Analysis and Infrastructure Suggestion for a Reactive Emergency Incident Management System: case of enhancing an existing legacy system for Hewler city

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Abstract

Effective emergency management is vital for optimizing resources and responding efficiently to critical situations, which directly impact lives and the environment. This study focuses on enhancing emergency management in the Kurdistan Region of Iraq by analysing the current system and proposing a modernized approach using information systems. The analysis reveals current system limitations due to outdated technology and slow response times. To overcome the underlying challenges, we propose a proactive technology-driven framework based on a user-friendly mobile application with accurate geographic location data. In-situ testing verifies its potential to reduce response times to approximately 10 minutes, aligning with the average worldwide range. Suggestions for further enhancement and implementation are also provided.

Keywords: Incident management, IT service management, IT Infrastructure

1. Introduction

In today's dynamic and ever-evolving world, emergencies happen unexpectedly, demanding immediate action. Where every second counts, time become a critical factor in life-threatening situations. At the heart of effective emergency response lies the Emergency Management System, a complex network of strategies, resources, and coordinated efforts that can mean the difference between survival and tragedy.

Emergencies occurs in different forms, from natural disasters like earthquakes to health crises and acts of violence. Regardless of their nature, emergencies share a common sense of urgency, requiring immediate intervention to mitigate damage and restore normality.

Effective emergency management relies heavily on a well-defined communication and information sharing among response agencies and the public. Governments play a crucial role in establishing response and preparedness plans to ensure the coordination, and allocation of resources efficiently and effectively.

On the other hand, citizens play a pivotal role in emergency response, accessing emergency services through various channels such as a unified emergency number, mobile apps, and text messaging. Governments must ensure that these channels are accessible and effective, adjusting to the needs and regulations of each region.

Emergency services have evolved significantly over time, driven by societal shifts and technological advancements. Modern fire services emerged in the 17th and 18th centuries, followed by the establishment of dedicated police forces and the development of specialized medical care during emergencies (George D. Haddow, n.d.). Technological breakthroughs, particularly in communication systems, have revolutionized emergency response, enabling faster coordination and improved situational awareness.

A significant milestone in emergency management was the introduction of uniform emergency reporting numbers. The United States implemented 911 in 1957 (Anon., n.d.), simplifying emergency reporting and expediting assistance. Similarly, Europe adopted 112 in 1991 (Paris, n.d.), ensuring reliability across the continent.

Mobile applications have become popular tools for reporting emergencies, providing accurate location data and multimedia reporting options. The FEMA app in the United States exemplifies this trend, offering real-time alerts and direct communication with emergency responders (Anon., 2023).

Middle Eastern countries like the UAE have also embraced advanced technologies in emergency services, introducing unified emergency numbers like '999' and mobile applications such as "Aman" for reporting emergencies directly to authorities. utilizing GPS tracking for precise location identification (Anon., n.d.).

in some countries and regions, including the Kurdistan region, the presence of multiple emergency numbers can lead to delays in connecting with the appropriate authorities during crises, especially when individuals are panicked or confused. Additionally, the lack of street addressing, and geo-localization capabilities poses challenges for emergency responders in

locating incidents swiftly. Moreover, the coordination among emergency respondent teams is hindered by the absence of a centralized emergency center. in the light of these issues, the objectives of this study can be summarized in the following points:

1. To investigate and analyze the currently adopted emergency system and its impact on citizens.
2. To find a measure to evaluate the current system's efficiency and reactiveness.
3. To suggest an Information system-based approach (Mobile Application) for modernizing the Emergency system and compare its reactiveness.

Worth mentioning, this study acknowledges limitations concerning the proposed mobile application and the scope of research. While the app may lack certain standard functionalities, its design aligns with the study's objectives. Additionally, the findings and solutions may not directly apply to regions outside the Kurdistan Regional Government due to differing contexts. Adaptation to specific regional needs is crucial.

The paper is organized in different sections starting with the related work in section 2, followed by the research methodology of the work and the suggested information system in section 4. Finally, the results and discussions conclude the work in sections 5 and 6.

2.Related works

Many authors have tackled the problem of emergency management systems. Some suggested the best performance criteria to evaluate the different systems and the factors that impact these criteria, while others they introduced location based along with mobile systems to improve the reaction time. Researchers in different countries are exploring statistical methods and operational research to analyze response times data and develop models for improvement. In this regard, a group of authors (CabralI, et al., 2018) systematically reviewed published studies and assessed the factors impacting response times in various countries from 2007 to 2017. The factors that have been evaluated in their review included Gross Domestic Product (GDP) percentage spent on health, life expectancy, public health policies, demographic density, size of localities, and traffic conditions on public roads hindering the circulation of ambulances. Results revealed that higher economic development and healthcare access can positively impact response times. Moreover, with a focus on investigating the crucial link between response time and survival

rates, Blackwell and Kaufman (2002) conducted research in a metropolitan country with a population of 620,000, utilizing data from a paramedic Emergency Medical System (EMS) that handled all emergency requests. The findings suggested that response time significantly affects survival rates for EMS patients; calls with response times under 5 minutes were associated with improved survival compared to those exceeding 5 minutes.

In regards to the location of emergency, In emergency systems, the accuracy of a caller's location is a pivotal piece of information. It facilitates the accurate routing of emergency calls and allocation of resources, underscoring the urgency of pinpointing incident locations accurately (Anon., 2009).GPS and Location Based Services (LBS) are transformative factors in enhancing response times and optimizing resource deployment by providing real-time, accurate location information. LBS is a set of applications and technologies that consider the geographic position of a given mobile device and provide the user's device value-added information based on the derived location data (Aloudat, et al., 2009). LBS has drawn the attention of several applications in the field of geoinformation science to provide day to day services on traffic information, trace of the fleet, and emergency services (Rao, et al., 2013).In recent years, attention has been given to using mobile applications as one of the trending technologies to provide an alternative emergency notification channel for citizens and emergency organizations. In this context, Repanovici and Nedelcu (Repanovici & Nedelcu, 2021) highlighted the importance of utilizing a standardized mobile emergency application in their research. Using a Multi-Criteria Analysis, they evaluate three alternative solutions for communication during an emergency: voice calls, Emergency SMS (eSMS), and mobile applications. They argued that while voice communication is essential, eSMS and mobile applications offer greater flexibility when reporting emergency cases. eSMS can be particularly beneficial for people with communication disabilities. Moreover, mobile apps provide event details and accurate location information that can be used as an alternative to improve efficiency and accessibility in emergencies.

3. Research methodology

To understand the current situation and challenges of the current emergency management system operating within the region, we begin with the data collection process from two key governmental agencies who are actively engaged in the region's emergency management process: the Directorate of Civil Defense and the Emergency Coordination Center (ECC).

Data collection process consists of two main methods: conducting structured interviews with key personnel within these agencies, then observing how they respond to emergencies. Key personnel including dispatchers, administrators, and ambulance drivers who have been closely involved in the emergency management process participated in the interview. Additionally, observations made on how they react to emergencies by witnessing their procedures directly. With the observation of these operations, a more in-depth understanding was obtained about the effectiveness of resource allocation, coordination mechanisms, and their ability to respond to emergencies quickly.

The interviews were conducted using a structured format with a predefined list of open-ended questions, targeted to collect detailed information from the participants as well as allowing them to share their perspectives and experiences. The interview questions explored various aspects of the emergency response process, including handling emergency calls, dispatching responders, communication and coordination among responders, and challenges faced on their day-to-day operations. Additionally, the interviews sought information on current technologies for call management, the impact of lacking advanced technology like GPS tracking, challenges in resource allocation during emergencies, and the adapted measures for data collection and storage related to emergency cases and response operations.

3.1 Analysis of existing legacy system

The following sections cover the key findings obtained through the interviews conducted with EMC and the Directorate of Civil Defense agencies. During the data collection process, the capabilities of Google Maps utilized to simulate real emergency scenarios for both agencies, serving as an informative tool to collect valuable insights in a controlled environment to examine and evaluate emergency response procedures closely.

3.1.1 Emergency Coordination and Civil Defence Centres

These two facilities coordinate the actions following the receptions of emergency calls. The Emergency Coordination Center (ECC), situated inside the city, operates 24/7, providing ambulance services. It utilizes a Cloud Call Center (3CX) software based on SIP standard, handles incoming calls, including those from different providers through the short code '122', directing them to dispatchers. The software supports call blocking, voice recording, and generating comprehensive reports. The city is divided into two zones of actions: westren and eastrn zones. The Emergency Management Center (EMC) in Erbil city serves as a secondary facility that receives calls from ECC via mobile handsetsto coordinate the actions concerning the westren geographical area of action, after a first evaluation of the emergency calls by the ECC based on the caller's location.

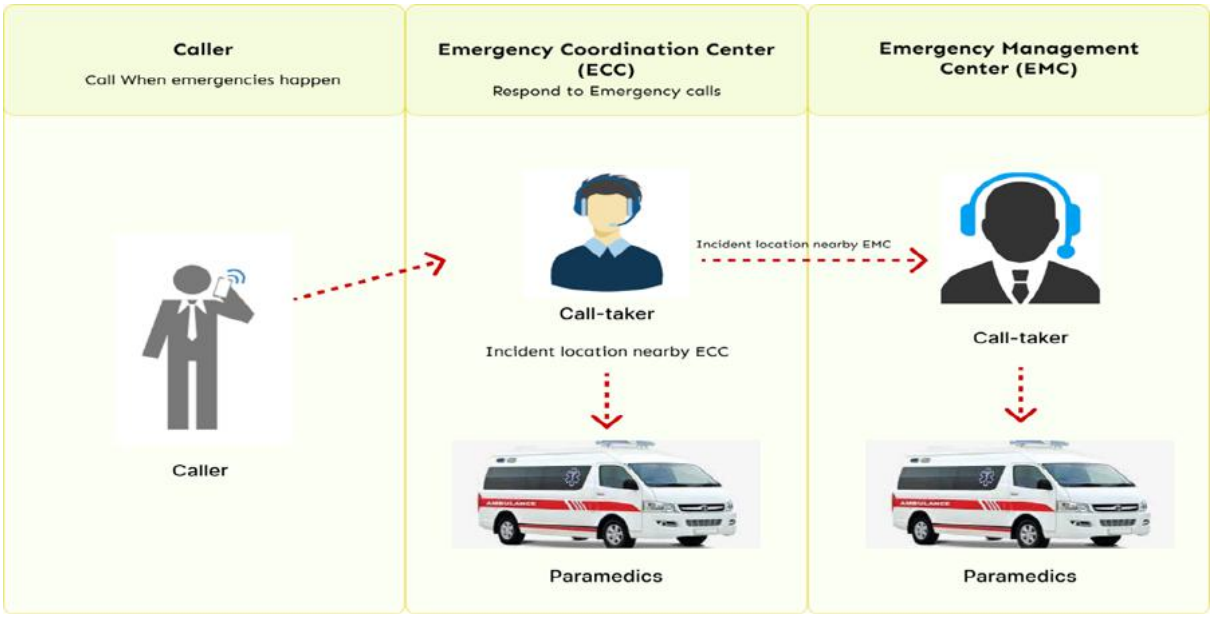

Figure 1 The caller and ECC dispatcher communication and then the EMC.

Upon an emergency call, the dispatcher at the ECC initiates an information-gathering process. The dispatcher collects critical information essential to respond to the emergency at hand

effectively. The collected information includes:

1. Incident type: to document the nature of the emergency and identify the incident's severity.

2. Phone number: to facilitate communication and maintain a direct communication channel with the incident reporter. This information is a method to obtain more detailed information while the responder team departs from the emergency station.

3. Incident Nearest Location: pinpointing the incident's nearest location to facilitate the dispatching process of the appropriate emergency responder team.

The Directorate of Civil Defense (DCD), situated also inside the city , is pivotal in civil defense and emergency management, overseeing various tasks to ensure public safety and minimize emergency impacts. Staffed by five officers and a supervisor per shift, their duties include receiving calls, documenting information, and dispatching resources. To enhance response efficiency, eight fire stations in Erbil city and ten in surrounding rural areas operate continuously, facilitated by Walkie-Talkie devices for instant wireless communication with the central operation room.. After an initial assessment of the situation, the dispatcher allocates the necessary resources from the fire stations. The allocation is made based on the geographic location of the incident, relying significantly on the dispatcher's familiarity with the various areas within Erbil city. Other assessment is made to determine the need to involve other authorities, such as the police station or ambulance services considering incident's nature and severity.

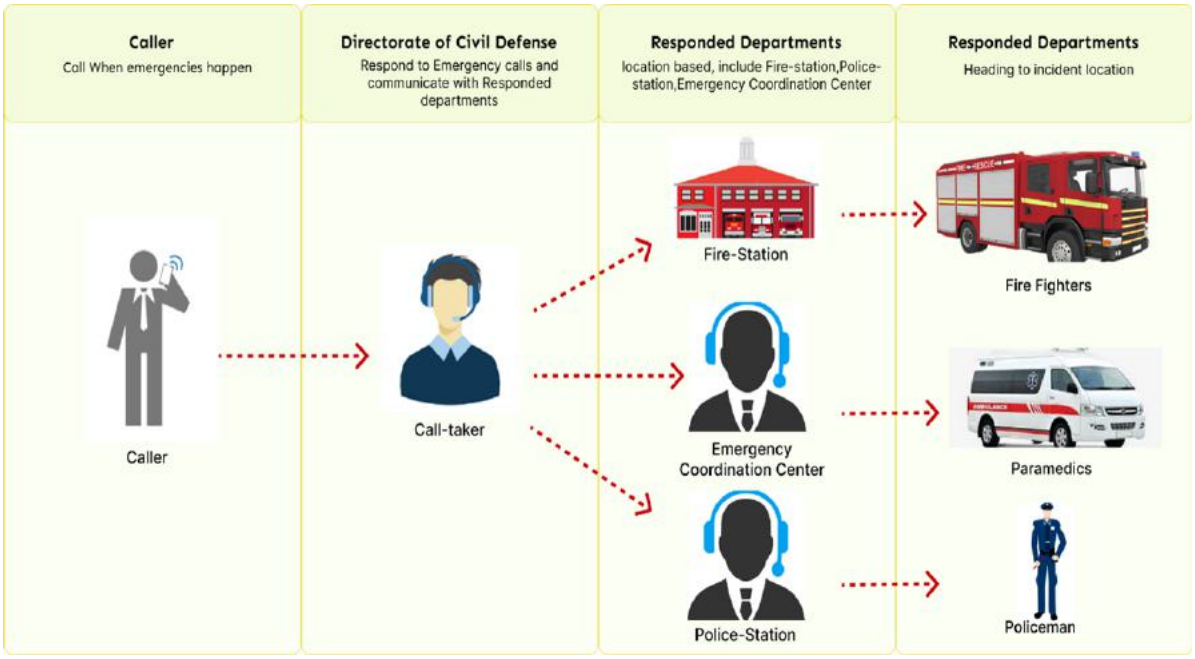

Figure 2 Caller dispatcher communications with DCD

3.1.2 The Legacy System Simulations

We use the capability of Google Maps employed to simulate emergency cases for ECC and the DCD in a location and estimate the time to access that location. The process involved inputting the incident location with the starting location at the emergency center station into Google Maps; subsequently, optimal routes determined, taking into account traffic conditions and visualizing these routes on the map.

First simulation was for an emergency call reporting an incident in Hawlery Nwe located at the right hand side of Erbil's Map, received by the ECC at 8:08 AM on January 5th, 2023. The dispatcher provided necessary information to an ambulance driver, and the ambulance was dispatched at 8:11 AM without routing assistance. Google Maps estimated a 10-minute travel time via Koya Street, but the actual travel time was approximately 18 minutes, with the

ambulance taking a different route than the optimal route provided by Google's Map. This resulted in a total response time of 21 minutes from call reception to ambulance arrival at the scene.

Table 1 Response time of a simulated call with human guidance

ECC Call Reception	ECC Ambulance Departure	Ambulance Arrival
08:08 AM	08:11 AM	08:29 AM

In the second simulation, an emergency call was received by the ECC on January 14th, 2023, at 12:20 AM, reporting an incident at Tayrawa located in the westren side of Erbil's Map. The ECC promptly contacted the EMC for coordination, and the ambulance was dispatched at 12:24 AM, just four minutes after the call. Despite Google Maps suggesting a 6-minute travel time, the actual time was around 15 minutes, resulting in a total response time of 19 minutes.

Worthy to mention, language barriers hindered the ambulance driver's communication with non-Kurdish speakers during the emergency call, delaying response time and potentially impacting timely medical assistance.

Table 2 The response time of a simulated call to ECC dispatched to EMC

ECC Call Reception	EMC Ambulance Departure	Ambulance Arrival
12:20 AM	12:24 AM	12:39 AM

3.1.3 Legacy system limitations

Several drawbacks associated with the current operations of the Emergency Coordination Center and the Directorate of Civil Defense have been identified through the data collection process. These shortcomings include:

1. Manual data collection lacks accuracy and doesn't include ambulance arrival time.
2. Outdated mobile devices and paper-based methods hinder efficient operations.
3. Additional step of contacting responding fire stations/ECC adds to response time.
4. Language barrier between ambulance drivers and non-Kurdish speakers impacts communication.
5. Reliance on dispatcher and driver familiarity with the city's layout may delay response.
6. Lack of advanced technology like GPS tracking affects routing and response efficiency.

3.2 Performance Measurement Criterion

In emergencies, every second counts. Therefore, the selection of response time as a performance measurement criterion for both the ECC and the Directorate of Civil Defense is essential due to the critical nature of timely emergency response. Response time refers to the duration it takes emergency responders to reach the incident location from the moment the emergency call is received, crucial in saving lives and ensuring public safety. Monitoring and setting targets for response times enhance emergency service efficiency and foster public trust in the emergency management system.

According to a document published by The European Emergency Number Association (ENNA) (Andy Heward, 2014) Response time standards in emergency services are affected by factors like incident type, location, and available resources. Governments and organizations must set clear standards to ensure effective responses, providing reassurance to citizens during emergencies. Below figure outlines various time elements in the overall response times, highlighting the

significance of the time from the emergency call to the arrival of the emergency vehicle from the citizen's perspective.

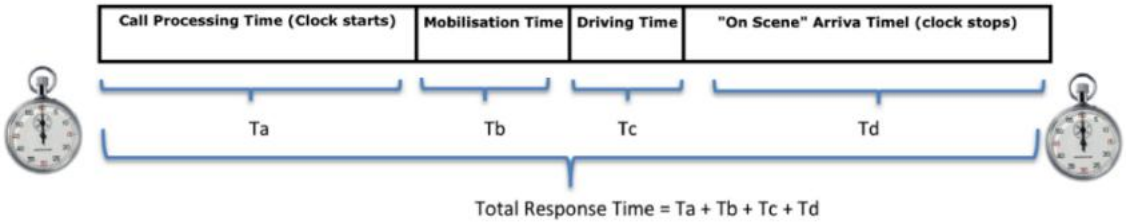

Figure 3 Response time partitions

1. Call Processing Time: Call processing time is the period from receiving an emergency call to taking necessary action. From the citizen's perspective, it starts when they hear the call's ringing tone and involves locating the caller and understanding the incident for an appropriate response.
2. Mobilisation Time: Mobilization time refers to the period for an emergency responder to get ready and leave the base station. It starts with the dispatcher's notification and ends when the responder confirms departure. Delays in notifications should be taken into account.
3. Driving Time: Driving time is the period from the emergency responder leaving the base to reaching the incident site. It starts with their departure and ends upon arrival, influenced by factors like location (rural, semi-rural, urban), environmental conditions, and the type of vehicle used.
4. Arrival Time: The arrival of emergency responders marks the start of the intervention stage, where specific actions, such as providing medical aid, are executed.

4. A New Emergency Management Framework

An efficient Emergency Management Framework requires strategic decision-making to select various elements such as procedures, technologies, resource management, and training programs. These elements collaborate to support coordination and rapid response efforts during emergencies, serving as a structured approach to enhance capabilities. This research emphasizes the technological aspect, introducing a mobile application for prompt and accurate emergency reporting. This reflects the significance of digital tools in modern emergency management worldwide.

In the proposed framework, a mobile application serves as a centralized platform for efficient emergency management in the Kurdistan Region. Its core function is to collect, store, and dispatch incidents among relevant emergency response teams, aiming to improve emergency management, reduce response times, and enhance communications. Citizens report location-based emergency requests to a centralized call center, where trained dispatchers assess and dispatch the requests to the appropriate response teams. This streamlined process eliminates call processing time intervals, provides accurate location coordinates, and optimizes resource allocation, ultimately reducing response times and improving emergency response strategies. The app also accumulates data on emergency responses over time, enabling trend identification and continuous improvement. The figure () ebelow illustrates the process flow of the proposed framework.

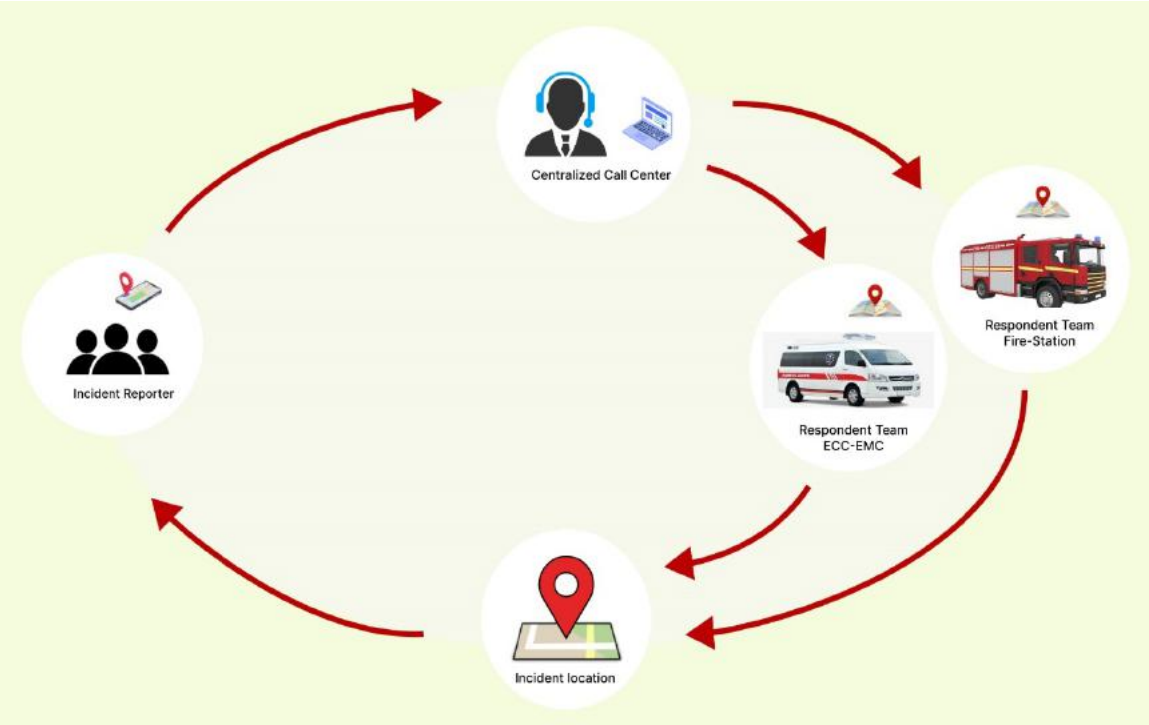

Figure 4 The process flow of the suggested system

The proposed Emergency Management system consists of interconnected elements designed for specific tasks utilized by emergency management agencies and one by citizens to report emergencies. Figure () provides an overview of these integrated elements in the back end of the application which operates as follows:. when an incident is reported, citizens' mobile applications send essential data, including location, and incident type, to the Centralized Call Center. This data is stored for future analysis, and dispatchers assess then dispatch cases to respondent teams. Continuous updates and notification exchanges ensure the stored data remains current.

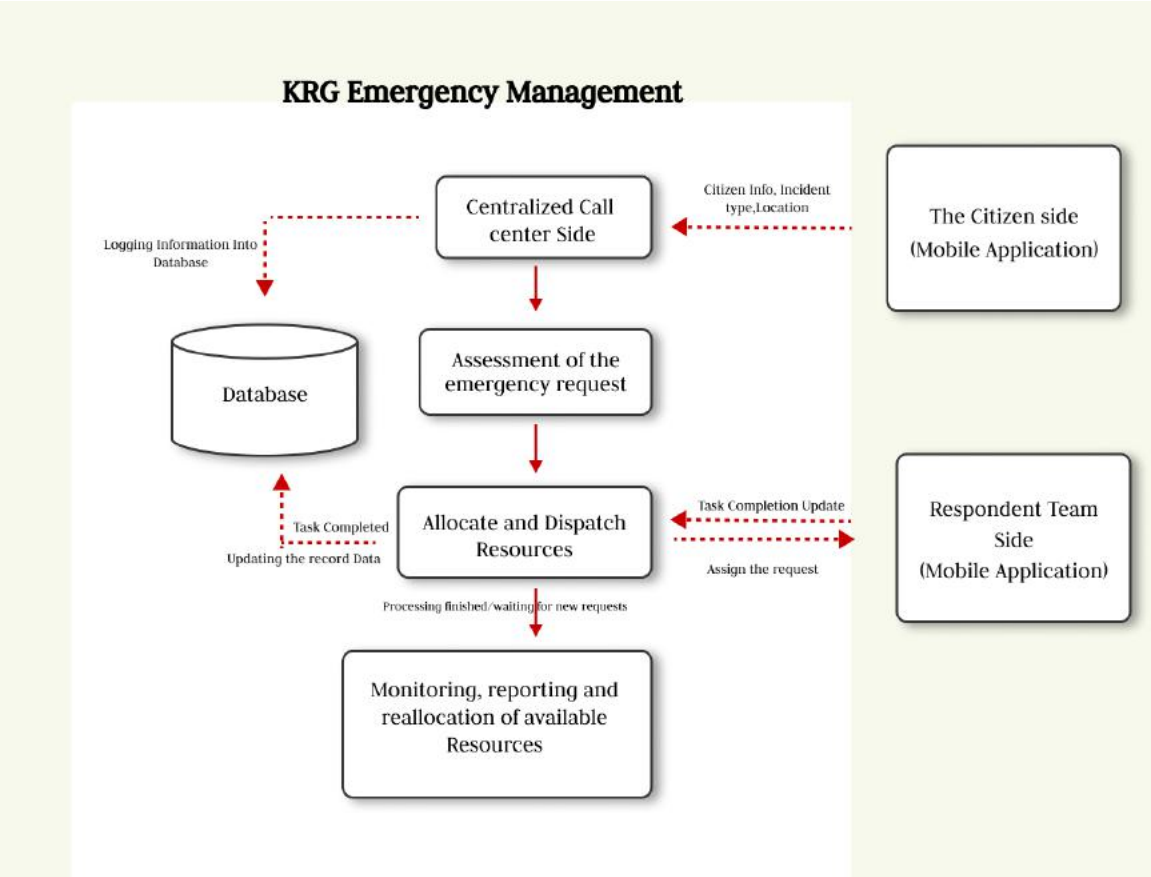

Figure 5 The suggested information system block diagram

4.1 Mobile application based system

The prototype of the mobile application that responds to citizens and emergency responders needs developed using Flutter Version 2.1 with Dart. The administrator web interface, accessible by the centralized call center, has a design concept composed of two components. Firstly, the User Interface designed with Hypertext Markup Language (HTML), Cascading Style Sheets (CSS), JavaScript, and Bootstrap. Secondly, the backend configuration implemented through the application of the Hypertext Preprocessor (PHP) programming language. The data originating from both the mobile application and the web interface stored in a MySQL database.

4.1.1 Emergency Submission Screen

The app's user interface prompts users to log in with their registered phone number and password or sign up as new users. In this prototype version, the administrator user manages the sign-up process. Users can quickly submit emergency requests through a simplified interface, requesting an ambulance or a firefighter. Additional details can be provided if needed. The submitted request is next forwarded to the Centralized Emergency Center for assessment and assignment to the appropriate response team. latitude and longitude coordinates transmitted with the emergency request enhances the accuracy of incident location identification, enabling emergency agencies to dispatch the nearest responders promptly hence reducing response times.

4.1.2 Centralized Call Center Screen

The Centralized Emergency Call Center is a web-based interface, accessible by dispatchers, in which facilitates the collection and management of incoming emergency requests. It provides crucial information such as the citizen's details, service type, and incident location coordinates. Dispatchers from the call center can visualize the incident location on a map and communicate with responders in real-time, ensuring seamless coordination. Emergency requests can be assigned to the appropriate response team based on the incident type and location, with options for ambulance drivers from ECC, EMC, or firefighters.

4.1.3 Respondent Team Screen

The Respondent team interface, accessible via the mobile application, provides responders with a comprehensive view of the assigned emergency requests. Upon logging in to the mobile app, responders can view assigned requests with relevant details such as the incident reporter's name, phone number, address, and geographic location of the incident. They can use the 'Get Directions' button to access the map, guiding them to the incident location efficiently. This minimizes delays and ensures a timely response. Once the emergency is addressed, responders can mark the task as completed, signaling their availability for the next assignment.

5. Simulations and Results

After completing the development of the mobile application, subjective testing sessions were

conducted to gather feedback from stakeholders in emergency agencies regarding its usability and impact on emergency management. Participants included dispatchers, drivers, and administrators from both agencies involved in emergency response operations. The Android Package (APK) of the application was provided to participants, who were guided on its usage. Administrators submitted emergency requests, dispatchers verified centralized emergency management functions, and drivers responded to emergency cases during the testing. Due to governmental constraints, challenges were faced in dispatching ambulances and firefighters to incident locations for real-time travel time comparison with Google Maps. However, the travel time for an emergency case was measured using a private car. A request was submitted through the mobile app at 02:30 PM, and despite Google Maps suggesting a 5-minute travel time, the simulated departure at 02:32 PM took 7 minutes to reach the incident location.

Table 3Table 3 A response time of the suggested procedure

App Request Submission	Departure from EMC	Arrival at the scene
02:30 PM	02:32 PM	02:39 PM

5.1 Comparison of Actual and Estimated Travel Time

During the analysis phase of the current emergency management system, several simulations were conducted to assess the driving time interval of response times. Insights gained from these simulations provided an evaluation of the effectiveness of the emergency response efforts within the current framework. Simulations were conducted for various scenarios, including emergency cases handled by ECC and EMC, as well as the Directorate of Civil Defense referred to as scenario A, B, C respectively. additionally, a simulation using the developed mobile application conducted referred to as Scenario D. Disparities between the actual travel time and Google Maps' suggested travel time were summarized in below Table.

Framework	Scenario	Estimated Time	Actual Time	Disparity	Percentage
Current Framework	Scenario A	10	18	8	44%
	Scenario B	6	15	9	60%
	Scenario C	3-6	4	0-1	25%
Proposed Framework	Scenario D	5	7	2	28%

The findings present the significant impact of modern technology on reducing response times in emergency management systems. Scenario D particularly highlights this, with only a 2-minute gap between actual and estimated arrival times. Conversely, Scenarios A and B demonstrate much larger disparities of 8 and 9 minutes respectively. In Scenario A, deviation from Google Maps' suggested route potentially extended response times, while in Scenario B, language barriers hindered precise incident location communication. Scenario C, however, achieved exceptional results with a maximum 1-minute difference, possibly due to the close proximity of the fire station to the incident site, despite not utilizing modern technology.

6. Conclusion

This thesis explores enhancing the emergency management system in the Kurdistan Region by analyzing its current state and identifying areas for improvement. Challenges identified include reliance on traditional paper-based methods, lack of advanced technology, and longer response times. We propose a technology-driven framework, including a mobile application, to improve efficiency and responsiveness. The prototype of the KRG Emergency Management app shows promise in reducing response times, as indicated by testing sessions. While the Directorate of Civil Defense supports the app, the Emergency Coordination Center expresses concerns about its

potential misuse and reliance on internet connectivity.

The research outlines potential avenues for refining the proposed emergency management framework. Addressing the app's reliance on internet connectivity is a key focus, with suggestions including collaboration with governmental bodies and internet providers for free internet access during emergencies. Incorporating Location-Based Services (LBS) features could enhance usability by enabling users to locate nearby medical services. Future directions also include gathering feedback from citizens to evaluate usability and implementing a secure user registration process to prevent misuse.

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