	
8	DEF_1771155908395	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.8081723	67.120835	AlligatorCrack	94.42	
9	DEF_1771155908384	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.8082371	67.120866	Patches	62.53	
10											
11											

	A	B	C	D	E	F	G	H	I	J	K
1	Defect ID	Survey ID	Road Name	Start Time	Distance	End Time	Latitude	Longitude	AI Label	Confidence	Remarks
2	DEF_1775828993725	SURVEY_1003	Masoon Bukhari Road	2026-04-10T18:48:51.5605(	0	2026-04-10T18:49:53.67617	24.8360964	67.224415	AlligatorCrack	73.84	
3	DEF_1775828993719	SURVEY_1003	Masoon Bukhari Road	2026-04-10T18:48:51.5605(	0	2026-04-10T18:49:53.67617	24.8362759	67.224348	AlligatorCrack	39.57	
4	DEF_1775828993713	SURVEY_1003	Masoon Bukhari Road	2026-04-10T18:48:51.5605(	0	2026-04-10T18:49:53.67617	24.8362759	67.224348	AlligatorCrack	82.49	
5	DEF_1775828993710	SURVEY_1003	Masoon Bukhari Road	2026-04-10T18:48:51.5605(	0	2026-04-10T18:49:53.67617	24.8362749	67.224337	patholes	81.92	
6	DEF_1775828993704	SURVEY_1003	Masoon Bukhari Road	2026-04-10T18:48:51.5605(	0	2026-04-10T18:49:53.67617	24.8362629	67.224351	patholes	69.15	
7											
8											
9											
10											
11											
12											

The collected survey data is extracted into Microsoft Excel for reporting and analysis purposes. This enables the data to be formatted in a structured form that is easier to scan through,

filter and interpret the pavement condition findings. The Excel report consists of road name, form of defect, location coordinates, timestamp and comments. This would enhance the ease of accessing data and better decision making towards road maintenance and management.

	A	B	C	D	E	F	G	H	I	J	K
1	Defect ID	Survey ID	Road Name	Start Time	Distance	End Time	Latitude	Longitude	AI Label	Confidence	Remarks
2	DEF_1771155908447	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.8076793	67.120586	patholes	38.22	
3	DEF_1771155908442	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.8076772	67.120586	TransverseCrack	94.63	
4	DEF_1771155908436	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.807688	67.120297	patholes	88.26	
5	DEF_1771155908432	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.8077316	67.120329	Patches	40.76	
6	DEF_1771155908425	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.8077806	67.120347	Nonroad	93.6	
7	DEF_1771155908402	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.8077965	67.120365	patholes	43.54	
8	DEF_1771155908395	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.8081723	67.120835	AlligatorCrack	94.42	
9	DEF_1771155908384	SURVEY_5306	Creek Road	2026-02-15T16:42:3	93.4757312	2026-02-15T16:45:08.35610	24.8082371	67.120866	Patches	62.53	
10											
11											

Figure 1.7 Result Analysis

	A	B	C	D	E	F	G	H	I	J	K
1	Defect ID	Survey ID	Road Name	Start Time	Distance	End Time	Latitude	Longitude	AI Label	Confidence	Remarks
2	DEF_1775829088963	SURVEY_1827	EPZ 2	2026-04-10T18:50:2	0	2026-04-10T18:51:28.907614	24.83617	67.2244	patholes	64.94	
3	DEF_1775829088957	SURVEY_1827	EPZ 2	2026-04-10T18:50:2	0	2026-04-10T18:51:28.907614	24.83625	67.2243	patholes	30.9	
4	DEF_1775829088917	SURVEY_1827	EPZ 2	2026-04-10T18:50:2	0	2026-04-10T18:51:28.907614	24.83628	67.22435	patholes	49.09	
5											
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12											

	A	B	C	D	E	F	G	H	I	J	K
1	Defect ID	Survey ID	Road Name	Start Time	Distance	End Time	Latitude	Longitude	AI Label	Confidence	Remarks
2	DEF_1775828993725	SURVEY_1003	Masoon Bukhari Road	2026-04-10T18:48:51.5605(	0	2026-04-10T18:49:53.67617	24.8360964	67.224415	AlligatorCrack	73.84	
3	DEF_1775828993719	SURVEY_1003	Masoon Bukhari Road	2026-04-10T18:48:51.5605(	0	2026-04-10T18:49:53.67617	24.8362759	67.224348	AlligatorCrack	39.57	
4	DEF_1775828993713	SURVEY_1003	Masoon Bukhari Road	2026-04-10T18:48:51.5605(	0	2026-04-10T18:49:53.67617	24.8362759	67.224348	AlligatorCrack	82.49	
5	DEF_1775828993710	SURVEY_1003	Masoon Bukhari Road	2026-04-10T18:48:51.5605(	0	2026-04-10T18:49:53.67617	24.8362749	67.224337	patholes	81.92	
6	DEF_1775828993704	SURVEY_1003	Masoon Bukhari Road	2026-04-10T18:48:51.5605(	0	2026-04-10T18:49:53.67617	24.8362629	67.224351	patholes	69.15	
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This was succeeded by testing database. The test results were the answers to the fact that all data of the survey were properly stored in the local database and there was no problems with data loss even during the offline mode.Integration testing was also done to test the interaction between the database modules and the GPS camera. In the course of the tests, GPS positions and images taken were properly correlated to database entries reflecting the general stability of the system.Field testing was also an important part of system testing. Real road conditions were also tested using the application wherein scenarios like variation in movement lighting and network unavailability

were tested. Field tests provided the confirmation that the application can operate in a stable environment in the field.The fourth step was a user acceptance testing (UAT) during which field engineers would test the application and give feedback as to whether the application was user-friendly, responsive and fit to be used in the field.

Conclusion

The main objective of this research project was to analyse the pavement condition and evaluate the current condition of the road. In the research the different road sections were surveyed where data was gathered whereby such issues as cracks, potholes, and roughness of the surface and deterioration of the road were observed. Once the data has been collected it was analysed correctly to determine the general condition of the road.As part of research it was noted that there is more damage of roads where there is more traffic. Heavy machinery such as trailers and trucks cause greater stress on the pavement structure because of which cracks and potholes are formed rapidly. Likewise, other environmental conditions such as the temperature change in rainfall and water seepages also contribute significantly to road erosion. Damage to pavements occurs more rapidly in areas with weak drainage system.Data analysis also showed that failure to maintain roads on time even when they have smaller damages can escalate to big structural issues. Preventive maintenance like crack sealing and surface treatment prove to be of great use in prolonging the life of roads. However, when maintenance is delayed rehabilitation or reconstruction may be required which is costlier.The significant conclusion of this study was that both the road safety and the cost should be checked and monitored by regular inspection and monitoring systems provided that the road authorities perform timely surveys. This mode of controlling damage is cost effective to government and transport departments since it can be done early enough.Overall research concludes that pavement condition evaluation is a very important part of road infrastructure management. Adequate maintenance planning does not only enhance the durability of roads but also the comfort of the travelling population as well as their safety.

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