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MSE907.1 Research Development and Plan

SafeRoads Navigator:

A System for Real-Time Road Hazards Monitoring Using Crowdsourced Data and Dual Vetting Approach

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Abstract

SafeRoads Navigator is a capstone project proposal for a real–time road hazards monitoring system that leverages crowdsourced data with a dual vetting mechanism to ensure information accuracy. The system empowers both the citizens and road safety authorities to collaboratively identify, track, and resolve roadway safety issues in real time. The system addresses the critical need for timely and reliable hazard alerts by enabling motorists, cyclists, & pedestrians to report road dangers — such as potholes, obstacles, accidents, broken signage, adverse conditions, etc. — and employing two levels of validation (peer confirmation & expert/administrative review) before broad dissemination. This proposal outlines the motivation and background for such a system, identifies gaps in existing solutions, and formulates research questions to guide development. Through an intuitive React frontend and a Node.js / Express backend tied to Google Maps API, users can report road hazards via automatic GPS location capture, or manual entry as the case maybe, attach multimedia evidence, & select from predefined categories of hazards. Crowdsourced verification and road safety stakeholder moderation ensure data reliability, while configurable alerts automatically notify authorities when single or clustered hazards exceed severity thresholds. City planners and policy makers gain access to interactive dashboards featuring dynamic maps, heatmaps of top hazard zones, supporting data-driven decisions for infrastructure improvements & strategic planning. By integrating user authentication, role–based access, and open data export capabilities, the system balances accountability with wide accessibility. Through iterative

development, usability testing, and performance evaluations, SafeRoads Navigator aims to demonstrate a measurable reduction in reporting latency, enhanced situational awareness of road users (which eventually lead to reduced road incidents), and provide road safety authorities with a data–driven tool, laying the groundwork for a smarter, safer urban transport network.

Introduction

Road safety remains a pressing public health and transportation concern worldwide. Traffic crashes are 16 one of the leading causes of death and injury, accounting for approximately 1.19 million fatalities globally each year, of which, 92% 13 occur in low– and middle–income countries (WHO Report, 2023). In New Zealand, the NZ Transport Agency reports 341 road fatalities and 2,442 serious injuries, averaging one death and seven serious injuries per day in 2023. This makes New Zealand's rate of road deaths amongst the worst in the OECD (NZTA, 2024), with a rate of 6.5 deaths per 100,000 population (NZAA, 2025). Road hazards such as potholes, debris, poor signage, and other safety risks pose serious threats to motorists, cyclists, & pedestrians alike. Traditional approaches to identifying and fixing these hazards rely on periodic inspections or public complaints, which are often slow and reactive. Swift awareness of road hazards can significantly reduce secondary accidents and improve emergency response times (Young et al. 2019).

Crowdsourced data has emerged as a promising solution to provide real–time, widespread coverage of road conditions. Such community–driven reporting can fill critical information gaps, especially for hazards that might not trigger immediate official action, i.e. a fallen tree branch or localised flooding. Despite their benefits, crowdsourced hazard systems face challenges regarding the reliability and accuracy of user–contributed data (Leal et al. 2017). False or outdated reports can occur, whether due to user error, changes in conditions, or even malicious misuse. Ensuring data integrity is essential for maintaining user trust and effectiveness of the system. There is a need for more robust verification to minimize false alarms while preserving the speed and breadth of crowdsourced inputs. Thus, the need for dual vetting solution.

This capstone project, **SafeRoads Navigator**, proposes a novel approach to real–time road hazards monitoring by combining the strengths of crowdsourced data with a dual vetting approach. In this system, hazard reports from the public are subjected to two layers of vetting: first by road users (through peer confirmations or upvotes) and second by road safety authorities to ensure higher accuracy. 14 The goal is to create a reliable, user–driven road hazard alert network.

Literature Review

We all want 5 to make transportation greener, smarter and more sustainable. However, 5 road authorities everywhere face increasing challenges in managing traffic and infrastructure to provide critical services to citizens. It is therefore vital that cities have an integrated solution that allows them to monitor and manage traffic infrastructure & transport operations in real time. Numerous studies and projects in recent years have explored the use of crowdsourced data to improve road safety and traffic management. Early research recognised the potential of social and mobile platforms in capturing real–time traffic information. For example, in Christou et al. (2023), it highlighted that a government–backed, national–level crowdsourcing app can achieve high uptake and rapid response times, which could lay the groundwork for broader smart–city deployments. This work reported that citizen–generated data offered more frequent and geographically comprehensive coverage, particularly on secondary roads, than traditional inspections or vehicle–based surveys. Thier app, FixCyprus—a national mobile app in Cyprus that collects citizen reports of road infrastructure defects, demonstrated the impact of a government–adopted, country–wide crowdsourcing tool. In Olma et al. (2022), it identified that traditional road–safety work in Germany and the EU largely depends on collision black–spot analyses, which are inherently reactive, slow to identify hazards (since collisions are rare events), and *ethically problematic because human harm must occur before action is taken*. They introduced a web–based platform where road users can mark “danger spots” on an interactive map, providing details on the type of hazard and road users at risk, i.e. poor visibility affecting pedestrians. This approach treats the crowd as “underestimated experts”, asserting that daily road users experience conditions first–hand and can alert others and authorities to risks before accidents occur. Indeed, the study found optimism among stakeholders that active public participation could serve as an early warning system in road safety work, though they cautioned about the subjective nature of such reports and potential misuse. It concluded that systematically collected danger–spot submissions, especially those with higher user engagement, can serve as timely, cost–effective indicators for proactive road–safety interventions. It goes further by saying that danger spots that garnered more user interactions (clicks, supports, comments) were significantly more likely to be confirmed as hazardous, indicating that collective attention reinforces report accuracy. In Telima et al. (2023), it mentioned crowdsourcing as a proactive tool, citing that systematic collection and analysis of user–generated incident reports provide an early–warning mechanism—capturing risks before collisions occur & complementing traditional crash records. It investigated the use of crowdsourced incident reports (including not only collisions but also near–misses and infrastructure issues) to analyze pedestrian safety in urban areas. A complementary study by Ibtissem et al. (2022) was proposed in Tunisia to leverage data from multiple crowdsourcing platforms for urban road safety improvements. The R–Secure system features two main functionalities: first, collecting rich road anomaly data (including images and GPS location) from citizens, and second, utilizing that data to enhance road safety outcomes.

In parallel to manual user reports, technology is being used to automatically detect road hazards, which can complement crowdsourcing. An innovative approach by Cafiso et al. (2022) used bicycles and e–scooters as probe vehicles to monitor road pavement conditions via built–in smartphone sensors. By collecting accelerometer data as these micro–mobility devices traversed urban roads, the researchers could identify road surface anomalies. Notably, the e–scooter and bike data were able to detect various severities of cracks and even potholes that did not register in traditional car–based road condition surveys.

There were also more focused studies done on the subject of road safety. One in particular is Desai et al. (2024) where they developed an application that aimed at revolutionizing road safety by proactively identifying and preventing accidents caused by potholes. This research leverages the integration of Internet of Things (IoT) technology to provide real–time updates and alerts to drivers, significantly mitigating the risks associated with pothole–induced accidents. This was achieved by combining LiDAR, radar, GPS, & accelerometer data to produce reliable pothole detections across varying road conditions & speeds. A similar study was done in Bhoyar et al. (2023). In this study, they devised a pothole detection system that utilizes an ultrasonic sensor mounted on a vehicle to measure the depth of potholes. The sensor continuously measures distance to the road surface and readings exceeding an 8cm threshold are flagged as a potential pothole. In Yang et al. (2021), the research employed technology that collects pothole data using smartphone accelerometers and cameras mounted on vehicles to obtain images of road surface anomalies. The images collected are then analysed with an image recognition–based convolutional neural network model to determine if the road surface scanned contains potholes. The final verified pothole images are then transmitted to a server along with the vehicle's GPS data. Then, the system generates road hazard information in the form of a four–level index indicating the road risk. This road hazard index can better assist road safety authorities in establishing road maintenance plans and planning for their costs. In a similar study, Pena–Caballero et al. (2020) focused on a limited scope of road hazard classes, i.e. Manhole, Pothole, Blurred Crosswalk, & Blurred Street Line. It trained a segmentation model that recognizes the four classes mentioned above and achieved great results with this model allowing the machine to effectively and correctly identify and classify the four classes in an image. Another recent study is the use of semantic web and ontologies to manage road hazard information. Kindo et al. (2024) introduced an ontology–based system to handle community–reported potholes, aiming to formalize how pothole data is described and shared between different systems. This ontology–based, community–assisted system bridges the gap between grassroots pothole detection and formal municipal maintenance, offering a scalable, cost–effective, and interoperable solution for improving road safety.

A body of literature has focused on evaluating the accuracy of crowdsourced road hazard data. In one study, a quasi–randomised audit of 77 user–reported danger spots across four German cities was done and over half were confirmed to have infrastructural deficits (i.e., true hazards), while about one quarter were classified as "uncertain" due to insufficient detail or lack of clear deficits, Olma et al. (2022). In a related study, R–Safety, devised a mobile crowdsourcing platform that allows road users to report their "road safety feeling indexes" in real time. Their platform focuses on subjective safety perceptions and even lets users report traffic violations they witness, with the goal of informing citizens about risky areas through a vulnerability map (Khedher et al. 2022).

While the related literature presented thus far demonstrates clear benefits to using crowdsourced road hazard information, it also consistently highlights challenges that SafeRoads Navigator aims to address—data quality control. First, an open contribution model, i.e. crowdsourced, raises some concerns about misinformation. Also, these community–driven validations can be slow or insufficient, i.e. areas with few users. The present study suggests that combining community validation with an additional layer—moderator oversight (aka dual vetting)—could improve reliability.

The literature shows a strong foundation for **SafeRoads Navigator**. Crowdsourced data is a powerful tool for real–time road hazard monitoring, offering speed and coverage advantages over traditional methods. Multiple studies have proven that user reports are generally reliable (with low false alarm rates) and can even save lives by enabling faster responses. It can also provide rich datasets for analysis. However, to fully realize this potential, a system must tackle data redundancy and trustworthiness as well. These insights directly inform the **SafeRoads Navigator** project. The proposed system builds on the success of crowdsourcing seen in prior research and explicitly addresses the identified gaps by introducing a structured dual vetting process for quality assurance. In the next section, I will define the specific problem this project will solve in light of the literature discussed and outline our research questions.

Problem Definition

I. Gaps Identification

From the above review, several gaps in current solutions become evident. On one hand, crowdsourced reporting can dramatically improve the timeliness and coverage of road hazard information. On the other hand, ensuring the accuracy and credibility of these reports remains an open challenge. Current navigation apps, for example Waze, & research prototypes largely rely on single–layer crowd validation—if enough users report or confirm an incident, it is considered credible. This approach, while useful, has its limitations. Minor hazards may not get multiple confirmations before they cause harm, and false reports can linger if no moderator intervenes. There is also a gap in seamlessly integrating crowdsourced hazard data with verification mechanisms in a way that is fast & reliable. Also, community engagement features such as crowdsourced verification, voting, or commenting are not universally present. The EDDA+ danger spot platform did implement support/upvote mechanisms and discussion threads (Olma et al., 2022), but many other systems do not leverage the crowd beyond the initial report. This can lead to issues with data quality and prioritization: for instance, without community feedback, authorities might not know which of many reports are most urgent or if some reports are duplicates. Thus, there is a gap in using the crowd not just as reporters but as filters and enhancers of the data.

Second, many crowdsourced hazard reporting systems focus on one aspect of the problem. Some are focusing only on one particular type of road hazard, i.e. pothole detection. Some are primarily for reporting and notifying authorities, i.e. FixCyprus focuses on submitting reports to public works (Christou et al., 2023), while others emphasize collecting data for analysis or public awareness, i.e. the danger spots map in Germany for safety research (Olma et al., 2022). There is a lack of an integrated platform that seamlessly supports end–to–end hazards management—from immediate reporting and verification, through operational response, to strategic trend analysis—in a unified system.

Finally, the siloing of data is a concern. Data collected by one platform often isn’t readily accessible for other purposes. The Korean citizen science study had to perform significant data processing (text mining) on the complaints to evaluate maintenance efficiency (Kim et al., 2023), implying that the system used to collect complaints wasn’t inherently providing those insights. Likewise, danger spot data needed to be combined with collision and kinematic data externally to derive hazard scores (Olma et al., 2022). This suggests a gap in MIS design: hazard reporting platforms could better incorporate data analytics and open data principles from the start. **SafeRoads Navigator** will attempt to close this gap by including dashboards and data export features that make analysis easier and allow stakeholders (planners, researchers) to directly use the information.

The gaps identified are:

1. Reliability of crowdsourced data – how to filter out incorrect or malicious reports without losing the benefits of real–time community inputs. The literature indicates trust mechanisms are needed, but an effective implementation in the road hazard domain is lacking;
2. Lack of a unified system covering reporting, response, and analysis;
3. Limited use of crowdsourced verification to improve road safety initiatives as data is not readily analysed or shared for policy use.

These gaps inform the problem statement and objectives of this capstone project.

II. Problem Statement

There is a need for a real–time road hazard monitoring system that maximizes the advantages of crowdsourced data (speed and breadth of coverage) while minimizing misinformation through effective validation. Additionally, there is currently no comprehensive, real–time platform for road hazard management that connects the general public, road maintenance authorities, and city planners on a common information system. As a result, many road hazards either go unreported, unassessed, or are addressed too slowly, leading to avoidable accidents, damage, and inefficiencies. Traditional reporting channels (phone hotlines, periodic surveys) are reactive and often fail to capture the full scope or urgency of issues. Furthermore, data that is collected (through isolated apps or studies) remains under–utilised for long–term safety improvements due to fragmentation and lack of analytical tools.

The core problem then can be summarised as: “How can we design and implement a real–time road hazard alert system using crowdsourced reports enhanced with a dual–layer vetting process to deliver timely and trustworthy information to all stakeholders?” The absence of an integrated solution means that cities struggle to prioritize repairs effectively, road users lack awareness of known danger spots, and decision–makers do not have consolidated data on which to base infrastructure improvements. We need a system that not only gathers hazard reports from road users in real time, but also ensures those reports are reliable, promptly acted upon, and aggregated into meaningful insights for future road safety strategies.

SafeRoads Navigator directly addresses these problems by providing a unified platform for road hazards reporting, visualization, alerting, and analysis. By doing so, it bridges the communication gap between citizens experiencing road hazards and the authorities responsible for fixing them, while also creating a valuable data repository for planners and researchers for present and future use. In essence, the project seeks to transform the current reactive and fragmented approach into a proactive, data–driven, one–stop–shop, road hazard management process.

III. Research Questions

To tackle the stated research gaps above, the project will be guided by the following research and design questions:

1. How can real–time trust and reputation mechanisms be designed to automatically validate and filter crowdsourced road–hazard reports without significantly delaying the reporting process?
   Justification: This addresses the first gap identified which is about increasing the reliability of crowdsourced data by minimizing false or malicious submissions.

2. What architectural and workflow models enable the seamless integration of an end–to–end road hazards management within a single platform?
   Justification: This addresses the second gap identified by creating a unified solution covering the aspects of crowdsourced reporting, multi–layer verification, operational response, and strategic trend analysis.

3. In what ways can built–in data analytics and open–data interfaces be embedded into crowdsourced hazard reporting systems to facilitate immediate policy-relevant insights and stakeholder collaboration?
   Justification: This addresses the third gap enumerated above by enabling the proposed solution to export datasets on road hazard incidents to be used by city planners, researchers, maintenance teams, and other concerned relevant parties.

Project Objectives

The objectives of SafeRoads Navigator are defined to address the identified problems / research gaps stated above. The successful completion of the capstone project will be measured against the three objectives outlined below:

1. To design and implement a real–time road hazards system that introduces a mechanism (1) for road users to verify or upvote existing hazard reports, and (2) allow road safety stakeholders to filter out false or malicious submissions without introducing perceptible reporting delays, thus improving the accuracy and trustworthiness of crowdsourced road hazard data.
2. To develop a unified, end–to–end road hazard management platform prototype that integrates (a) crowdsourced reporting, (b) multi–layer verification workflows, (c) operational response coordination, and (d) strategic trend–analysis capabilities.
3. To embed interactive data analytics dashboards and open–data interfaces within the hazard management system—enabling stakeholders, i.e. city planners, maintenance teams, & researchers, to generate policy–relevant insights, export cleaned datasets, and to

assess the platform’s impact on decision–making efficiency and possibly, inter–agency collaboration.

Methodology

This capstone project will employ a design and development methodology typical of software engineering projects, enriched with elements of design science research. The approach can be outlined in several phases:

1. Requirements Analysis – based on the literature review and the defined use cases, I will detail the functional requirements (what the system should do) and non–functional requirements (performance, security, usability, etc.). This will involve creating use case diagrams and user stories, i.e. “As a driver, I want to quickly report a road hazard with a photo so that others are warned and it gets fixed”. I will also identify the data requirements—what information each report will contain (timestamp, location, type, description, reporter info, etc.) and how data flows between frontend, backend, and any external services.
2. System Design and Architecture – using the requirements, I will design the system architecture. This will follow a client–server model: the frontend React application will communicate with a backend Node.js server via RESTful API calls using JSON data. I will design API endpoints for operations such as submitting a new report (`POST /hazards`), retrieving hazard data (`GET /hazards?area=X`), voting on a report (`POST /hazards/{id}/vote`), and admin actions (`PUT /hazards/{id}` to update status, etc.). A relational database schema (using SQLite) will be designed to store users, reports, votes, and any other related data. The Google Maps API will be incorporated for

the map interface; this requires obtaining an API key and deciding on using features like Google's Marker Clusterer for grouping close markers and the Heatmap layer for density visualization. A particular focus in design will be on the dual vetting logic, i.e. designing how a hazard status transitions from "unverified" to "verified" and what triggers that (number of confirmations or admin approval).

3. Implementation (Iterative Development) – as an agile practitioner, I will adopt an agile iterative development methodology, aiming to produce incremental prototypes that can be tested and refined. For instance, in the first iteration, I will implement core reporting and mapping without all features, then gradually add verification, alerts, and analytics in subsequent iterations. This approach allows early feedback loops.
4. Testing and Evaluation – throughout development, I will test each component. This includes unit testing of backend logic and integration testing. I will also perform scenario testing: simulate a user reporting a hazard and ensure it appears on the map; simulate multiple users voting on a report and see that it escalates appropriately; test that an alert email is sent when it should, etc.
5. Project Management and Milestones – I will break the work into tasks with a rough timeline (see Project Plan below). Version control (Git) will be used to manage code, and regular progress meetings with the supervisor will ensure I stay on track. If certain aspects prove too complex, i.e. implementing a fully automated clustering algorithm for alerts, I will adapt by simplifying the approach.

Proposed Solution and Project Plan

SafeRoads Navigator is proposed as a web–based application implementing the ideas discussed. This section describes the solution's key features, the technology stack and architecture, and the project plan including timeline and milestones for completion within four months.

I. Proposed Solution Overview

The SafeRoads Navigator system will be composed of several integrated components, forming a cohesive solution (see Figure 1 for a high–level architecture diagram). On the client side, a React–based web application will serve as Hazard Reporting and Viewer. On the server side, a Node.js application with an Express framework will act as the API Server and Processor, connected to a database that serves as the Hazard Data Repository. Surrounding these core components, there will be external integrations: the Google Maps API for mapping and geocoding services, and notification services, i.e. an SMTP server, for sending out alerts.

II. Proposed Solution Use Cases

The applicable use cases for the proposed solution are as follows:

1. Emergency road reporting – a road user notices a large pothole that could cause an accident and submits a report through the mobile web interface. The system captures the location automatically or allows the user to enter it manually. The report is then plotted on a real–time map for awareness.
2. Crowdsourced validation – after a report is submitted, other users can view the hazard on the map, add comments, or vote on whether the hazard is genuine, improving data reliability.

3. Traffic and road safety analysis – city planners use the dashboard to view heat maps of hazard reports. They identify the top 10 areas with frequent reports and schedule repairs or road safety audits in those locations.
4. Automated alerts for road safety stakeholders – depending on the severity type or when the system detects a cluster of hazards in a specific area, it automatically sends notifications to the local road maintenance team for rapid response.
5. Historical trends for policy making – the system aggregates data over time, providing downloadable reports and visualizations that help local authorities understand long–term road hazard trends and plan infrastructure improvements accordingly.

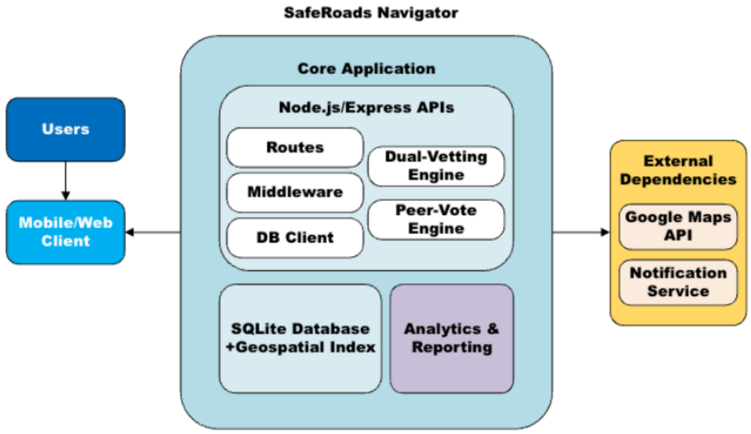
III. Key Features and Functionality

1. Crowdsourced Hazard Reporting – users can submit reports of road hazards through a simple interface. A hazard report includes details such as hazard type, i.e. accident, roadblock, pothole, flood, etc., optional description, and the location (captured automatically via GPS or entered manually).
2. Interactive Map with Real–Time Updates – the front–end features an interactive map (powered by Google Maps API) that displays all reported hazards as markers or icons at their locations. The map updates in real time to reflect new reports or changes in hazard status (unverified, verified, cleared). A heatmap overlay can be toggled to show areas with high concentration of hazard reports over a period, helping visualize hotspots.
3. Dual Vetting Workflow – each hazard report goes through two layers of validation:

- Peer Confirmation – when a hazard is reported, other nearby users (or any user viewing the map) can see it marked as “unverified” and have the option to confirm if they observe it as well. Confirming adds a vote of confidence. Likewise, users can flag a report as “not present” if they pass the location and find no such hazard. The system tallies confirmations vs. Dismissals.
- Moderator Verification – the system will automatically verify a report if it receives sufficient independent confirmations (for example, two other users confirm it). Alternatively, an admin or moderator user (with elevated privileges) can verify or reject reports via a dashboard that lists new unverified reports. The admin can use external judgment or cross–check, i.e. use local traffic cameras if available, to make a decision. Once a report passes this second layer, it is marked as verified in the system.

4. Administrative Dashboard – a back–end interface (could be a simple protected web page) for an administrator or the project team to monitor incoming hazard reports. It will list new reports with their details and any user confirmations. The admin can manually mark a report as verified or remove it if it’s known to be false. The dashboard also provides an overview of hazard stats and user contributions for analysis.

IV. Architecture Diagram



V. Technology Stack and Architecture

The project will employ the specified technology stack and a modular architecture:

1. Front–End – the client side is built with HTML/CSS/JavaScript/React Framework. A responsive design will ensure usability on various devices (mobile phones, tablets, laptops, as drivers may use their phones on a mount). The Google Maps JavaScript API is used to embed the map, place markers, and render heatmaps. JavaScript will also handle asynchronous calls to the server (using Fetch API) to send new reports and fetch updates without full page reloads, enabling a smooth real–time experience.
2. Back–End – Node.js will serve as the runtime environment, using the Express framework to set up a RESTful API. The server exposes endpoints such as:

    - `POST /report` to submit a new hazard report (with details in the request body).
    - `POST /confirm` or `/vote` to submit a confirmation or falsification vote on a hazard.
    - `GET /hazards` to retrieve current reported hazards (with parameters to filter by area or only verified ones, etc.).
    - `POST /verify` (admin-protected) to allow an admin to mark a hazard verified/false.
3. Database – SQLite is chosen for the database due to its lightweight nature and ease of use (no separate DB server needed, simplifying deployment for a capstone demo). For the photo upload, instead of saving the uploaded in the database, a directory path is saved instead because of the inherent limitations in SQLite.
4. Integration of Google Maps API – the Google Maps API will be central to the front–end. It provides the base map and utilities for markers and heatmaps. For heat mapping, the system may aggregate hazard data, i.e. number of reports in an area over time, and feed those as weighted points to the Google Maps Heatmap layer. This visualizes hotspots where hazards frequently occur (for instance, an intersection that often has accidents, indicated by a warm area on the heatmap). This addresses a use case of historical analysis, which could be beneficial to city planners or the community.
5. Security and Privacy – while not the primary focus, basic security will be considered. Node.js will sanitize inputs to prevent SQL injection (especially important since SQLite is file-based). If user accounts are used, passwords would be hashed. Google Maps API key management will be handled securely (not exposing keys in public code). The admin dashboard will be behind a login.

VI. Project Plan and Timeline

The SafeRoads Navigator project is planned to be completed within a four – month period, which roughly translates to 15 weeks. To ensure timely completion, the following timeline with milestones is proposed (aligned with the methodology steps):

1. Month 1 (Weeks 1–4) – Planning and Design (complete requirement analysis and finalize the system design. This includes the literature review (already in progress), drafting use cases, designing the database and API, and creating wireframes for the UI. By the end of Week 4, a design review will be held with mentors to validate the approach.
    - Milestone(s): Requirements & Design Document finalized; development environment set up (Node.js server skeleton, SQLite schema created).
2. Month 2 (Weeks 5–8) – Core Implementation (develop the core features (Iteration 1). By around Week 6, aim to have the hazard reporting and display loop functional: a user can submit a hazard and see it appear on the map (persisted in the DB). By Week 8, integrate user confirmation functionality and have a basic dual vetting logic working in a rudimentary form.
    - Milestone(s): By end of Month 2, internal demo of the system showing multiple users reporting and confirming hazards, with the map updating live.
3. Month 3 (Weeks 9–12) – Feature Completion and Refinement (implement remaining features and the full dual vetting rules. Build the admin dashboard in this phase and enforce the workflow for hazard status changes (unverified → verified or removed). Also implement the heatmap view and any additional niceties (like user

accounts or notifications) if time permits. Begin testing with sample data.

- Milestone(s): Feature–complete beta version of SafeRoads Navigator by end of Week 12. At this point, all primary use cases can be executed on the system.

4. Month 4 (Weeks 13–14) – Final testing, Evaluation, & Finalization (rigorously test the system for bugs, fix any issues, and polish the UI/UX. Conduct the evaluation plan: simulate usage to gather data on how the dual vetting performs. Analyze the results relative to research questions and incorporate findings into the final report. Concurrently, prepare the capstone presentation and documentation.
   - Milestone(s): Week 15, project completion. Deliverables include the final research proposal document (with results from any experiments or tests), the working prototype deployed for demonstration, and a presentation for the academic panel.

Evaluation Plan

The evaluation of SafeRoads Navigator will concentrate on three core dimensions:

- Accuracy and Reliability – this is to measure how well the dual–vetting mechanism filters false or malicious reports without introducing perceptible delay of road hazard reports reaching road users (Project Objective 1). Accuracy will be quantified using the following metrics:
  - Precision & recall of verified hazards vs. ground truth, i.e. field inspections
  - False Positive Rate (FPR) or the proportion of flagged hazards that are not real

    - False Negative Rate (FNR) or the proportion of real hazards missed by dual vetting
- System Integration & Performance – to assess the end–to–end platform's responsiveness, reliability, and capacity to handle real–time reporting use cases (Project Objective 2). Performance & scalability metrics can include:
    - API response times, i.e. throughput under simulated workloads
    - Throughput, i.e. maximum reports processed per second under load
    - System Uptime, i.e. percentage over evaluation period, i.e. target ≥ 99.5%
- Analytical Utility & Stakeholder Impact – this is to evaluate how effectively the interactive dashboards and open–data interfaces can support policy–relevant insights and decision–making (Project Objective 3). Analytical insights metrics can include:
    - Dashboard Usage, i.e. number of dashboard sessions by planners/authorities
    - Data Export Count, i.e. number of CSV/API exports performed
    - Policy Actions Triggered, i.e. number of maintenance actions initiated via system alerts

These metrics provide a comprehensive, industry–standard view of how effectively the solution filters hazards in real time, performs under load, delivers measurable improvements in road–hazard awareness, gains traction among stakeholders, and drives actionable safety insights.

Conclusion

Road safety and maintenance management are entering a new era where community engagement and real–time data play a pivotal role. **SafeRoads Navigator** is a capstone project that proposes an innovative solution to a well–recognised problem in transportation safety: obtaining timely and reliable information on road hazards. In this study, I have proposed and designed a solution that unifies hazards reporting, response coordination, strategic analysis, and dual vetting into one platform. By harnessing the power of crowdsourced data and addressing its weaknesses through a structured dual vetting approach, the project bridges the gap between raw community reports and trustworthy alerts that drivers and authorities can act upon. The formal literature review underscores that while crowdsourcing platforms such as Waze have revolutionised real–time traffic reporting—often detecting incidents faster than official channels, SafeRoads Navigator's contribution is to introduce a two–layer verification mechanism that builds on prior research recommendations for trust and quality control in volunteered information and thereby increasing user confidence.

Over the course of the proposal, I've outlined how **SafeRoads Navigator** will work: road users can quickly report hazards via a mobile–optimised web app; those reports are visualised on an interactive map and automatically routed to the appropriate stakeholders; community feedback (voting, comments) and admin moderation ensure the data's integrity; and the accumulated information is analysed to guide policy and infrastructure decisions.

By achieving the project objectives, I expect to demonstrate several key outcomes: (1) a reduction in the delay between hazard occurrence and awareness, (2) an increase in citizen participation in infrastructure upkeep, and (3) enhanced knowledge for city planners about where and when hazards happen most. In simulation, the system will showcase scenarios like an emergency road obstruction being reported and broadcast to authorities in minutes, or a heatmap revealing a pattern of potholes in a particular district over a year. These use cases emphasize how proactive and data-driven approaches to road safety can save time, resources, and ultimately lives—supporting the claim that a connected community is a safer community (Olma et al, 2022).

In conclusion, **SafeRoads Navigator** aims to serve as a capstone achievement that is both academically insightful and practically impactful. The proposed system embodies the concept of "Safer Roads through Shared Responsibility". It takes a step toward smarter cities by empowering everyday road users to be the "eyes and ears" for road safety, and by providing public agencies with a platform to act on citizen information efficiently and transparently. Should this prototype be successful, it could form the basis for a real–world pilot in partnership with the Auckland local government. By leveraging technology and community input, it strives to make travel safer for everyone. This proposal has laid out the vision, justification, and plan for realizing that vision. I am confident that, with the planned methodology and the support of the academic review panel, the project will succeed and provide a meaningful contribution to the field of Intelligent Transportation Systems in general, and a strong capstone project for this academic program in particular.

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