DESIGN AND DEVELOPMENT OF A CROWDSOURCED FAULT REPORTING SYSTEM FOR PUBLIC INFRASTRUCTURE IN ZAMBIA

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Abstract

Public infrastructure plays an important role in supporting transportation, economic activities, public safety, sanitation, and the general well-being of communities. However, Zambia continues to experience infrastructure problems such as damaged roads, blocked drainage systems, burst sewer pipes, damaged or missing manhole covers, and malfunctioning traffic lights. Existing methods of reporting these faults, including physical visits to local authority offices, telephone calls, letters, and social media platforms, are often fragmented and time-consuming. They also provide limited mechanisms for capturing accurate geographical information and multimedia evidence, making it difficult for authorities to verify, locate, prioritize, and track reported infrastructure faults.

This study focuses on the design and development of a Crowdsourced Fault Reporting System for Public Infrastructure in Zambia. The proposed system will provide citizens with a mobile or web-based platform for reporting infrastructure faults by submitting descriptions, photographs or short videos, and automatically capturing GPS coordinates. The system will incorporate an interactive map for visualizing reported faults and an administrative dashboard through which responsible authorities can review reports, update their status, and monitor reported infrastructure problems.

The study will examine the existing methods used for reporting public infrastructure faults and identify the challenges associated with these methods. Scrum will be used as the system development methodology because it supports iterative development, continuous testing, and incorporation of feedback. The proposed system will incorporate technologies including mobile or web application development tools, Node.js, MySQL, GPS services, and Google Maps API or OpenStreetMap for location visualization.

The expected outcome of the study is a functional prototype that provides a simple and efficient means of reporting public infrastructure faults. The system is expected to improve communication between citizens and local authorities, enhance the accuracy of reported fault locations through GPS, provide supporting evidence through multimedia, and improve transparency through report status tracking. The study will demonstrate the potential of crowdsourcing, GPS, multimedia, and Geographic Information Systems in improving public infrastructure fault reporting and management in Zambia.

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List of Abbreviations

Abbreviation	Full Meaning
API	Application Programming Interface
CSS	Cascading Style Sheets
GIS	Geographic Information System
GPS	Global Positioning System
HTML	HyperText Markup Language
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
MySQL	My Structured Query Language
OECD	Organisation for Economic Co-operation and Development

OSM	OpenStreetMap
REST	Representational State Transfer
Scrum	Scrum is not an abbreviation
SQL	Structured Query Language

CHAPTER 1

1. Introduction

Public infrastructure is essential for the social and economic development of communities. However, faults such as potholes, blocked drainage systems, damaged roads, faulty traffic lights, and missing manhole covers can affect public safety and the quality of life when they are not reported and addressed promptly [8]. This report presents the design and development of a Crowdsourced Fault Reporting System for Public Infrastructure in Zambia, which provides a digital platform for members of the public to report infrastructure faults and for responsible authorities to manage the submitted reports [5].

1.2. Background Of Study

In Zambia, public infrastructure faults are common in many communities and may include potholes, blocked drainage systems, damaged roads, faulty traffic lights, and uncovered manholes (Office of the Auditor General Zambia, 2024a; Office of the Auditor General Zambia, 2024b). Reporting these faults through traditional channels can be inconvenient and may make it difficult to provide accurate information about the location and condition of the problem.

The use of digital technologies provides an opportunity to improve the reporting of public infrastructure faults. A crowdsourced reporting system can allow citizens to submit reports together with information such as descriptions, photographs, and locations[5]. This project therefore aims to provide a centralised platform for reporting and managing public infrastructure faults in Zambia.

1.3. Problem Statement

Blocked drainage systems, faulty traffic lights, damaged bridges, and missing manhole covers can pose significant challenges to communities when they are not reported and addressed promptly. In Zambia, reporting of such faults may involve different channels and responsible authorities, which can result in fragmented information and difficulties in tracking reported problems (Office of the Auditor General Zambia, 2024a; Office of the Auditor General Zambia, 2024b).

Traditional reporting methods may also provide limited information about the exact location and condition of an infrastructure fault. For example, a written or telephone complaint may not adequately communicate the geographical location or severity of the problem. In addition, members of the public may have limited ability to determine whether their complaints have been received, reviewed, assigned, or resolved. Digital crowdsourcing platforms can improve the collection of location-based reports and provide greater visibility of reported problems and their progress[7] .

The absence of a centralised digital platform for crowdsourced reporting can therefore limit the efficient collection, management, and tracking of public infrastructure faults. There is a need for a system that enables citizens to submit infrastructure fault reports with supporting information such as descriptions, photographs, and location data, while allowing relevant administrative users to manage and respond to these reports[7] .



1.4. Objectives Of Study

1.4.1 Main Objective

The main objective of the project was to design and develop a crowdsourced fault reporting system for public infrastructure in Zambia.

1.4.2 Specific Objectives

The specific objectives of the project were:

1. To identify common public infrastructure faults that can be reported by members of the public in Zambia.

2. To design and develop a crowdsourced fault reporting system for reporting and managing public infrastructure faults.
3. To evaluate the developed system in terms of its functionality and usability.

1.5 Research Questions

The project was guided by the following research questions:

1. What are the common public infrastructure faults that can be reported by members of the public in Zambia?
2. What information is required for effective reporting and management of public infrastructure faults?
3. How can a crowdsourced system be designed and developed to support the reporting and management of public infrastructure faults?
4. How can location-based features support the identification and visualisation of reported infrastructure faults?
5. How effective and usable is the developed crowdsourced fault reporting system?

1.6 Ethical Considerations

Ethical considerations in any research have been identified or specified as one of the most important parts of the research. Researchers have identified research ethics as the core aspect of research and the foundation of a research design, an integral part of the research that needs to remain at the forefront of the research work. The importance therefore of the research ethics cannot be understated.This project intends to shield users' information from any actions that may be perceived as a threat to their identity and privacy. Some of the ethical issues related to this project may include the following:

1.6.1 Informed consent

With the use of natural language processing, this research project will work in line with the terms and conditions for the particular software tools that will be used for design and implementation. This will consist of using free and open source software.

1.6.2 Respect of privacy

Privacy breaches disturb trust and run the risk of diluting or losing security. It is a show of disrespect to the law and a violation of ethical principles. Therefore, this project will ensure that only people who ask for copyright permission will be able to share or publish the work.

CHAPTER 2

2. Related Work

2.1 Identification of Common Approaches for Reporting Public

Public infrastructure faults can be reported through traditional and digital reporting approaches. Traditional approaches may include physical visits to local authority offices, telephone calls, written complaints, and direct communication with responsible institutions. These approaches provide channels through which citizens can communicate infrastructure problems, but they may provide limited structured information about the exact location, type, severity, and status of a reported fault.

The development of digital reporting platforms has provided alternative ways for citizens to report infrastructure problems. Digital platforms can allow citizens to submit information electronically and may incorporate geographical locations, descriptions, photographs, and other supporting information. [7]. examined FixMyStreet Brussels, a web-based civic participation platform that allows citizens to report environmental defects such as potholes and damaged pavements to government authorities. Their study demonstrates how digital platforms can be used to collect citizen-generated information about infrastructure-related problems.

Crowdsourcing has also provided an alternative approach to collecting information about urban problems.[5]explain that advances in positioning technologies, smartphones, online platforms, and digital mapping have increased the availability of crowdsourced geospatial information for understanding urban environments.The proposed research builds on these approaches by providing a centralised digital platform through which citizens can report public infrastructure faults. The proposed system will allow users to provide structured information including the fault category, description, geographical location, photographs or videos, and severity of the reported problem.

2.2 Crowdsourcing for Public Infrastructure Fault Reporting

Crowdsourcing involves obtaining information, ideas, or contributions from a large group of people, usually through digital platforms. In the context of public infrastructure, crowdsourcing allows citizens to contribute information about infrastructure problems that they encounter within their communities. Explain that crowdsourced geospatial data has become increasingly important in urban sciences due to the widespread use of smartphones, positioning technologies, online mapping platforms, and other digital technologies. Such data can provide information about urban infrastructure and functionality that may not be readily available through traditional data sources.[5]

Reviewed the use of crowdsourcing technologies for citizen participation in smart cities. Their review identified applications of crowdsourcing in areas such as urban infrastructure maintenance, urban mobility, environmental monitoring, geographical information collection, and citizen participation[13]. The study demonstrates the potential of participatory reporting and participatory sensing for collecting information from citizens.Demonstrated the application of crowdsourcing to structure through a smartphone-based system for reporting potholes. Their system allowed citizens to provide information about potholes using smartphones and incorporated image-processing techniques to assist with pothole identification.

2.3 Geographic Information Systems for Locating Infrastructure Faults

Crowdsourcing involves obtaining information, ideas, or contributions from a large group of people, usually through digital platforms. In the context of public infrastructure, crowdsourcing allows citizens to contribute information about infrastructure problems that they encounter within their communities. [5].explain that crowdsourced geospatial data has become increasingly important in urban sciences due to the widespread use of smartphones, positioning technologies, online mapping platforms, and other digital technologies. Such data can provide information about urban infrastructure and functionality that may not be readily available through traditional data sources.

[13]. reviewed the use of crowdsourcing technologies for citizen participation in smart cities. Their review identified applications of crowdsourcing in areas such as urban infrastructure maintenance, urban mobility, environmental monitoring, geographical information collection, and citizen participation. The study demonstrates the potential of participatory reporting and participatory sensing for collecting information from citizens.Enigo et al. (2016) demonstrated the application of crowdsourcing to road infrastructure through a smartphone-based system for reporting potholes. Their system allowed citizens to provide information about potholes using smartphones and incorporated image-processing techniques to assist with pothole identification. Mmm

2.4 Mobile and Web-Based Infrastructure Fault Reporting Systems

Mobile and web-based technologies provide convenient platforms through which citizens can communicate information to public institutions. Mobile devices are particularly relevant because they can provide access to cameras, GPS services, internet connectivity, and other sensors. Explain that modern smartphones can support participatory sensing by allowing ordinary citizens to collect and share information about their surrounding environments. This makes smartphones suitable for infrastructure reporting because citizens can collect information at the location where a fault is observed. demonstrated this approach through a smartphone-based crowdsourcing system for pothole reporting.

Their research showed how mobile devices can be used to collect information about road defects and communicate the information to relevant authorities.[7].also demonstrated the use of a web-based civic participation platform through FixMyStreet Brussels. Citizens could use the platform to report environmental defects and communicate these problems to government authorities.The proposed research builds on these approaches by developing a digital platform specifically designed for public infrastructure fault reporting in Zambia. Users will be able to select a fault category, provide a description, attach photographs or videos, capture GPS coordinates, and submit the report.

2.5 Multimedia Evidence in Infrastructure Fault Reporting

Multimedia evidence can improve the amount of information available in an infrastructure fault report. A written description may not always adequately communicate the physical condition or severity of an infrastructure problem. Photographs and videos can therefore provide additional evidence that assists authorities in understanding the reported fault.

Enigo et al. (2016)[12] incorporated images into their crowdsourcing-based pothole reporting system. Their research demonstrated how photographs captured through smartphones could contribute to the identification and assessment of road defects. [10]. also examined a civic digital platform through which citizens could submit requests and supporting information to government authorities. This demonstrates how digital reporting platforms can combine citizen-generated information with government processing and feedback.

However, citizen-generated multimedia and geographical information can also present data-quality challenges. Koswatte et al. (2018) explain that crowdsourced geographic information may have issues involving credibility, reliability, relevance, incomplete location information, and missing metadata. These challenges demonstrate the importance of designing structured reporting systems that collect sufficient information to support the assessment of submitted reports.The proposed system will therefore allow citizens to attach photographs or short videos to their infrastructure fault reports. These files will be associated with the corresponding report together with its description, category, location, and other metadata.

2.6 Existing Public Infrastructure Fault Reporting Approaches in Zambia

In Zambia, public infrastructure faults can be reported through different channels, including physical offices, telephone communication, social media platforms, and other forms of direct communication with responsible institutions. Although these approaches provide opportunities for citizens to communicate infrastructure problems, they may not provide a centralised mechanism for recording, locating, tracking, and managing reports.

The absence of a unified reporting platform may make it difficult to maintain a structured database of infrastructure faults. Reports received through informal channels may also lack important information such as precise geographical coordinates, photographs, videos, fault categories, or the status of the reported problem. Consequently, responsible institutions may face challenges in prioritising faults and monitoring their resolution.The proposed research seeks to address these challenges by designing and developing a crowdsourced fault reporting system for public infrastructure in Zambia. The system will provide a centralised platform where citizens can submit infrastructure fault reports containing relevant information. The proposed solution will focus on infrastructure categories such as potholes, drainage systems, sewer systems, manholes, and traffic lights.Unlike conventional reporting approaches, the proposed system will combine crowdsourcing, geographical location, multimedia evidence, and digital fault management. This will provide a structured approach to collecting infrastructure-related information from citizens and may support authorities in identifying and prioritising infrastructure faults.

2.7 Summary of Related Work

The reviewed literature demonstrates that crowdsourcing, GIS, mobile applications, multimedia evidence, and digital reporting platforms can contribute to more effective identification and management of public infrastructure faults. Crowdsourcing provides a mechanism through which citizens can contribute information, while GIS enables reported faults to be associated with specific geographical locations. Mobile and web technologies provide convenient reporting platforms, and multimedia evidence can improve the quality and reliability of submitted reports. However, existing approaches do not fully address the requirements of a crowdsourced public infrastructure fault reporting system specifically designed for the Zambian context. The proposed research therefore seeks to integrate these approaches into a single system that allows citizens to report infrastructure faults using descriptions, photographs or videos, fault categories, and GPS coordinates. The system will also consider offline functionality to address possible connectivity limitations in some areas of Zambia.

Overall, the proposed system aims to improve the collection, organisation, and communication of public infrastructure fault information while providing a foundation for better identification and prioritisation of infrastructure maintenance needs.

Table 1. Metadata Elements for Public Infrastructure Fault Reports

Metadata Element	**Definition**
Fault ID	A unique identifier assigned to each reported infrastructure fault.
Type	The category of infrastructure problem being reported, such as pothole, drainage, sewer, manhole, or traffic light.

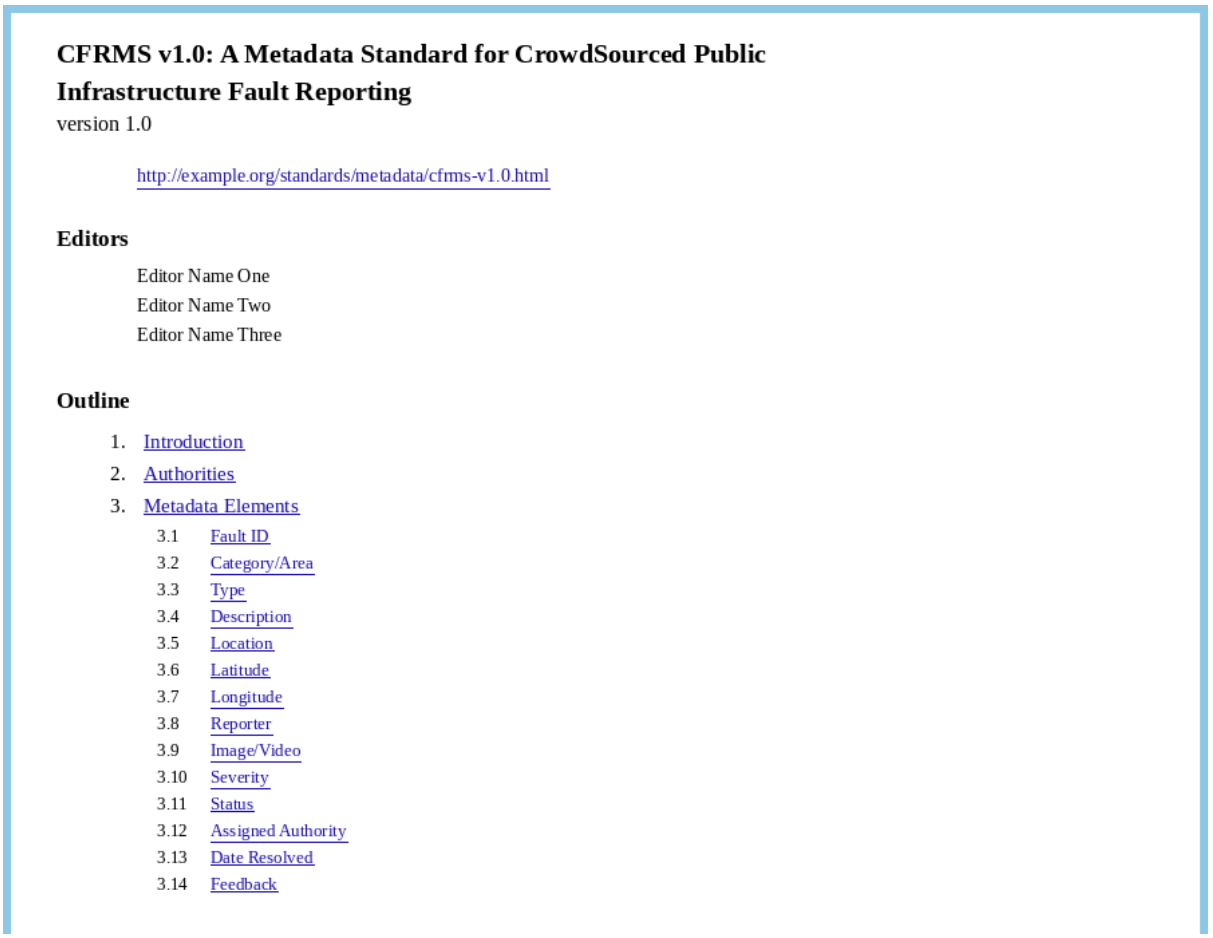
Description	A detailed explanation of the reported infrastructure fault.
Location	The geographical location where the infrastructure fault was identified.
Latitude	The east–west geographical coordinate of the reported fault.
Longitude	The east–west geographical coordinate of the reported fault.
Reporter	The citizen or user who submitted the infrastructure fault report.
Image/Video	Photographic or video evidence attached to the infrastructure fault report.
Severity	The level of seriousness or urgency of the reported infrastructure fault.
Status	The current state of the reported fault, such as pending, verified, in progress, resolved, or rejected.
Assigned Authority	The institution or responsible authority assigned to investigate or resolve the reported fault.
Date Resolved	The date on which the reported infrastructure fault was resolved.
Feedback	Additional information, comments, or feedback concerning the reported fault.
Category/Area	The administrative or geographical area in which the infrastructure fault is located.

No

2.8 Crowdsourced Fault Reporting Metadata

Crowdsourced fault reporting systems define a standard set of information elements used to describe public infrastructure faults. Institutions responsible for managing public infrastructure have developed different approaches or adapted existing reporting systems to collect information about infrastructure faults. In line with these approaches, fault reporting systems attempt to describe the

type of fault, its location, severity, supporting evidence, and the context in which the fault occurred in a way that will be useful to citizens as well as the relevant authorities responsible for maintaining public infrastructure. However, the existing reporting approaches are not a replacement for the metadata elements developed for a particular infrastructure management environment. Rather, they provide guidelines for developing an appropriate set of information elements that can be used to consistently capture and share information about public infrastructure faults. Below is Figure 2.1.0 and Figure 2.2.0 showing screenshots of existing crowdsourced fault reporting systems with their prescribed information elements[11].



CFRMS v1.0: A Metadata Standard for CrowdSourced Public Infrastructure Fault Reporting

version 1.0

http://example.org/standards/metadata/cfrms-v1.0.html

Editors

Editor Name One
Editor Name Two
Editor Name Three

Outline

1. Introduction
2. Authorities
3. Metadata Elements
   - 3.1 Fault ID
   - 3.2 Category/Area
   - 3.3 Type
   - 3.4 Description
   - 3.5 Location
   - 3.6 Latitude
   - 3.7 Longitude
   - 3.8 Reporter
   - 3.9 Image/Video
   - 3.10 Severity
   - 3.11 Status
   - 3.12 Assigned Authority
   - 3.13 Date Resolved
   - 3.14 Feedback

Figure 2.1.0: CrowdSourced metadata standard

Metadata Elements

3.1 Fault ID

3.2 Category/Area

3.3 Type

3.4 Description

3.5 Location

3.6 Latitude

3.7 Longitude

3.8 Reporter

3.9 Image/Video

3.10 Severity

3.11 Status

3.12 Assigned Authority

Figure 2.2 Public Infrastructure Fault Reporting Process

2.9 Crowdsourcing for Reporting Public Infrastructure Faults

Crowdsourcing is an approach that involves obtaining information, ideas, or services from a large group of people, particularly through digital platforms. In the context of public infrastructure, crowdsourcing can be used to allow members of the public to report faults such as potholes, damaged roads, blocked drainage systems, broken traffic lights, damaged manholes, and other infrastructure-related problems.Previous studies have demonstrated that crowdsourced information can provide useful data for identifying problems within communities. Instead of relying entirely on government agencies or infrastructure authorities to identify faults through periodic inspections, members of the public can report problems as they encounter them. This can provide authorities with more current information about infrastructure conditions and help them prioritise areas requiring attention.

Similarly to these studies, the current research focuses on using members of the public as sources of infrastructure fault information. The proposed system will allow citizens in Zambia to report faults affecting public infrastructure using a digital platform. However, unlike general crowdsourcing systems, the proposed system specifically focuses on public infrastructure faults in the Zambian context. Users will be able to submit information about the type of fault, its location, description and supporting evidence such as photographs or videos[9]. The system will therefore provide a channel through which citizens can contribute information about infrastructure problems while enabling responsible authorities to access and manage reported faults.

2.9.1Citizen Participation in Public Infrastructure Management

Citizen participation is an important component of effective public service delivery because members of the public are often the first to observe problems within their communities. Digital reporting platforms provide an opportunity for citizens to communicate infrastructure problems to relevant authorities without necessarily having to visit government offices physically. Previous research on citizen participation has shown that digital platforms can improve communication between citizens and service providers by providing mechanisms for submitting complaints, reporting problems and monitoring responses. Such systems can increase transparency and provide authorities with information that may not be readily available through conventional inspection processes.

This literature is relevant to the current research because the proposed crowdsourced fault reporting system also seeks to improve communication between citizens and authorities responsible for public infrastructure. The system will allow users to report infrastructure faults from their mobile devices and provide relevant information that can assist authorities in understanding the reported problem [10]. However, the current research differs from general citizen-feedback systems because it focuses specifically on infrastructure faults. The proposed system will categorise reports according to infrastructure types, including potholes, drainage systems, sewer and manhole problems, traffic lights and other public infrastructure faults. This categorisation will help make the submitted reports more organised and easier to manage.Location information is an important component of infrastructure fault reporting because authorities need to know where a reported problem is situated before appropriate action can be taken. Location-based technologies, particularly Global Positioning System (GPS) technology and digital maps, can be used to capture and display the geographical position of reported faults.Previous location-based reporting systems have demonstrated the usefulness of geographical information in identifying and managing problems occurring at specific locations.

Integrating GPS with reporting applications allows users to submit reports together with their geographical coordinates. Map-based interfaces can then be used to visualise reported problems and assist authorities in locating them[9].The current research applies a similar concept by incorporating GPS and mapping functionality into the proposed crowdsourced fault reporting system. When reporting an infrastructure fault, a user's location can be captured and associated with the submitted report. The location can subsequently be displayed on a map to help relevant authorities identify where the fault occurred.The difference is that the proposed system combines location information with other evidence, including photographs, videos and descriptions of infrastructure faults. This provides more comprehensive information than relying on location alone and can assist authorities in assessing the reported problem.

2.9.2 Determination of the Appropriate Method for Reporting Public Infrastructure Faults

Mobile and web technologies have increasingly been used to provide digital platforms through which citizens can communicate information to organisations and public authorities. Mobile applications are particularly useful for reporting infrastructure faults because users can submit information while they are physically located near the problem.Existing reporting systems generally provide users with forms

through which they can enter descriptions, select categories and submit supporting information. Some systems also incorporate location services and multimedia functionality to improve the quality of submitted reports[9]. This approach is relevant to the current research because the proposed system will provide a digital platform through which citizens can report public infrastructure faults. The system will provide reporting fields that allow users to specify the category of the fault, provide a description and attach photographic or video evidence.However, the current research is designed specifically for public infrastructure reporting in Zambia. The proposed system will focus on common infrastructure problems experienced by citizens in the Zambian context, including potholes, drainage problems, sewer and manhole faults and malfunctioning traffic lights.

The system will also provide a centralised platform for managing submitted reports rather than limiting the reporting process to simple complaint submission.Multimedia Evidence in Fault ReportingThe use of multimedia evidence can improve the quality and reliability of reports submitted through digital reporting systems. Photographs and videos can provide visual evidence of the condition of infrastructure and enable authorities to better understand the nature and severity of a reported fault. Previous digital reporting systems have incorporated image-upload functionality to allow users to provide evidence when submitting complaints or reports. Such evidence can assist administrators in determining whether a reported problem requires further investigation and can help reduce ambiguity in textual descriptions.Similarly, the proposed research will allow users to attach photographs or videos when reporting infrastructure faults. For example, a citizen who encounters a pothole can take a photograph of the pothole and submit it together with its location and a description of the problem.The difference is that the proposed system combines multimedia evidence with categorisation, geographical coordinates and structured fault information. This allows each report to contain several forms of evidence that can assist authorities in verifying and prioritising infrastructure faults[14] .

Offline Reporting and Connectivity Challenges Internet connectivity is an important consideration when developing digital reporting systems, particularly in developing countries where network availability may vary between locations. A system that requires continuous internet connectivity may prevent users from submitting reports when they encounter infrastructure faults in areas with poor or unavailable network coverage.Previous mobile applications have addressed connectivity limitations by incorporating offline functionality. Such functionality allows users to capture and store

information locally before transmitting it to a central server when an internet connection becomes available [6] .This approach is relevant to the current research because the proposed fault reporting system is intended for use across different locations in Zambia where network connectivity may not reliable. The system will therefore consider offline reporting functionality so that users can capture relevant information even when they temporarily lack internet access. Unlike systems that depend entirely on continuous connectivity, the proposed system can store reports locally and synchronise them with the central system once connectivity is restored. This can improve the accessibility and usability of the system in areas with unreliable network connections.

2.9.3 Determination of Appropriate Technologies for the Proposed Fault Reporting System

Web technologies provide a practical platform for developing systems that can be accessed through different devices without requiring users to install specialised software. Technologies such as HTML, CSS and JavaScript can be used to develop interfaces through which users submit and view information.The current research will make use of web technologies to provide an accessible interface for reporting and managing public infrastructure faults. HTML will provide the structure of the system, CSS will support the presentation and layout, while JavaScript will provide interactive functionality.The proposed system differs from conventional static reporting websites because it will incorporate dynamic reporting, geographical information, multimedia evidence and administrative management of submitted faults.Database management systems are important for storing and organising information submitted by users. A crowdsourced infrastructure reporting system requires a database capable of storing information such as user details, fault categories, descriptions, geographical coordinates, images, videos, dates and report statuses.Previous information systems have demonstrated the importance of structured databases for storing and retrieving user-generated information. Relational database management systems can organise information into related tables, allowing reports to be efficiently stored, searched and updated [1].The proposed system will similarly require a database to store infrastructure fault reports and their associated information. A relational database such as MySQL can be used to manage the submitted reports and support operations such as creating, updating, retrieving and tracking the status of reports.

This differs from simple complaint systems because the proposed database structure will be designed specifically to support infrastructure fault categories, geographical locations, multimedia evidence and report-status tracking. Mapping technologies are useful for visualising the geographical

distribution of infrastructure faults. A map-based interface can allow users and administrators to identify where faults have been reported and determine whether multiple reports relate to the same geographical area.Existing systems that incorporate digital maps have demonstrated that geographical visualisation can improve the interpretation and management of location-based information. Mapping APIs and open mapping platforms can provide functionality for displaying locations, markers and geographical information[4] .Existing systems that incorporate digital maps have demonstrated that geographical visualisation can improve the interpretation and management of location-based information. Mapping APIs and open mapping platforms can provide functionality for displaying locations, markers and geographical information[3] .

2.9.4 Summary of Related Work

The reviewed literature demonstrates that crowdsourcing, citizen participation, location-based technologies, multimedia evidence, mobile and web applications, databases and mapping technologies can be used to improve the reporting and management of public infrastructure problems .Crowdsourcing provides an opportunity for citizens to contribute information about infrastructure faults, while GPS and mapping technologies provide the geographical location of reported problems.

Multimedia evidence can improve the quality of reports, while databases provide mechanisms for storing and managing submitted information[3]. Offline functionality can further improve accessibility in areas where internet connectivity is unreliable

CHAPTER 3

3. Methodology

This chapter presents the methodology used in the study titled Design and Development of a Crowdsourced Fault Reporting System for Public Infrastructure in Zambia. The methodology was guided by the objectives of the study and focused on understanding common infrastructure faults, examining existing reporting practices, and using the information obtained to design and implement the proposed ZamFault system. The chapter presents the research approach, the process used to identify common infrastructure faults, and the design and implementation of the crowdsourced fault reporting system.

3.1 Research Approach

The study adopted a qualitative descriptive research approach to obtain detailed information about public infrastructure faults, experiences with existing reporting mechanisms, and users' expectations of a digital fault reporting system. A qualitative approach was considered appropriate because it allowed participants to describe their experiences and opinions in their own words. The study was conducted at the University of Zambia (UNZA), which was used as the main study setting for examining infrastructure conditions and obtaining information from students who regularly use university facilities .The study population consisted of members of the university community who had experience using public facilities and could provide information about infrastructure faults and their reporting. Students from different academic backgrounds were purposively selected to participate in the study. Purposive sampling was used because participants were selected based on their experience with infrastructure-related problems and their ability to provide relevant information to the study. The participants included students who had encountered infrastructure faults within the university environment.

Data were collected using direct observation and semi-structured interviews. Direct observation was used to examine the condition of selected facilities and identify visible infrastructure faults. The areas observed included lecture venues, laboratories, hostels, sanitation facilities, roads, walkways, and other shared spaces. Photographs were taken where appropriate to provide visual evidence of observed infrastructure conditions. Semi-structured interviews were conducted using an interview guide containing open-ended questions. The questions focused on participants' experiences with infrastructure faults, how they reported such faults, challenges encountered during reporting, and their views about using a digital system such as ZamFault.The data collection process began with the observation of selected areas within the University of Zambia. The researchers recorded infrastructure

problems observed in the study setting and subsequently conducted interviews with selected students. Before each interview, the purpose of the study was explained to the participant and participation was voluntary. The information obtained from the interviews was organised according to the objectives of the study.

The information collected through observations and interviews was analysed using thematic analysis. Similar responses and observations were grouped according to recurring ideas and issues[2]. The analysis focused on infrastructure faults, the effects of such faults, existing reporting practices, challenges associated with reporting, and the features expected from a digital reporting system. Ethical considerations were also observed throughout the study. Participants were informed about the purpose of the study, participation was voluntary, and the information provided was treated confidentially and used for academic purposes. Photographs taken during observation focused on infrastructure conditions while taking reasonable measures to protect the privacy of individuals.

3.2 Identification of Common Infrastructure Faults

The identification of common infrastructure faults was conducted through direct observation and semi-structured interviews. The observations provided direct evidence of infrastructure conditions within the University of Zambia, while the interviews provided information about problems experienced by students and their experiences with reporting such problems.The observations identified several infrastructure-related problems within the study setting. These included poor sanitation, inadequate or damaged seating, insufficient seating in lecture venues and laboratories, poorly managed waste disposal, and other problems affecting the condition and usability of public facilities. For example, damaged classroom furniture was observed in some learning spaces, while waste disposal problems were also identified in areas used by students. These observations demonstrated that infrastructure faults could affect the comfort, safety, and effective use of public facilities.

The interview responses supported the observations by showing that students had experienced similar infrastructure problems. Participants reported problems involving sanitation, broken or inadequate chairs, insufficient seating, waste management, and conditions affecting the usability of shared facilities. Some participants explained that inadequate seating could result in students standing during lectures or sharing limited seating spaces, while sanitation-related problems affected their comfort and use of the facilities.The interviews also examined how participants reported infrastructure faults and the challenges they experienced. Some participants indicated that they reported problems through student leaders, while others did not report faults because they were unaware of where or to whom they should report them. In some cases, participants indicated that action taken after reporting a problem was temporary and that some problems later recurred. These experiences demonstrated the need for a reporting mechanism that is accessible, clear, and convenient for users.

The information obtained from the observations and interviews was therefore used to determine the types of faults that could be supported by the proposed ZamFault system. The participants' views also helped establish the requirements of the system. Participants considered features such as **fault** descriptions, photographic evidence, automatic location capture, user accounts, report tracking, feedback, and a simple reporting process to be useful. These requirements provided the basis for the design and development of the proposed system.

3.3 Design and Implementation of Crowdsourced Fault Reporting System

The information obtained from the research process was used to design and implement the proposed ZamFault crowdsourced fault reporting system. The system was designed to provide users with an accessible digital platform through which they could report public infrastructure faults and provide relevant information about the reported problem. The design was guided by the requirements identified from the observations and interviews.The study adopted Scrum as the software development methodology. Scrum was selected because it supports iterative development, allowing the system to be developed and improved progressively. The development process involved requirements identification, system planning and design, development of the user interface, implementation of fault reporting functionality, location functionality, image uploading, report management, integration of system components, testing, debugging, and refinement.

ZamFault was designed to allow users to provide a description of an infrastructure fault, indicate its location, attach photographic evidence, and submit the report. Location functionality was included to assist in identifying where a fault had occurred. The system also provided functionality for managing submitted reports and updating their status as they progressed through the reporting process. The proposed system therefore aimed to provide a clearer reporting channel while allowing submitted faults to be monitored.

The system was implemented using HTML, CSS, and JavaScript for the user interface, while MySQL was used for database management. Mapping and location functionality was implemented using an appropriate mapping service such as OpenStreetMap or Google Maps API, together with GPS functionality for capturing geographical coordinates. Git and GitHub were used for version control and collaboration during development. After implementation, the system was tested to determine whether it operated according to the identified requirements. Testing covered important functions including user registration and login, fault report submission, description entry, image uploading, location capture, database storage, report management, and status updates. Unit testing was used to examine individual components, while integration testing examined the interaction between different system components. System testing was conducted on the complete system to determine whether the major functions operated correctly when integrated. User acceptance testing was also conducted to

assess whether the system was understandable and usable from the perspective of intended users. Problems identified during testing were used to improve the system.

Overall, the methodology provided a structured process through which information about infrastructure faults was collected, analysed, and translated into system requirements. The identified requirements then guided the design, implementation, and testing of the ZamFault crowdsourced fault reporting system.

3.4 System Testing and Evaluation

System testing and evaluation were conducted to determine whether the developed ZamFault system functioned as intended and was easy for users to understand and use. The testing involved allowing selected participants to interact with the system and perform the main tasks involved in reporting public infrastructure faults. Participants were asked to navigate through the system, access the fault reporting function, select a fault category, enter a description of the fault, provide the location, add photographic evidence, and submit the report. During the testing process, the researcher observed whether participants were able to complete these tasks successfully and noted any difficulties, errors, or areas where users experienced challenges. The information obtained from the testing was used to identify areas that required improvement before the final version of the system was completed.

The usability of ZamFault was evaluated using the System Usability Scale **(SUS)**, a standardized method for measuring the perceived usability of systems (Brooke, 1996). After completing the assigned tasks, participants were asked to respond to the ten SUS statements using a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The SUS statements assessed aspects such as ease of use, complexity, consistency, learnability, and users' confidence when interacting with the system. The responses were collected using a Google Form and were later used to calculate the overall SUS score for the ZamFault system. The evaluation results were used to determine the level of usability of the system and identify areas that could be improved.

3.5 Summary

This chapter presented the methodology used to conduct the study and develop the proposed ZamFault system. A qualitative descriptive research design was adopted, with the University of Zambia serving as the main study setting. Direct observation and semi-structured interviews were used to identify infrastructure faults, understand existing reporting experiences, identify reporting challenges, and establish requirements for the proposed system.Their responses were analysed thematically. The findings highlighted common infrastructure problems such as sanitation issues, inadequate or broken seating, overflowing waste bins, and other facility-related faults. The interviews also revealed challenges associated with the lack of clearly known reporting channels.The identified requirements informed the development of ZamFault, particularly features for fault descriptions,

photograph uploads, automatic location capture, user accounts, and report status updates. Scrum was adopted as the system development methodology, followed by implementation and testing of the developed prot

CHAPTER 4

4.1 System Architecture Diagram

The proposed system adopts a client-server architecture consisting of the client, server, and database. The client allows citizens to register, log in, report infrastructure faults, upload photographs or short videos, capture GPS coordinates, and view report status. The server processes user requests, validates and manages reports, updates report status, and sends notifications. The database stores user, report, media, location, notification, and administrator information. The system also integrates GPS and Google Maps or OpenStreetMap services for location identification and mapping.

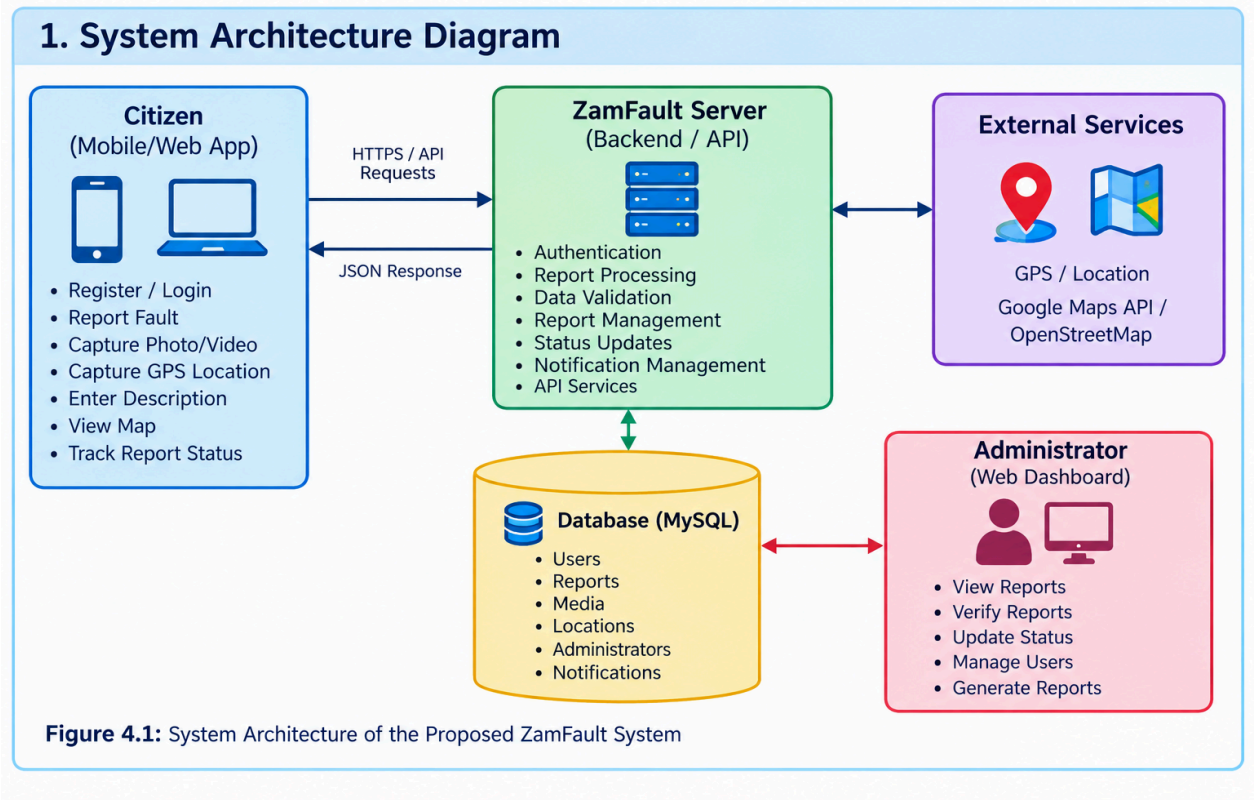


Figure 4.1: System Architecture of the Proposed ZamFault System

4.2 Context Diagram

The context diagram shows how citizens, administrators, and GPS or map services interact with the ZamFault system. Citizens can register, submit and track fault reports, while administrators verify reports, update statuses, manage users, and generate reports. The system processes and stores information, sends notifications, and uses GPS or map services to support location identification and

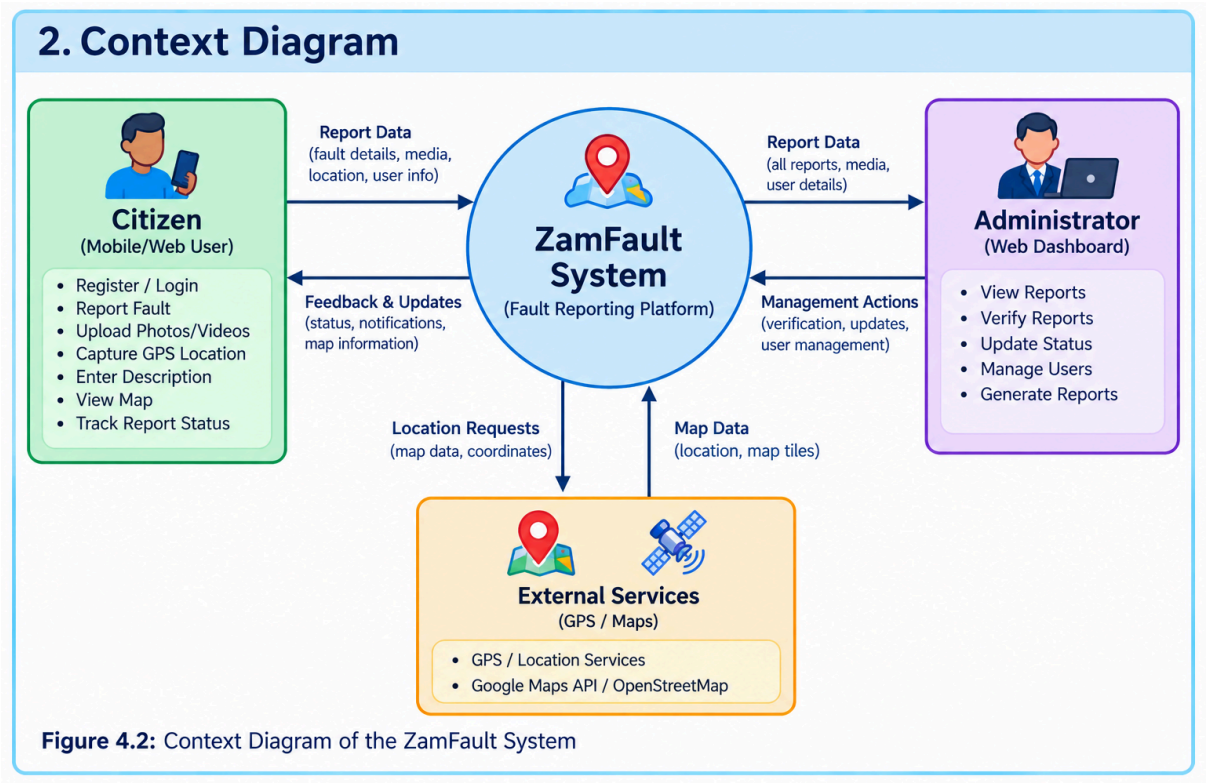


Figure 4.2: Context Diagram of the ZamFault System

4.3 The Use Case Diagram

The use case diagram illustrates how citizens and administrators interact with the ZamFault system. Citizens can register, log in, submit fault reports, upload photos or videos, capture GPS locations, view reports, track report status, and receive notifications. Administrators can log in, view and verify reports, update report status, manage users, and generate reports.

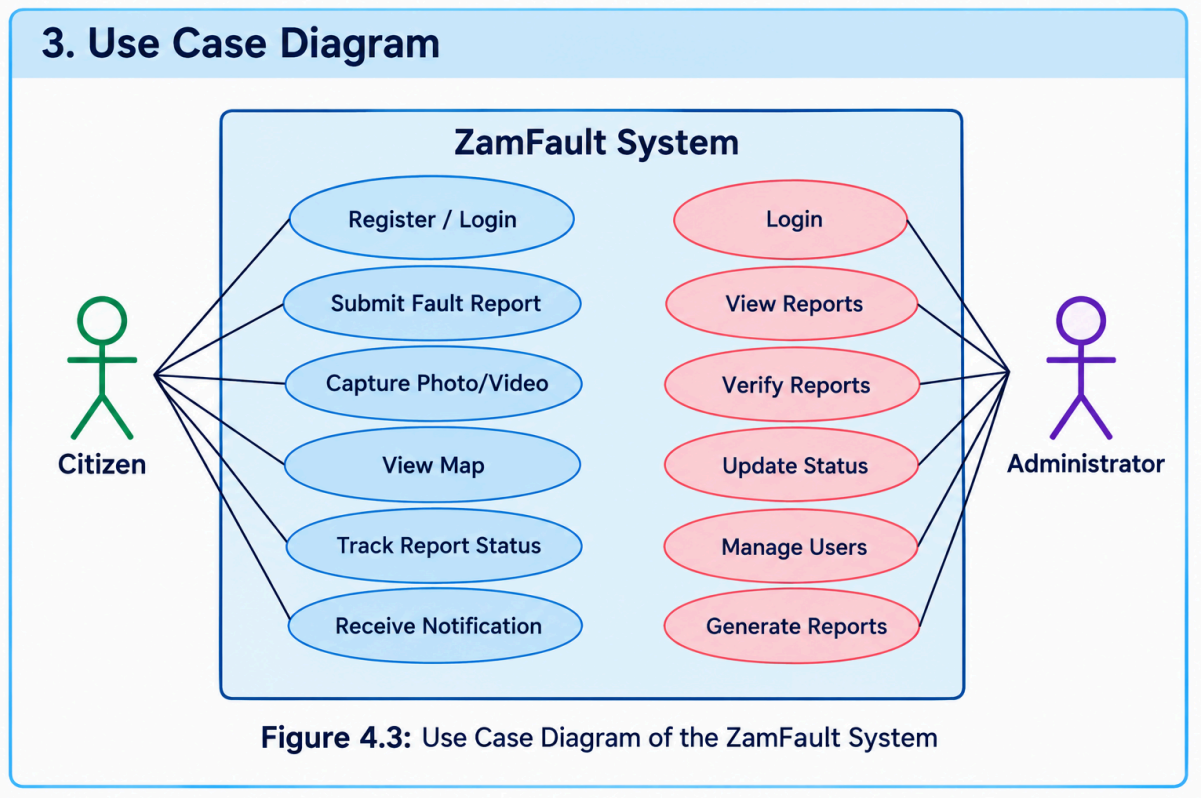


Figure 4.3: Use Case Diagram of the ZamFault System

4.4Class Diagram

The class diagram shows the six main classes of ZamFault: User, Report, Location, Media, Notification, and Administrator. Each class stores information needed for user management, fault reporting, location tracking, media uploads, notifications, and system administration.

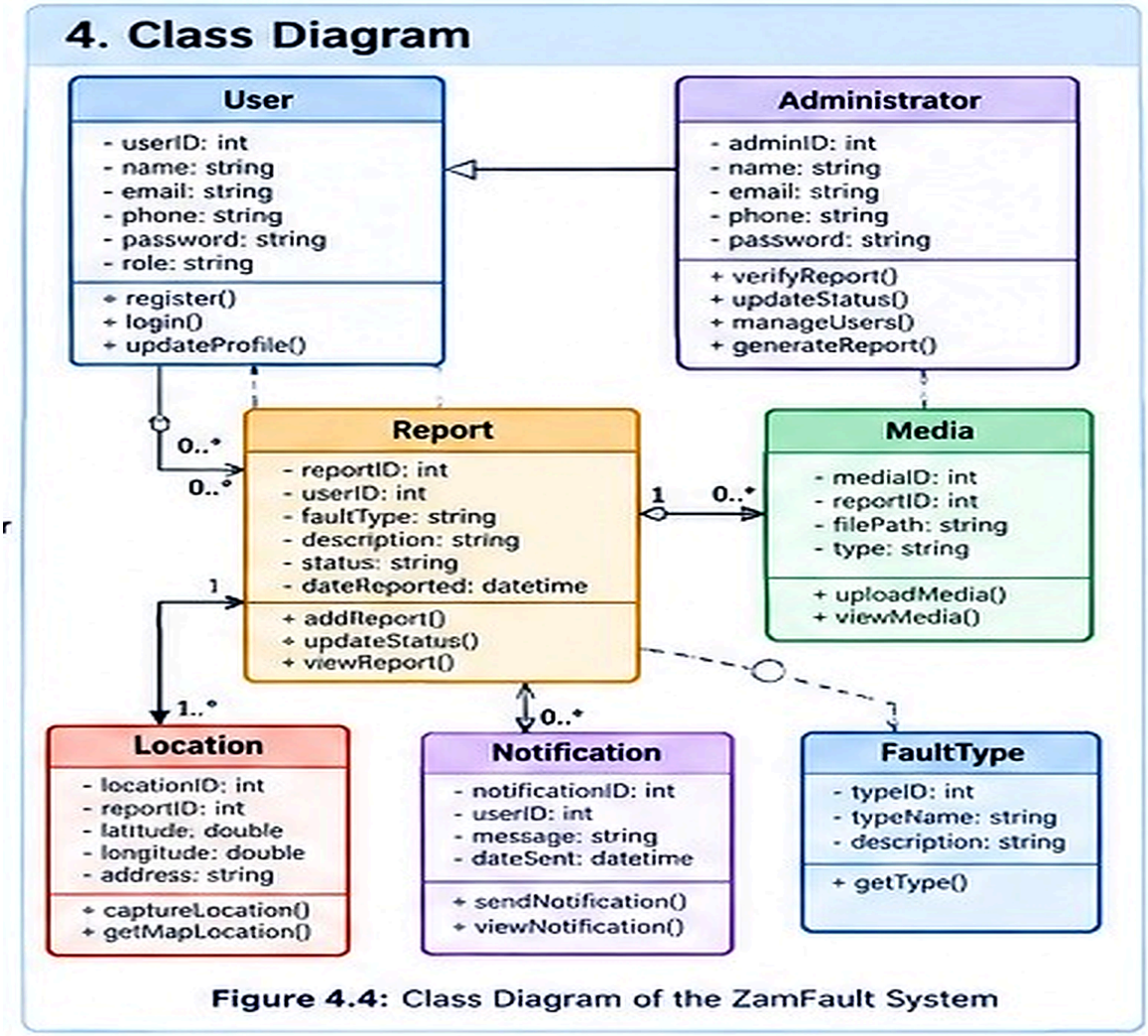


Figure 4.4: Class Diagram of the ZamFault System

4.5 The Sequence Diagram

The sequence diagram illustrates the interaction between the Citizen, ZamFault App, Server, and Database during fault reporting. The citizen submits fault details, photographs or videos, and GPS location. The server validates the report, stores the information in the database, and displays a confirmation message to the citizen.

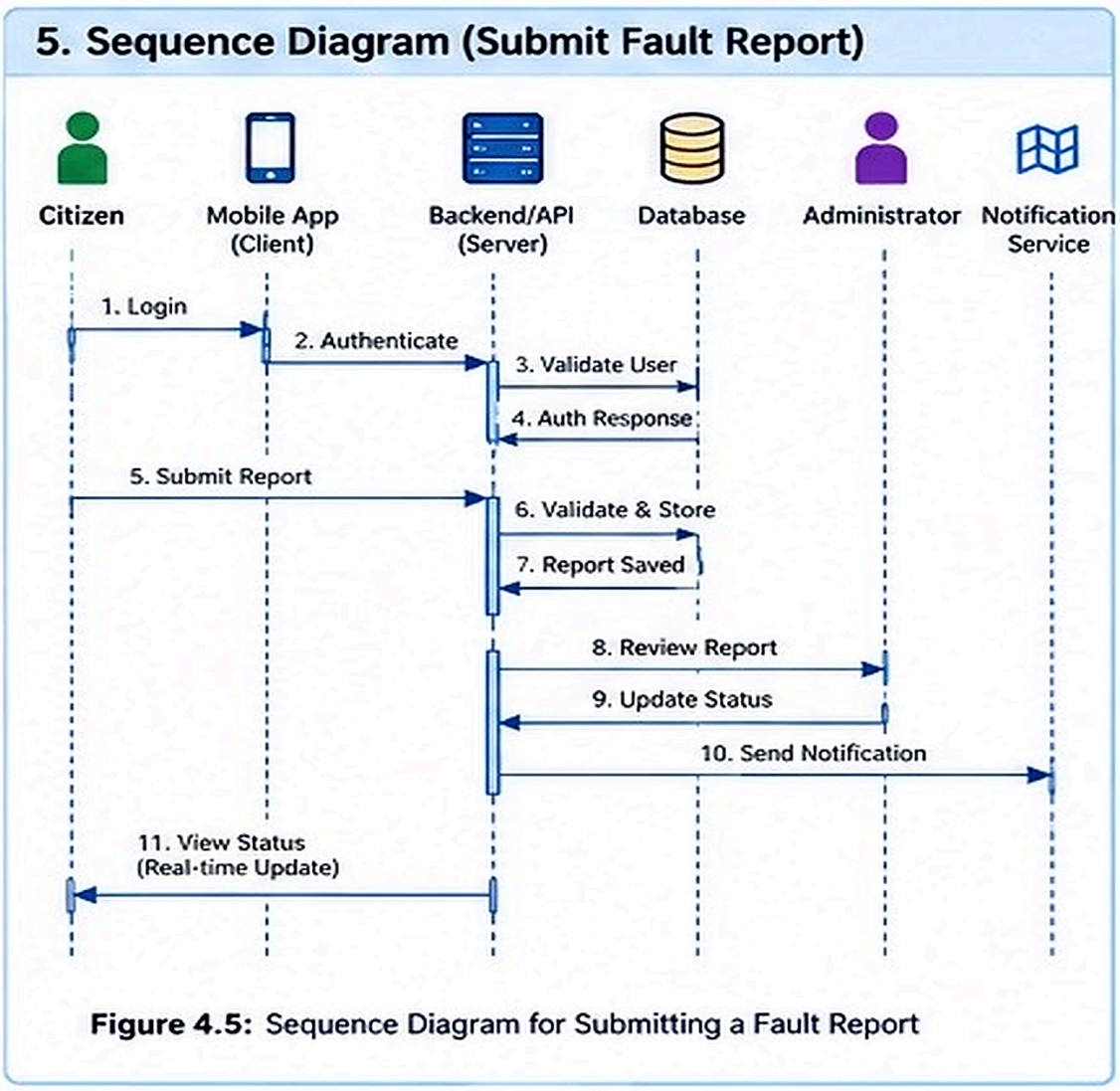


Figure 4.5: Sequence Diagram for Submitting a Fault Report

4.6 Activity Diagram

The activity diagram shows how citizens submit fault reports, from logging in and providing fault details to submitting the report. The system validates and stores the information, while the administrator reviews the report, updates its status, and notifies the citizen, who can track progress.

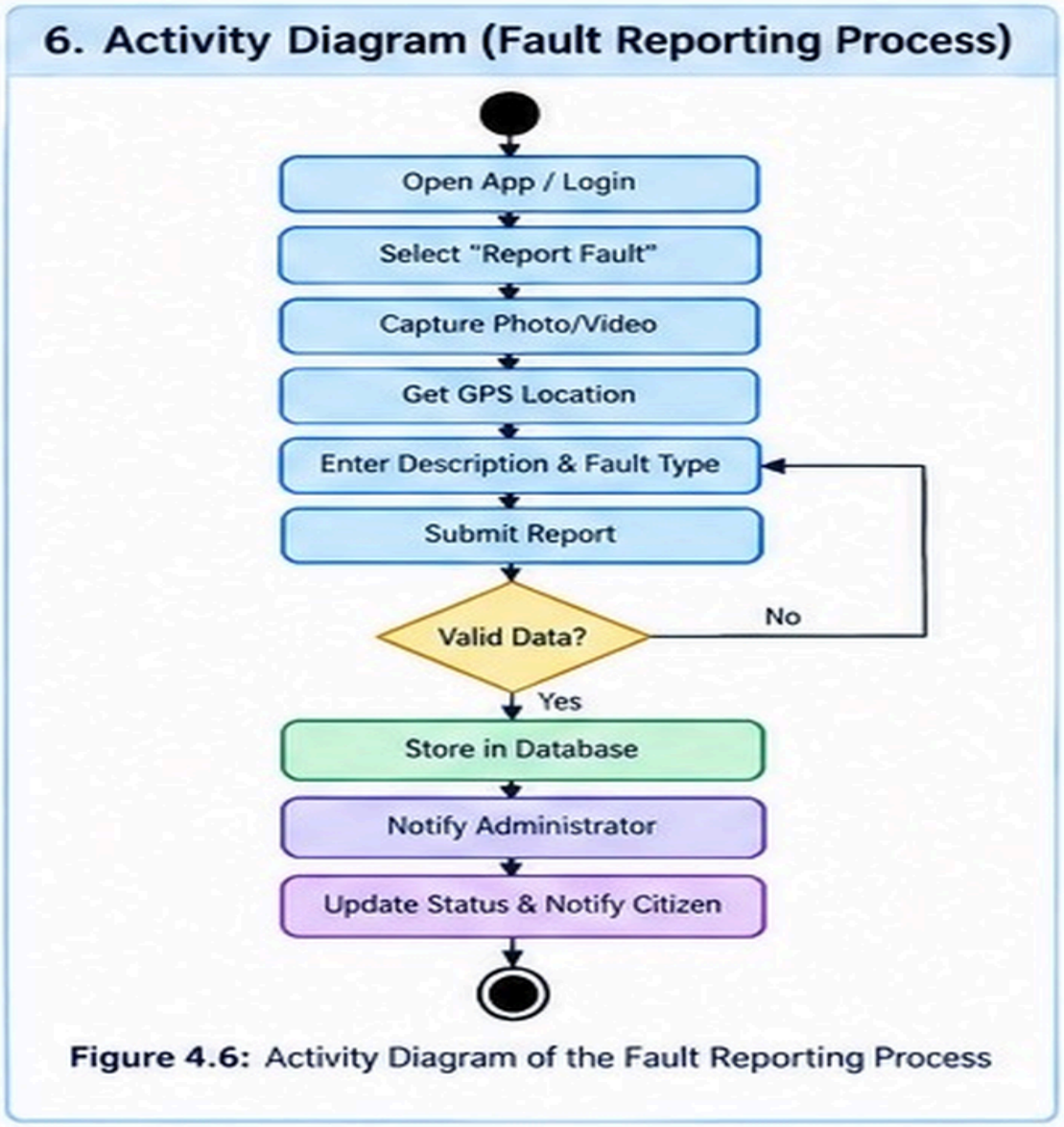


Figure 4.6: Activity Diagram of the Fault Reporting Process

CHAPTER 5

5.1 Results and discussion

The findings are presented according to the study objectives, which include identifying infrastructure faults that can be reported by the public, designing and developing the ZamFault system, and

evaluating the functionality and usability of the developed system. The chapter also presents screenshots of the system to demonstrate its main features and discusses how these features respond to the infrastructure reporting challenges identified during the research.

5.2 Research Findings on Public Infrastructure Faults

The study investigated infrastructure problems that can be reported by members of the public using a digital reporting system. The research considered the need for a convenient way of communicating infrastructure faults and providing information that could help relevant authorities identify and respond to reported problems.The geographical scope of ZamFault extends across Zambia. However, the findings discussed in this section are based on the locations and participants actually covered during data collection. The University of Zambia was included in the study because infrastructure-related challenges can also occur within the university environment and affect students and other members of the community. Therefore, the study considered both general public infrastructure problems and faults that may arise in institutional settings.The research identified several categories of infrastructure faults that could be accommodated by the system, including damaged roads, blocked drainage, broken chairs, damaged electrical sockets, sewer problems, and other infrastructure faults. These categories provide users with options for classifying the problems they wish to report.

Infrastructure Challenges at the University of ZambiaThe University of Zambia was considered as one of the institutional settings relevant to the study. Infrastructure problems within a university can affect the daily activities of students, lecturers, and other members of the university community. For example, damaged furniture, faulty electrical sockets, drainage problems, and sanitation-related issues may interfere with the use of university facilities.The inclusion of UNZA demonstrates that the proposed system can accommodate reports from institutional environments as well as public spaces. Users could report a fault, describe its location, and provide photographic evidence where available.

This information could help the relevant personnel understand the nature of the reported problem.

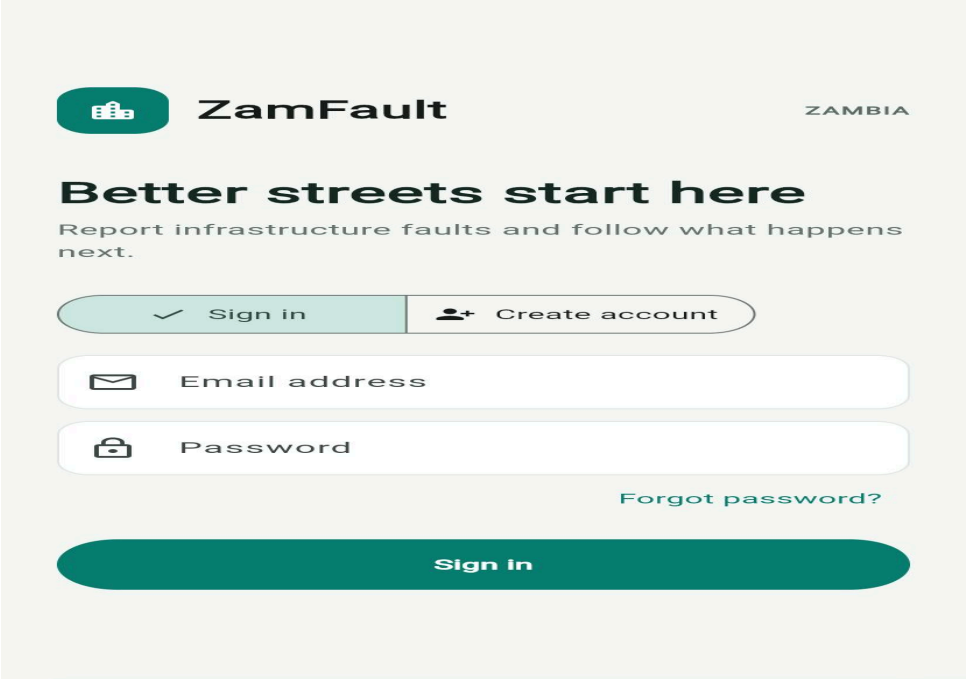


Figure 4.2: Example of a sanitation-related infrastructure problem observed during the study. The photograph shows accumulated rubbish in a waste collection area, demonstrating a sanitation problem that requires attention. The problem was observed at **[At unza hostel Ruins)** A reporting system such as ZamFault could help users submit photographs, describe the problem, and provide location details to the responsible authorities. This would improve communication and make it easier to track reported sanitation problems and their progress towards resolution.

5.3 Design and Development of the ZamFault System

Following the identification of the infrastructure reporting requirements, the ZamFault system was developed to provide a digital platform through which users can submit infrastructure fault reports.The system was designed with a simple interface to make its functions accessible to users with different levels of technical knowledge. Its main functions include account access, viewing the home page, selecting an infrastructure fault category, entering a description, specifying a location, capturing or providing location information, and attaching photographic or video evidence where necessary. The system also provides a user profile interface and navigation options for accessing reporting-related features. These functions were intended to make the reporting process straightforward and allow users to provide information about the infrastructure problems they encounter.

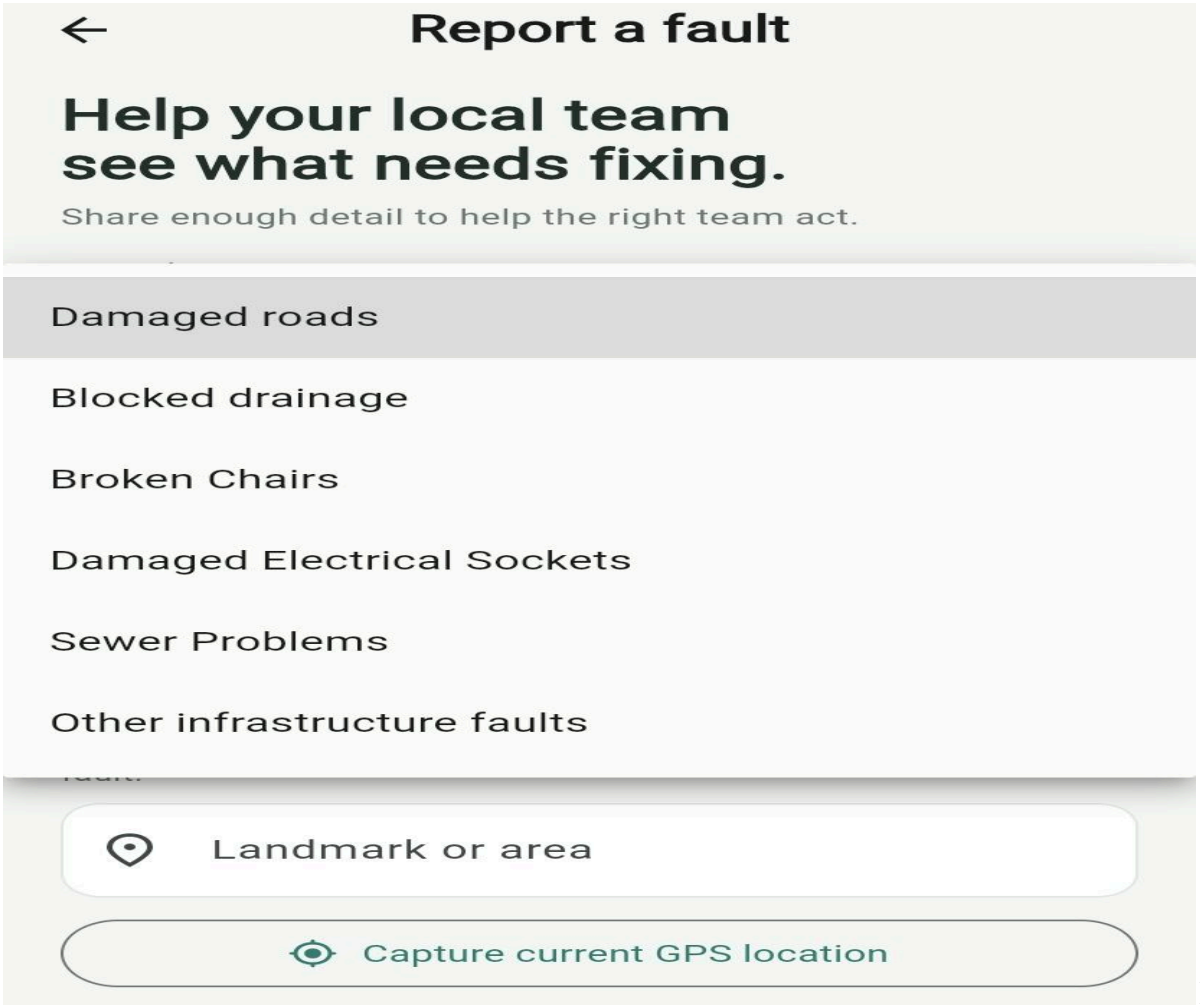
User Registration and Sign-InThe system provides an authentication interface through which users can sign in to an existing account or create an account. This interface allows users to access the reporting features available within ZamFault.



User authentication interface of the ZamFault system. *Source: ZamFault system, 2026.*

The interface supports access to the ZamFault reporting system by allowing users to sign in to an existing account or create a new account. The password recovery option also helps users regain access if they forget their passwords. Once signed in, users can access the main dashboard and report infrastructure faults. This makes the system easier to access and use. However, further security testing would be required to confirm the effectiveness of its authentication and account protection features.

Reporting an Infrastructure FaultThe fault reporting interface is one of the main components of ZamFault. It allows users to provide information about an infrastructure problem by selecting a fault category, describing the problem, indicating its location, and attaching photographic or video evidence where supported.

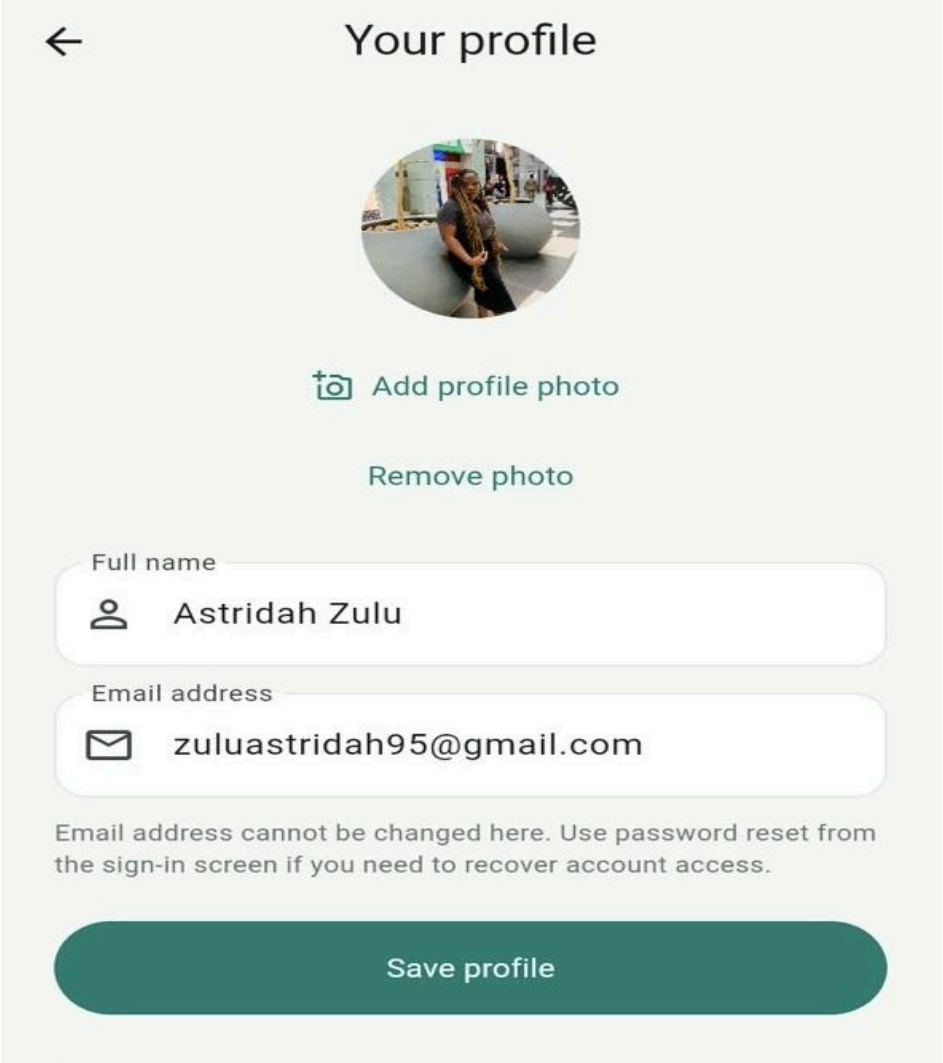


Figure

Fault reporting interface of the ZamFault system. *Source: ZamFault system, 2026.*

The reporting form includes categories such as damaged roads, blocked drainage, broken chairs, damaged electrical sockets, sewer problems, and other infrastructure faults. It also provides a field for entering a landmark or area and an option for capturing the user's current GPS location. The location feature is intended to help users provide information about where a fault occurred. Therefore, before describing GPS functionality as successfully tested,

User Profile ManagementThe user profile interface allows users to view and update supported profile information, including their displayed name and profile photograph. It also provides an option to sign out of the account.



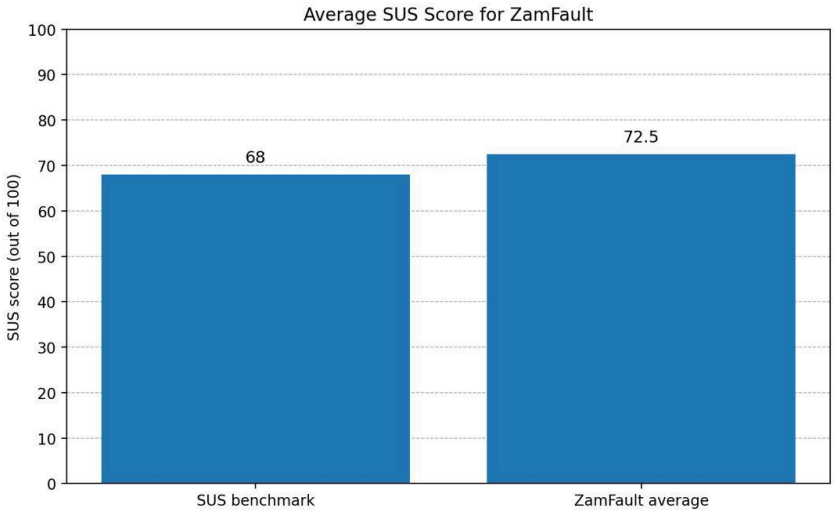
5.4 Usability Evaluation Using the System Usability Scale

The usability of the ZamFault system was evaluated using the System Usability Scale (SUS), a standardised questionnaire consisting of ten statements measured on a five-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5). A total of 13 participants completed the questionnaire. The participants comprised seven fourth-year students, four third-year students and two second-year students. The evaluation focused on ease of use, system complexity, consistency, confidence and the need for technical assistance.**SUS Scoring Procedure**

The SUS scores were calculated using the standard method described by Brooke (1996). For positively worded statements (questions 1, 3, 5, 7 and 9), one was subtracted from each response. For negatively worded statements (questions 2, 4, 6, 8 and 10), each response was subtracted from five. The adjusted scores were added together and multiplied by 2.5 to obtain an individual SUS score ranging from 0 to 100.

Overall SUS Results

The analysis produced an average SUS score of **72.5 out of 100**, with individual scores ranging from 42.5 to 100. The average exceeded the commonly used SUS reference benchmark of 68, suggesting that participants generally perceived ZamFault as reasonably usable. However, differences in individual scores indicate that users did not all experience the system in the same way.



Average System Usability Scale score for the ZamFault system.

Analysis of Individual SUS Statements

The responses to the ten SUS statements provided further insight into the system's usability. Most participants indicated that they would like to use ZamFault frequently (76.9%) and felt confident using it (76.9%). Furthermore, 69.2% disagreed that the system was unnecessarily complex, while 84.6% disagreed that it contained too much inconsistency. These findings suggest that participants generally perceived the system as consistent and approachable.

Regarding ease of use, 53.8% agreed that the system was easy to use, while 69.2% believed that most people could learn to use it quickly. Additionally, 69.2% disagreed that they would need technical assistance, and the same proportion disagreed that the system was cumbersome to use. However, some participants expressed uncertainty or difficulty regarding ease of use and the amount of learning required. This suggests that clearer instructions and simpler navigation could improve the user experience.

5.5 Discussion of Findings

The findings and the development of the ZamFault system demonstrate the importance of providing a structured approach to reporting infrastructure faults. The system brings together several reporting functions, including fault classification, description entry, location information, and the attachment of visual evidence.These functions address practical information needs associated with reporting infrastructure problems. For example, a photograph can illustrate the condition of a damaged road or blocked drainage system, while a location description can help identify where the problem occurred. Classifying reports into categories can also make it easier to organise the submitted information.

The inclusion of the University of Zambia within the study's institutional context demonstrates the relevance of infrastructure reporting in environments beyond residential streets. However, the findings should be interpreted in relation to the actual participants and locations covered by the research. The design of a system intended for national use does not, by itself, establish that it has been evaluated or adopted throughout Zambia.The effectiveness of ZamFault also depends on the reliability of its implementation. Features such as location capture, evidence attachment, report submission, and report retrieval must be tested to establish whether they function as intended. Similarly, the usability questionnaire will provide additional evidence about how participants perceive the application after interacting with it.Overall, the SUS results suggest that ZamFault achieved a reasonably favourable level of perceived usability among the 13 participants. The average score of 72.5 indicates that the system performed above the commonly used SUS reference benchmark. The positive responses concerning confidence, consistency and willingness to use the system suggest that it has potential to support public infrastructure fault reporting.Nevertheless, the findings should be interpreted cautiously because the evaluation involved a relatively small group of participants. The results reflect users' perceptions of usability rather than independently proving that

every system function operates correctly. Further testing with a wider range of users and improvements to instructions and navigation could help enhance the system's usability.

CHAPTER 6

6.1 CONCLUSION

The study focused on the design and development of ZamFault, a crowdsourced infrastructure fault reporting system intended to provide a convenient means of communicating infrastructure problems in Zambia. The system was designed to allow users to select a fault category, describe the problem, provide location information, and attach photographic or video evidence where supported.

The inclusion of categories such as damaged roads, blocked drainage, sewer problems, broken chairs, and damaged electrical sockets enables the system to accommodate different types of infrastructure faults. The study also considered the University of Zambia as an institutional setting in which infrastructure problems may affect students and other members of the university community.

The developed interface provides the main user-facing components for accessing the application and preparing infrastructure fault reports. However, the overall effectiveness of the system must be assessed using the results of functional testing and the usability evaluation. The final conclusions about the system's reliability, ease of use, and achievement of the study objectives should therefore be based on the evidence collected during these evaluations.

6.2 Recommendations

Based on the objectives and development of the ZamFault system, the following recommendations are proposed.First, further functional testing should be conducted. All major features, including account access, fault reporting, evidence attachment, GPS location capture, report submission, and

report retrieval, should be tested to identify errors and confirm that the application behaves as intended.Second, the usability of the system should be evaluated with participants. The System Usability Scale questionnaire should be administered and analysed to determine how users perceive the application's ease of use and identify areas that may require improvement.

Third, the system should support reliable storage and retrieval of reports. Infrastructure fault reports should remain accessible after submission, and the system should provide appropriate feedback to users. The handling of photographs, location information, and account details should also be reviewed to protect users' information.Fourth, future development should consider institutional and national use. Since the system is intended for use across Zambia, future work could examine how it might be adopted by communities, universities, local authorities, and other relevant institutions. This would require further evaluation of the technical, administrative, and organisational arrangements needed to support its wider use.

Finally, future improvements should be guided by user feedback. Responses from the usability questionnaire and observations from functional testing should inform changes to the interface, reporting process, and other system features.

6.3 Limitations of the Study

The study's findings should be interpreted in light of its research scope and the extent of the evaluation conducted. Although ZamFault is intended to support infrastructure fault reporting across Zambia, the research findings reflect the participants and locations actually covered during data collection. If the main participants were recruited at the University of Zambia, the results should not be presented as representative of the entire country.Furthermore, the strength of the usability findings will depend on the number of completed questionnaires and the characteristics of the respondents. Any technical limitations identified during functional testing, including problems with GPS access or report storage, should also be acknowledged.Future research could involve participants from additional locations and institutions to examine how well the system meets the needs of different communities.

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APPENDEXI

Interview Questions

A. Experience with infrastructure faults

1. Have you ever come across a damaged or faulty public facility?
2. What type of fault did you encounter?
3. Where did you encounter it?
4. How did the fault affect you or other people?
5. How often do you come across these kinds of faults?

B. Reporting the fault

6. Did you report the fault?
7. If yes, how did you report it?
8. If you did not report it, why not?
9. What problems did you experience when trying to report it?
10. What do you think would make reporting faults easier?

C. Proposed ZamFault system

11. Would you use a mobile application to report an infrastructure fault? Why?
12. What information would you expect to provide when reporting a fault?
13. Would you find it useful to take a photo of the fault when reporting it? Why?
14. Would you find it useful for the application to automatically record your location?

15. What would you like to happen after you submit a report?
16. What features would you like the application to have?