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Integrating Spatial Data Analysis for Road Traffic Incident Response System

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ABSTRACT

In order to develop a mobile application for traffic incident emergency response system and integrate spatial data analysis, this study present a use case diagram and system features to determine the accident-prone areas of the locality and to enhance the capacity of response units to respond to traffic incidents. The result shows that it can be accessed on any mobile device in a user-friendly interface, accessible and useful to any community members for information about optimized routes to nearby response units. The user could easily report the accident and obtain the alert, while the response unit would review the report and determine the accident area coordinates. The features of the study were designed to improve the notification rate of an incident, enabling the responding units to easily access the site and respond immediately. Integrating spatial data analysis was supported with the assessment of the accident-prone areas and reporting process on the mobile application of the emergency response system for traffic incidents. The respondents evaluated the system as highly acceptable with a total average weighted mean of 4.66.

Key words : Emergency response, GIS, spatial analysis, traffic incidents.

1. INTRODUCTION

It has long been common practice for the concerned authorities to recognize places and times that are more vulnerable to emergency activities in order to reduce emergency-related incidents, especially road traffic and vehicle accidents. Consideration is being provided to an emergency response program for traffic incidents that would benefit both emergency providers and community members.

Emergency response always involves people and it is important to understand how people respond during an emergency. It includes any systematic response to an unexpected or dangerous occurrence. Emergency situations warranting a response can range from natural disasters to hazardous materials problems and transportation incidents [1]. Relatively, road accidents are increasingly recognized as a growing major issue. They provide significant economic and social losses [2]. Road accidents not only impose huge economic losses in most countries but also causes great emotional and financial stress to the millions of families affected. The continued steep increase in the number of road accidents indicates that these losses are undoubtedly inhibiting the economic and social development of the countries [3]. Traditional tools are now unable to solve and face the management of problems relating to traffic detection, traffic jams created by urban public transport, data on motorway tolls, meteorological data and traffic safety, etc. These types of traffic data are numerous and enormous [4]. Without an effective system for reporting, processing and dissemination of accidents, it would be extremely difficult to monitor road safety levels and formulate and implement cost-effective programmes. The need for action and expenditure to increase road safety is a major concern with the rapidly increasing rate of motorization [5].

The traffic management system is one of the major key components in modern society since automobiles are in demand today. Traffic management is important because it provides organizing the flow of traffic. [6]. With this situation, emergency response needs to be sustained, flexible and clear with proper communication. It is necessary to record decisions and communications. The emergency manager will promote this approach by ensuring that the communication technology is available and effective in the face of potential failure, procedures are developed for sending messages, and stakeholders are aware of the goals of communication [7]. Further, the technological growth of internet services and devices has enabled users' easier access to online information. [8] This tool could enhance emergency response and quickly access to reliable and updated information. Data can be critical to emergency management to allow the right resources to be deployed in the right places at the right time and to give priority to the most effective efforts. Such vital information has a spatial dimension, such as extent and position of damaged areas, position of resource and service, and secure transportation routes. These geographical or spatial information is useful in all phases of emergency response

Thus, this study developed a mobile applications emergency response system for traffic incidents that would enhance the response unit emergency response process. The researcher gathered relevant data from the Albay Provincial Police

Office (Albay PPO) and identified the study area for Legazpi City. The paper presented the use case diagram, identified the characteristics of the emergency response system and suggested an emergency response system for mobile applications with an integration of spatial analysis to geographically assess the location's accident areas. Spatial data analysis and mobile services would provide information to local response units on the accident-prone areas with highest frequency of incidents and routing information. The emergency response system was designed to increase the speed of traffic incident reporting and for the response units to easily reach the location and immediately respond to accidents.

2. LITERATURE REVIEW

Several studies on accident analysis tools and road design have increased significantly. Geographical Information Systems (GIS) has the ability to conduct spatial analyses among these tools. GIS software identifies where the crash occurs on a digital map and examines the hot spots of the traffic accident [9]. GIS shows the accident–prone areas by analyzing the spatial characteristics of identified locations and can identify the cause of accidents. Reasonable action can be taken to improve safety at accident-prone locations. GIS has been widely used in most developed countries, many academics and even government agencies are working on it, building new tools and improving existing road safety analysis scenarios [10].

Road accidents in India were analyzed at the national and metropolitan level. The main road safety issues and countermeasures to address it were discussed and identified. Study results show that the causes of accidental death and injury on the road differ according to month, time, age and gender [11]. In Myanmar, GIS methods of accident rate and quality control was used to identify Naypyitaw-Mandalay Expressway's hazardous road locations. Responsible authorities find it useful for other roads to determine the hazardous locations from the study's accident analysis methods [12]. In Nairobi, Kenya, the feasibility of spatial information for emergency services was analyzed and uses spatial autocorrelation to classify the accident-prone areas. The study presents a GPS and GIS approach aimed at reducing the number of accidents, increasing the level of road safety and providing fast emergency services. It also tells clients about sites of incidents, incident and condition data [13]. In Iran's Mashhad City, the traffic accident records have used geo-information technology and combined GIS spatial-statistical methods for accident analysis to evaluate the impact of spatial factors on their development [14]. And in the Philippines, the accident hotspots were identified using standard GIS geo-processing techniques and created blackspot maps on Katipunan Avenue. The researchers plot all the agencies like police station, hospital, and fire station on the map apart from identifying the hotspot or blackspot areas [15].

The literature and studies mentioned above are interconnected with this study because it shares similar ideas and thoughts. Previous studies help to broaden researcher' knowledge of traffic incidents, emergency response, coordination and communication process, spatial analysis of GIS and mobile technology, which is the main concern of this study. As of this day, there is still manual recording of the raw information on local traffic incidents. Police stations use social media to update the community what is happening in an event or operation, but they do not have the ability to manage restrictions based on the needs of emergency incidents, specifically in addressing the immediate response and determining locations of the map. The researcher has formulated an idea with this situation to develop a mobile application emergency response system for traffic incidents for Albay PPO that integrates GIS spatial analysis and has emergency reporting features for road traffic and vehicle accidents within Legazpi City.

3. METHODOLOGY

Rapid Application Development (RAD) was used in this analysis. The key advantage of a RAD approach is the quick turnaround of the design, making it an attractive choice for developers working in a fast-paced environment such as software development. RAD helps project managers and stakeholders to accurately measure progress and consult on emerging problems or improvements in real time by increasing planning time and promoting model iterations. This results in more performance, quicker growth and better interaction [16,17].

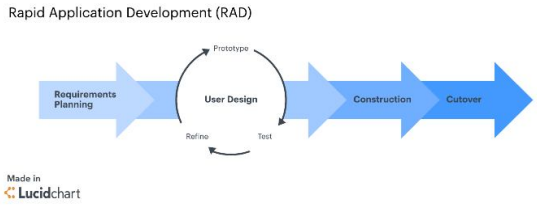

Figure 1: Rapid Application Development (RAD) Methodology

The researcher followed the following methodology phases: (1) Requirements Planning, the Legazpi City map, number of accidents and list of accident-prone barangays were determined to obtain accurate location data. (2) User Design, the proposed features of the system and its use case diagram was presented on this requirement. (3) Rapid Construction, spatial data analysis and GIS have been used as an engineering tool to accurately identify the geo-mapping and accident sites of Legazpi City. GIS has been integrated into the emergency response system for mobile application to ensure that the system is design-based and fulfills all the requirements set out in the specification documents. Finally, (4) Cutover is to show the study's output. In describing the entire project process to Albay PPO as the concerned police station response unit, a system presentation was carried out. Researcher did not cover the implementation and delivery of

the program, but on the development process, the researcher developed the emergency response system for mobile applications and still converted the design into executable code with supporting documentation and performed a simple test level. The characteristic and sub-characteristics of ISO 25010 were used to test and evaluate the proposed system [18].

4. RESULTS AND DISCUSSIONS

The study presents the location map, number of traffic incidents in Legazpi City, integrates the spatial data analysis and maps the list of barangays with highest number of traffic incidents in 2016-2018 geographically. It also drawn the use case diagram, describes the proposed system features and introduces the emergency response system for mobile applications that would speed up the incident reporting process and improve the response units' ability to respond to emergencies.

4.1 Location Map and Number of Incidents

Figure 2: Map of Legazpi City

Figure 2 shows the Legazpi City map and the number of traffic incidents from year 2016 to 2018 is shown in Table 1. Reckless Imprudence Resulting to Damage to Property (RIR-DP) was the highest number of road traffic and vehicle accidents in Legazpi City. In comparison, Reckless Imprudence Resulting to Homicide (RIR-Homicide) is 33 in total; Reckless Imprudence Resulting to Physical Injury (RIR-PI) is 1,300 in total; and Reckless Imprudence Resulting to Damage to Property (RIR-DP) is 3,050.

Table 1: Number of Accidents from Year 2016-2018

Year	Number of Accidents		
	RIR-Homicide	RIR-PI	RIR-DP
2016	13	485	888
2017	11	467	997
2018	9	348	1165
Total	33	1300	3050

Table 2 shows the number of accident-prone barangays in 2018. The top three barangays for RIR-Homicide are Brgy. 41-Bogtong, Brgy. 28-Victory Village North (Pob.) and Brgy. 37-Bitano (Pob.). The top five barangays for RIR-PI are Brgy. 42-Rawis, Brgy. 37-Bitano (Pob.), Brgy. 56-Taysan, Brgy. 47–Arimbay and Brgy. 34-Oro Site-Magallanes St. (Pob.). The top five barangays for RIR-DP are Brgy. 37-Bitano (Pob.), Brgy. 42-Rawis, Brgy. 39-Bonot (Pob.), Brgy. 16-Kawit-East Washington Drive (Pob.) and Brgy. 40-Cruzada.

In summary, it merely shows that the same barangay names have been involved in road traffic and vehicle accidents frequently and continuously. There is an urgent need to consider the barangay's road situation and actions should be taken to reduce the number of accidents and improve overall road safety.

Table 2: Number of Accidents in Year 2018

No.	Top 3 Barangays: 2018 - RIR-Homicide	No. of Accidents
1	Brgy. 41 - Bogtong	3
2	Brgy. 42 - Rawis	2
3	Brgy. 18 - Cabagñan West (Pob.)	1
No.	**Top 3 Barangays: 2018 - RIR-Homicide**	**No. of Accidents**
1	Brgy. 37 - Bitano (Pob.)	32
2	Brgy. 42 - Rawis	28
3	Brgy. 56 - Taysan	21
4	Brgy. 47 - Arimbay	14
5	Brgy. 34 - Oro Site-Magallanes St. (Pob.)	14
No.	**Top 3 Barangays: 2018 - RIR-Homicide**	**No. of Accidents**
1	Brgy. 37 - Bitano (Pob.)	162
2	Brgy. 42 - Rawis	96
3	Brgy. 39 - Bonot (Pob.)	65
4	Brgy. 16-Kawit-East Washington Drive (Pob.)	53
5	Brgy. 40 - Cruzada	49

4.2 Mapping of Accident-Prone Areas

As shown in Figure 3, the barangay accident-prone areas are plotted on the map of Legazpi City. As a technology tool, a GIS-based spatial analysis was used to accurately reference the geo-mapping and accident locations of Legazpi City. It was used to familiarize and visualize the location of the area of study and to obtain useful site information, such as the road, highway, and barangay name.

Figure 3: Legazpi City accident-prone area

4.3 Use Case Diagram and System Features

Figure 4 displays the use case diagram of the mobile application emergency response system for traffic incidents. Each actor on the network has a specific level of access. User reports an incident which is extended to the management of Albay PPO as the system administrator of the application and user's account. On the other hand, after responding to the incident, the response unit conducts an incident response report and it shall be reviewed and confirmed by Albay PPO,

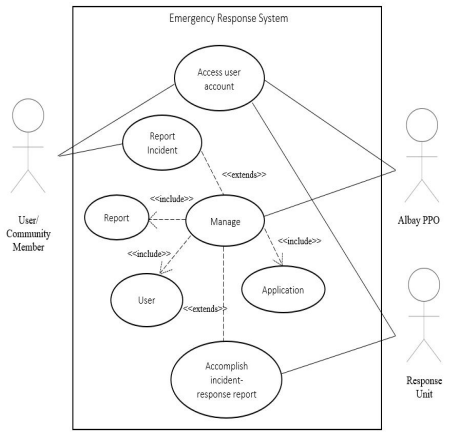

Figure 4: Use Case diagram of emergency response system

The researcher also analyzed the system requirements and designed a solution to be implemented taking into account the requirements, constraints and all applicable standards and guidelines. This requirement is presented in the proposed system features as shown in Table 3.

Table 3: Proposed Features of Emergency Response System

Module	Features
Registration	User registration Validation of user's profile
System Operations	Reporting or posting of incident and situation on Timeline Centralized whiteboard Coordinates with the concerned response units
Mapping System	Viewing of the real-time locations of road traffic and vehicular accidents with the use of android phones as GPS tracking device Recorded incidents would also be viewed in the map
Messaging System	Able to send real-time messages Send incident pictures
Mobile Application	Posting of incident and situation on timeline Access the GPS Get the locations of subordinates and incident Send pictures of the incident Send real-time messages

4.4 Emergency Response Mobile Application

Figures 5, 6 and 7 shows the interface of the emergency response system for mobile applications. This consists of a login page, user's page and accident-prone area location information in the form of spatial data in latitude and longitude. It has information on different fields such as a pin, barangay name, and the number of accidents recorded as of 2018. The user or concerned community will communicate and access a mobile application-built GUI.

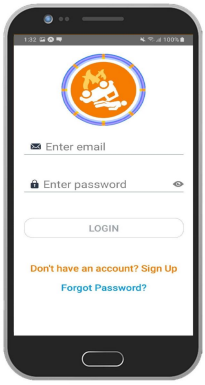

Figure 5: Log-in page area

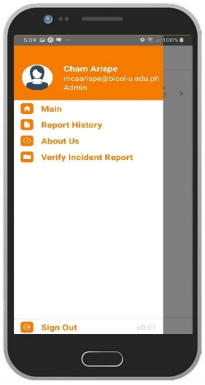

Figure 6: User page

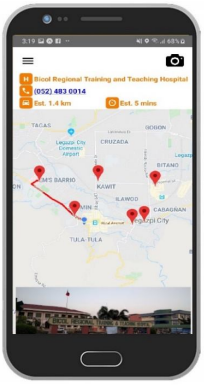

Figure 7: Accident-prone area page page

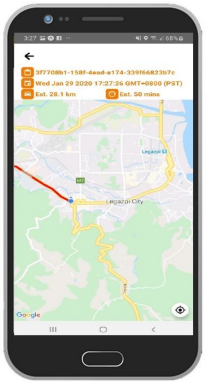

Figure 8: Location

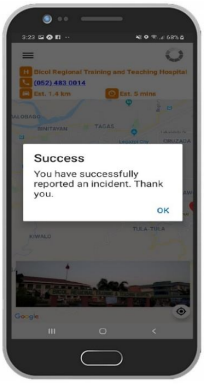

Figure 9: Reporting page

Figure 10: Report content page

In addition, the user can search the nearest response unit location such as police station, hospital or fire station. Then

the required information as per the requested service is retrieved from the server where the application indicates the distance between incident area's current position and the location of the response unit. Users can report the incident easily and send pictures of the actual accident, while the administrator of the emergency response system can easily identify the sender's spatial information as they received the reported incident. Figures 8, 9 and 10 shows the location, reporting and report content page.

4.5 Evaluation of the Emergency Response System

The randomly selected respondents: five (5) PIDMB officers, seven (7) Albay PPO personnel, and 108 community members evaluated the proposed emergency response system for traffic incidents using ISO 25010 characteristics and sub-characteristics. It was overall rated as highly acceptable. For functional suitability, the functional completeness, functional correctness and functional appropriateness has obtained an average weighted mean of 4.76, 4.71, and 4.79 respectively. For performance efficiency, the time behaviour, resource utilization and capacity has obtained an average weighted mean of 4.83, 4.71, and 4.59 respectively. For compatibility, the co-existence and interoperability has obtained an average weighted mean of 4.72 and 4.63.

For usability, it also obtained an average weighted mean of 4.81 for appropriateness, 4.65 for recognizability, 4.78 for learnability, 4.76 for operability, 4.66 for user error protection, 4.62 for user interface aesthetics, and 4.75 for accessibility. For reliability, an average weighted mean of 4.76 for maturity, 4.54 for availability, 4.63 for fault tolerance, and 4.64 for recoverability. For security, an average weighted mean of 4.56 for confidentiality, 4.40 for integrity, 4.59 for non-repudiation, 4.62 for authenticity, and 4.41 for accountability.

For maintainability, the modularity, reusability, analysability, modifiability, and testability has obtained an average weighted mean of 4.58, 4.66, 4.69, 4.66 and 4.46 respectively. For portability, the adaptability, installability and replaceability has obtained an average weighted mean of 4.76, 4.62, and 4.69 respectively.

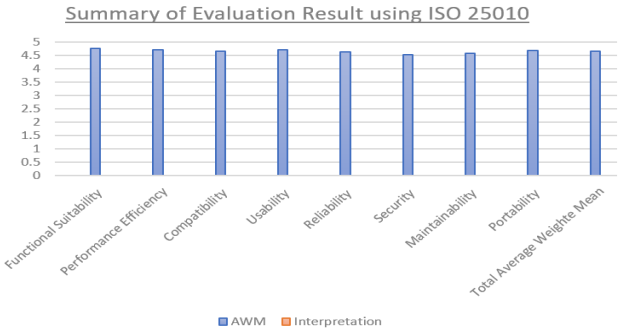

Figure 11: Summary of Evaluation Results using ISO 25010

Figure 11 presents the summary of evaluation results, it was also overall rated as highly acceptable with an average weighted mean of 4.76 under functional suitability, 4.71 under performance efficiency, 4.67 under compatibility, 4.72 under usability, 4.64 under reliability, 4.52 under security, 4.59 under maintainability, and 4.69 under portability. The total average weighted mean is 4.66 or highly acceptable.

5. CONCLUSION

Integrating GIS spatial data analysis to map areas that are prone to accidents accurately classify the locations and enhance incident reporting mechanisms, thus, developing the mobile application emergency response system for traffic incidents provide broader access to emergency response on road traffic incidents, available to any activated mobile device and useful for reporting accidents easily to any community member. As for the basis on the development of the study, the records of the number of accidents and the list of barangays vulnerable to accidents were established. The use case diagram and features of the emergency response system were utilized. The study results could help the response units in supporting emergency responses and to respond on traffic incidents immediately. The evaluation of the system was conducted using the ISO 25010 characteristics and sub characteristics. The respondents viewed the application as an improvement on the reporting process which will help the authorities act faster as they will be getting first-hand information in real-time features.

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