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Innovative Infrastructure Inspection System: Development And Pilot Deployment In Baguio City

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ABSTRACT
The Innovative Infrastructure Inspection System (INSPECT) will be designed in alignment with the local infrastructure audit tools and guidelines rolled out by the Department of Interior and Local Government (DILG) for Local Government Units (LGUs) to use. A key component of the infrastructure audit process involves data collection using the LGU Infrastructure Audit Form for Buildings (LIAF-1), which serves as the primary reference for system development. INSPECT consists of a mobile application for field data collection and a web-based platform for streamlined data processing and management. The mobile app enables real-time collection of inspection details, hazard vulnerability data, and structural assessment information, which are automatically analyzed to generate assessment reports and insights. The gathered data is then transmitted to the web application for further processing, visualization, and integration, facilitating a more efficient, data-driven approach to infrastructure inspection and management.

INTRODUCTION

The rapid pace of urbanization, population growth, and technological advancements has fueled the concept of Smart Cities, which aim to create sustainable, efficient, resilient, and livable urban spaces. The integration of digital innovations, data-driven decision-making, and advanced infrastructure defines a Smart City—one that leverages technology to enhance quality of life, optimize resource management, and address urban challenges.

In Baguio City, rapid urbanization has led to challenges such as overpopulation, traffic congestion, and environmental degradation. To address these concerns, Mayor Benjamin Magalong has initiated plans to transform Baguio into a Smart City. A key step in this transformation is the digitalization of manual systems and the improvement of government operations, starting with the assessment and management of infrastructure. Enhancing the process of building inspections and infrastructure assessment will not only streamline data collection and analysis but also contribute to the city's disaster resilience and urban development planning. Ultimately, this initiative supports Sustainable Development Goal (SDG) 11: *Making cities and human settlements inclusive, safe, resilient, and sustainable*.

As part of its efforts to strengthen disaster resilience, the Department of the Interior and Local Government (DILG) has developed infrastructure audit tools and guidelines and conducted nationwide training for Local Government Units (LGUs). These tools help LGUs assess the vulnerability of buildings, roads, and bridges in their jurisdictions. However, despite having these standardized forms and guidelines, LGUs face challenges in the manual collection, processing, and analysis of data for decision-making. This challenge has driven the development of the Innovative Infrastructure Inspection System (INSPECT)—a digital solution designed to streamline infrastructure assessment and improve knowledge management, ultimately supporting efficient infrastructure maintenance, disaster preparedness, and Smart City initiatives in Baguio.

STATEMENT OF THE PROBLEM

This research and development project seeks to modernize and enhance infrastructure assessment processes in Local Government Units (LGUs) through digital innovation. Specifically, it aims to answer the following questions:

1. Which infrastructure assessment processes require improvement through application software?
2. What types of data should be collected, processed, and managed for effective infrastructure assessment?
3. What technologies are most suitable for the development and deployment of the system?
4. How should the system be designed and developed to optimize efficiency and usability?

III. LIMITATION OF THE STUDY

This study is limited to the collection, storage, processing, and analysis of building infrastructure data within Baguio City. The system's development will be based on the LGU Infrastructure Audit Form for

Buildings (LIAF-1) provided by the Department of the Interior and Local Government (DILG). The scope includes the development of the INSPECT mobile application for automated data collection during assessments and the INSPECT web application for data management and processing.

IV. METHODOLOGY

A structured methodology will be adopted for the development of the system to ensure the efficient development, deployment, and evaluation. The Agile Software Development Methodology, specifically the Scrum framework, is recommended due to its iterative, flexible, and user-centered approach, ensuring continuous feedback and refinement. The development will follow these key phases:

1. Requirements Gathering and Analysis.

The first phase involves requirements gathering and analysis, where consultations are conducted with key stakeholders such as LGU officials, engineers, and urban planners to understand the system's requirements. The LGU Infrastructure Audit Form for Buildings (LIAF-1), as provided by the Department of the Interior and Local Government (DILG), serves as the primary reference for defining system functionalities, user roles, and data requirements. This phase ensures that the system aligns with existing infrastructure assessment processes while identifying pain points that need to be addressed through automation.

2. System Design and Architecture.

Following the requirements gathering, the system design and architecture phase focuses on creating the technical blueprint for the mobile and web applications. During this stage, system flowcharts, wireframes, and database schemas are developed to outline how data flows through the system. The mobile application is designed for on-site data collection, while the web application is structured for data management, visualization, and reporting. The selection of appropriate technologies, such as React Native for mobile development and Django for backend processing, ensures that the system is scalable, secure, and efficient.

3. Agile Development and Iterative Prototyping (Scrum Framework)

Once the design is finalized, the Agile development and iterative prototyping phase begins. The development follows the Scrum framework, which consists of short, iterative sprints lasting 2–4 weeks. Each sprint focuses on implementing a set of features, starting with basic UI/UX design and login functionalities, followed by mobile data entry and storage, web dashboard and report generation, and final system integration. Regular stand-up meetings and sprint reviews allow developers to address challenges, incorporate feedback, and make continuous improvements throughout the development cycle.

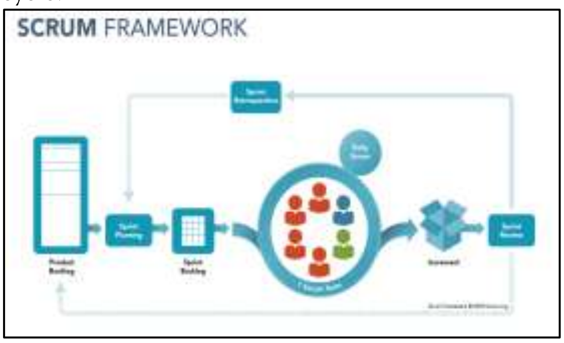

Figure 1 : Scrum Framework

The proposed system will be using Scrum, as shown in Fig. 1, to ensure quality of the project and effectiveness of the time and money. In the Scrum Model, it will be composed of *Sprint planning, Daily Scrum, Sprint review, and Sprint Retrospective*. The scrum model will be an effective approach to be used because it will make sure that each module of the system is delivered with quality through sprints. With the focused nature and approach of Scrum, it will allow the system to be maximised to its full efficiency at a reasonable time preventing any missed requirements and needs of users. For the scrum development process to become more efficient, A time box will be implemented to allow the team to use the time for each phase productively. This will prevent the team from slacking off and keeping focus to concretely address tasks. [1]

4. Testing and Quality Assurance

With the initial prototype completed, the testing and quality assurance phase ensures that the system functions correctly and meets user requirements. Various testing methodologies, including unit testing, integration testing, and user acceptance testing (UAT), are conducted to identify and resolve bugs. The pilot deployment in Baguio City allows LGU personnel and field inspectors to use the system in a real-world setting, providing valuable feedback on usability, performance, and accuracy.

5. Deployment and Implementation

Upon successful testing, the deployment and implementation phase begins. The INSPECT mobile and web applications are deployed to LGUs and field assessors, accompanied by training sessions to familiarize users with the system. A dedicated technical support team is assigned to assist in troubleshooting and ensure a smooth transition from manual to digital infrastructure assessment.

6. Evaluation and Continuous Improvement

The final phase, evaluation and continuous improvement, focuses on monitoring the effectiveness of the system and implementing refinements based on user feedback. Performance data is collected through surveys, interviews, and usage analytics to assess system reliability, data accuracy, and overall impact on infrastructure assessment efficiency. Regular updates and enhancements are made to improve functionality and adapt to emerging needs in disaster resilience and urban planning.

V. LITERATURE REVIEW

Recently, the Department of Science and Technology Region IV-A in partnership with the the DILG IV-A, OCD IV-A and their other partners in CALABARZON developed the Infrastructure Audit Manual (IAM) [1] based on the checklists, forms, guidelines, policies on infrastructure assessment from government agencies and the current practices by LGUs.

This Infrastructure Audit Protocol Manual is primarily developed to provide a tool to determine structural risk in the community and to identify those buildings that require a more detailed examination.It will aid in providing an quick assessment of the structural stability of the building from seismic and other natural forces after examination and evaluation to offer prescriptive measures. Also, it aims to harmonise efforts and update existing checklists/forms of the Department of Interior and Local Government, Department of Public Works and Highways, Association of Structural Engineers of the Philippines, Cavite State University, and University of the Philippines Institute of Civil Engineering to an easy to use and understand manual.

The development of the INSPECT system is then based on this manual.

Mobile applications as a means of data collection have gained popularity over the years, especially for the conduct of assessments which will require the collection of various types of data to include GPS coordinates, photos and other information.

In the study conducted by K. Kritikos et al. (2019), the success of Cloud computing promotes the use of computational and networked resources on demand to support application provisioning. As such, resource management is outsourced to cloud providers enabling to reduce or diminish operational and management cost.[2]

In an Article from the U.S Department of Homeland Security states that Infrastructure survey tools provides various benefits including safeguarding the Nation's critical infrastructure from physical and cyber threats that can affect national security, public safety, and economic prosperity.[3]

An Infrastructure report from Japan International Cooperation Agency (JICA)(2014) reported that the Infrastructure management System aids on the proper arrangement of infrastructure maintenance of assets in an organisation.[4]

In an artcle published by the Technische Universität München, Germany, an assessment system is presented to evaluate infrastructure objects such as roads after natural disasters in near-real time. A particular aim is the exploitation of multi-sensor and multi-temporal imagery together with further geographic information system data in a comprehensive assessment framework. The assessment system is applied to two different test scenarios evaluating roads after flooding, yielding very promising results and evaluation values concerning completeness and correctness. The benefit of the data combination, in particular the multi-temporal component, demonstrates the suitability of the proposed method for different application scenarios. [5]

VI. RESULTS and DISCUSSION

The development of the system commenced with the project conception and initiation which included the crafting of the project charter, requirements analysis and selection of technologies to be used.
The entire infrastructure audit process based on the IAM is shown below with the last two (2) processes being the focus of this project. According to the manual, the current Building Information System (BIS) being used is an excel file.
Discussion with LGU Baguio representatives provided the researchers with critical information related to the process as well as a validation of the processes presented in the IAM.

The Existing System

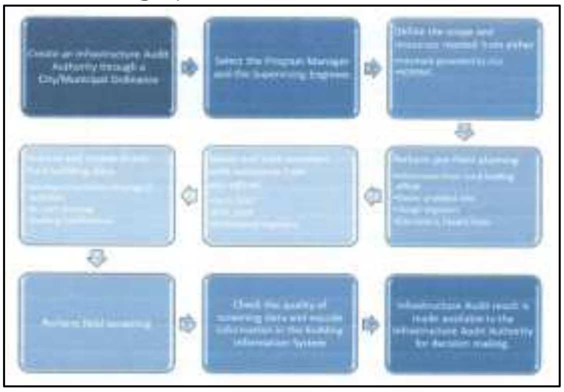

Figure 2. Overall representation of the infrastructure audit implementation process based on the IAM

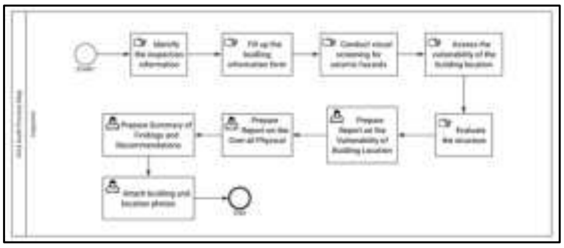

Figure 3. Existing Process map

The figure above shows the existing process map of the building infrastructure assessment based on the Local Infrastructure Audit Form 1 (LIAF 1 for Buildings) used by the DILG.

INFRASTRUCTURE AUDIT CHECKLIST FOR BUILDINGS
(Zone 4: Seismic Zone Map of the Philippines)

I. GENERAL INFORMATION
IDENTIFICATION

INSPECTION

II. BUILDING INFORMATION

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III. RAPID VISUAL SCREENING OF BUILDING FOR POTENTIAL SEISMIC HAZARDS

IV. VULNERABILITY OF BUILDING LOCATION

VI. SUMMARY REPORT

Figure 4. Pages 1, 2 and 8 of the 9-page Local Infrastructure Audit Form 1 (LIAF 1 for Buildings) used by the DILG.

The Proposed System

The sample pages of the LIAF 1 for Buildings shown above presents the numerous data and data types being obtained, indicating the need to streamline the process using an efficient information management system.

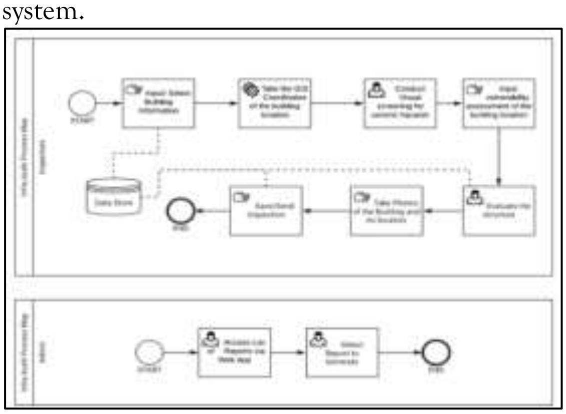

Figure 5. Process map of the proposed INSPECT System

The figure above depicts the suggested workflow using the INSPECT system. Authorised users shall be given accounts before using the INSPECT system. It should be noted that the existing manual procedure of filling out inspection and building information forms/checklists will be replaced by the use of the INSPECT mobile application, which will include the acquisition of GPS coordinates as extra data for future map display capabilities. Similarly, the results of the visual screening will be generated by the mobile application based on the entered data and the criteria set which can be viewed in the LIAF 1. The hazard vulnerability and structure assessment details should also be entered into the system using the mobile application, and once all is complete, the summary result will be created automatically. Photos should also be taken using the mobile app and to be included in the reports.

It should also be noted that all data gathered and processed by the mobile application are sent to the web application for further processing or analysis or for more efficient data management.

Figure 6. Use case diagram of the proposed INSPECT System

Technologies Selected

The use case diagram above depicts the users of the system. There will be two (2) types of users, the Inspectors and the Admin. The inspectors will be the authorised inspectors by the City Engineering Office (CEO), while the admin will be the Head and other authorised staff at the CEO.

Table 1. Technologies used for the system development

Vue.Js	Front End
Tailwind	Styling
MySQL	Database
Node.Js	Backend

In the development of the "INSPECT" System, the selection of technology tools is important in shaping the system's functionality, user experience, and overall success. The decision to employ Vue.js, Tailwind CSS, MySQL, and Node.js as key technologies was driven by a combination of factors that align with the project's goals, requirements, and desired outcomes [6].

1. Vue.Js: a modern JavaScript framework to enhance its user interface and overall user experience.

2. Tailwind: CSS is a modern utility-first CSS framework that can significantly contribute to the design and user interface aspects of the system.

3. MySQL: MySQL is a popular open-source relational database that plays a critical role in managing and storing the system's data.

4. Node.Js: is a powerful JavaScript runtime that enables server-side scripting and facilitates the system's backend development.

Collectively, these technology choices were made to enhance user interaction, streamline development processes, ensure data reliability, and provide a responsive and user-centric LGU Infrastructure Assessment System. Each technology was selected based on its specific strengths, ultimately contributing

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to the success of the "INSPECT" System in effectively supporting infrastructure assessment and decision-making in Baguio City.
After the gathering of data, and selection of technologies the researchers were able to create a prototype of the system that will be implemented soon.

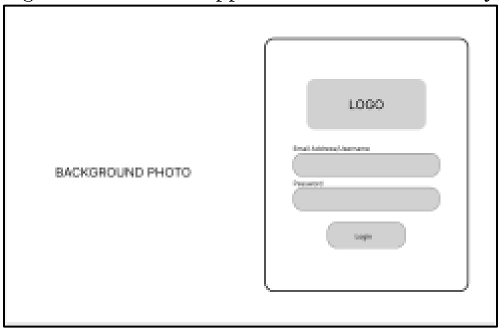
The Proposed Mobile Application
Based on the gathered data, we come up with the Low Fidelity UI as shown below, this will be the researchers basis on the design of the mobile and web application User interface.
Figure 6.1 Mobile Application UI Low Fidelity


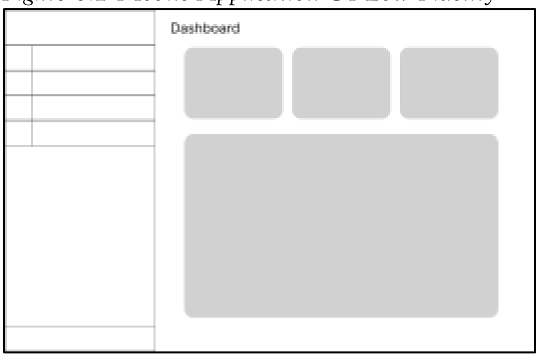
Figure 6.2 Mobile Application UI Low Fidelity


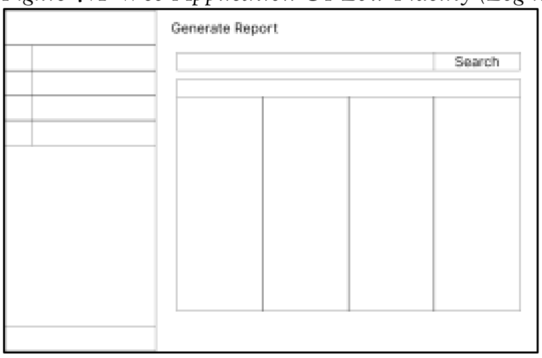
Figure 7.1 Web Application UI Low Fidelity (Log in)


Figure 7.2 Web Application UI Low Fidelity (Landing Page)

Figure 7.4 Mobile Application (Login and Landing page)

Login Page: This is where users would enter their credentials (username and password) to access the application's features. It could also include options for password recovery.
Landing Page: After successful login, users are directed to the landing page. This is a central starting point that provides an overview or access to key features within the application. Include navigation options, recent activities, and Report view.

Figure 7.2 Mobile Application (Sidebar Navigation)
Figure 7.2 illustrates a screen within the mobile application that involves a sidebar navigation menu. It allows users to navigate between different sections or functionalities of the application.

Figure 7.6 Mobile Application (Add Report page)
This is where users can add a new report by inputting the necessary data.

Figure 7.7 Success Message

Figure 7.7 shows the screen on the mobile application where the use successfully added/submitted a report.

Figure 7.8 Success Message

Figure 7.8 shows the reports submitted by the inspector user with a function of selecting a specific date to filter the results.

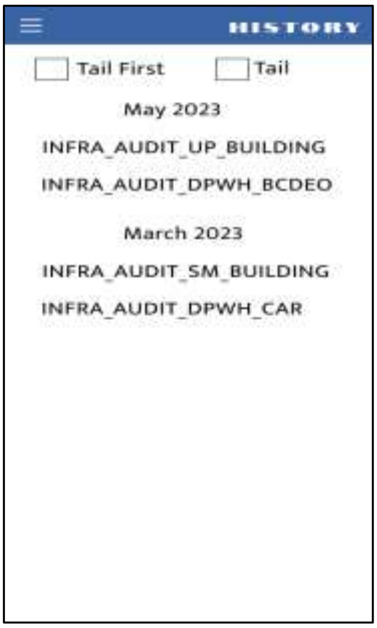


Figure 7.8 Success Message

The Proposed Web Application

Figure 7.8 shows the history of reports submitted by the user, with a functionality of tail first or tail filter.

Figure 8.1 Web Application (Login Page)

This is where users would enter their credentials (username and password) to access the web application's features. It could also include options for password recovery.

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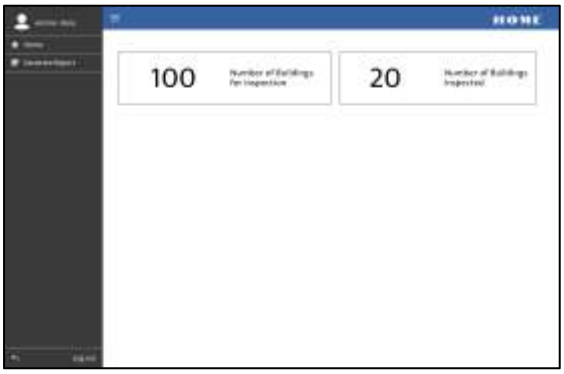

Figure 8.2 Web Application (Landing Page)

After successful login, users are directed to the Web Application landing page. This is a central starting point that provides an overview or access to key features within the application. It includes navigation options, recent activities, and report Generation.

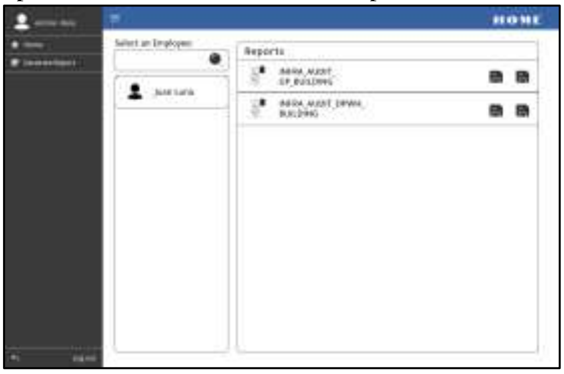

Figure 8.3 Web Application (Report Page)

VII. CONCLUSION and RECOMMENDATIONS

It is concluded that manual data collection and processing, as well as report generation, are just a few of the operations during the infrastructure audit that needs to be improved with an information management system, such as the proposed INSPECT system for buildings, using the methodology and technologies discussed in this study. Furthermore, it is found that using a mobile application is essential to collect and manage a comprehensive set of data to ensure effective inspection and maintenance of infrastructure. This data should include detailed information about the infrastructure, such as its location, type, identification number, construction date, materials used, and previous maintenance history. Additionally, condition assessment data is crucial, covering structural and surface conditions, including issues like cracks, corrosion, deformations, and other indicators of wear and tear. Similarly, the use of a web application is essential to efficiently handle and further process the obtained data.

The researchers also decided to employ Vue.js, Tailwind CSS, MySQL and Node.js as key technologies driven by a combination of factors that align with the project's goals, requirements, and desired outcomes. Align with, the design and development of the INSPECT will involve a systematic approach. Starting with a thorough assessment of the city's infrastructure needs, requirements gathering in collaboration with key stakeholders. The system will be meticulously designed with a focus on scalability, security, and user-friendliness, encompassing mobile applications for field inspectors and web interfaces for administrators. Rigorous testing and a pilot phase will ensure usability and reliability, and ongoing user feedback will drive continuous improvements. Collaboration between IT experts, and field inspectors will be vital to the project's success, enhancing infrastructure assessment and management capabilities in Baguio City.

Based on the findings and conclusions, the researchers recommend that future studies include the assessment of other infrastructure such as roads and bridges using the INSPECT system. It is also recommended that data accessed by entities other than the LGU be considered, provided that protocols, regulations, and data privacy concerns are reviewed and handled.

Recommended feature for the "Inspect" includes (1) real-time notification for Inspectors when buildings are due for inspection, (2) data analytics on the development of dashboard, (3) expanding the project scope by having data capturing capabilities, (4) and efficiency of infrastructure inspection by providing inspectors with immediate access to critical information.

VII. ACKNOWLEDGEMENT

The successful completion of this undertaking would not have been possible without the support, guidance, and contributions of many individuals—some of whom may not be named here but are deeply appreciated.

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Above all, I give glory and heartfelt thanks to the Great Almighty, the ultimate source of wisdom and strength, for His boundless love and guidance throughout this journey.

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