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Article

Design, development, and evaluation of a mobile application for safety engineers

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Abstract: Hazards are the primary cause of occupational accidents, as well as occupational safety and health issues. Therefore, identifying potential hazards is critical to reducing the consequences of accidents. Risk assessment is a widely employed hazard analysis method that mitigates and monitors potential hazards in our everyday lives and occupational environments. Risk assessment and hazard analysis are observing, collecting data, and generating a written report. During this process, safety engineers manually and periodically control, identify, and assess potential hazards and risks. Utilizing a mobile application as a tool might significantly decrease the time and paperwork involved in this process. This paper explains the sequential processes involved in developing a mobile application designed for hazard analysis for safety engineers. This study comprehensively discusses creating and integrating mobile application features for hazard analysis, adhering to the Unified Modeling Language (UML) approach. The mobile application was developed by implementing a 10-step approach. Safety engineers from the region were interviewed to extract the knowledge and opinions of experts regarding the application's effectiveness, requirements, and features. These interview results are used during the requirement gathering phase of the mobile application design and development. Data collection was facilitated by utilizing voice notes, photos, and videos, enabling users to engage in a more convenient alternative to manual note-taking with this mobile application. The mobile application will automatically generate a report once the safety engineer completes the risk assessment.

Keywords: safety engineering; occupational safety and health; mobile application; unified modeling language (UML); occupational safety and health policy; risk assessment; hazard analysis

1. Introduction

Most people use mobile devices and applications rather than desktop computers to accomplish simple tasks. Mobile applications are changing our daily activities and have become increasingly information-centric (Mushtaq and Wahid, 2024). Mobile application providers are developing business-oriented applications in response to the projected advancements in network connectivity, and the integration of the Internet of Things, Cloud Computing, and Artificial Intelligence technologies. The proliferation of application usage has led to a significant rise in smartphone addiction among individuals. Consequently, a recent Statista report shows that the combined number of available applications in the leading app stores, such as Google Play Store, Apple's App Store, and Amazon App Store, globally recognized as the major application marketplaces, has reached over 5.7 million (Ceci, 2023). In organizational safety management, exercising control over workplace hazards is imperative to mitigate risks.

Risk assessment involves identifying appropriate methods to manage and reduce occupational hazards effectively. Detecting potential hazards in the workplace is an essential step of the risk assessment process. Hazard detection systems are crucial in ensuring safety across various domains. Integrating artificial intelligence (AI) and machine learning (ML) technologies has significantly advanced these systems, enhancing their ability to detect and manage hazards efficiently. Zhao et al. (2020) demonstrated how YOLO (You Only Look Once) models could detect anomalies in industrial environments, leading to improved safety measures. Combining data from multiple sensors with AI enhances hazard detection. Zhang et al. (2019) explored sensor fusion techniques integrating cameras and Light Detection and Ranging, (LiDAR) for real-time obstacle detection, which is vital for autonomous vehicles. Natural Language Processing (NLP) is used to analyze textual data for hazard recognition. Liu et al. (2021) developed an NLP model for analyzing safety reports and identifying potential safety hazards, improving incident response strategies. Kumar et al. (2018) applied AI algorithms to predictive maintenance, reducing unplanned downtime and accidents in manufacturing.

Safety engineering methods, such as hazard analysis, are extensively employed to mitigate accidents or injuries and minimize instances of human error. Hazard analysis refers to the systematic examination of potential hazards that may arise inside a workplace and its surrounding environment, focusing on identifying and understanding their underlying causes. One of the critical components of risk assessment is hazard analysis. Integrating a mobile platform into hazard analysis can create a mobile application that can be a valuable tool for safety engineers when performing risk assessments. The development of the mobile application will facilitate the risk assessment process by making it easier to collect data and create instant reports, thus eliminating the need for paperwork. The features of mobile applications are determined by interviewing safety engineers and looking at the literature, and then implemented by applying user-centered design (Holeman and Kane, 2020; ISO 9241-210, 2010; Kucera, 2018; Workman et al., 2021). This paper proposes a hazard analysis framework for safety engineers by designing a mobile application using the Unified Modeling Language (UML) approach. In addition, the requirements gathering and usability testing results for the developed mobile application are presented. This framework can be applied to many different mobile application developments.

This paper is structured in the following manner: Section 2 provides an overview of the theoretical foundations and existing literature pertaining to hazard analysis, risk assessment, software engineering, mobile application development, and mobile applications in occupational safety and health areas. Section 3, the methodology, delineates the characteristics and integration of such structures within the mobile application, with a particular emphasis on the utilization of Unified Modeling Language. Section 4 provides an in-depth analysis of the requirements gathering process of the usability testing for the developed mobile application. In Section 5, this paper discusses the conclusions drawn from the research conducted, as well as outlines potential avenues for future work in this field.

2. Background

In the field of safety engineering, it is imperative to possess a comprehensive understanding of three fundamental concepts: harm, hazard, and risk. Harm can be delineated as the infliction of damage or injury resulting from the actions of an individual or the occurrence of an event. A hazard is a prospective origin of the detriment to an individual in a professional or personal capacity. Risk can be conceptualized as the union of the probability of an adverse event taking place and the magnitude of the resulting negative consequences. Hazard can be defined as a singular process or a set of processes. In the event that a process or condition occurs in an unchecked manner, it has the potential to result in unfavorable outcomes such as accidents, severe injuries, and property damage (Canadian Centre for Occupational Health and Safety, 2017).

2.1. Hazard analysis

Hazard analysis is a systematic procedure that involves the identification and assessment of potential hazards that may occur within a given work environment. This method includes documenting undesirable conditions and analyzing the various reasons that may give rise to these hazards. The hazard analysis entails the identification of prospective risks, and their prioritization based on two factors: the likelihood of accidents or injuries resulting from the hazards and the degree of accidents, injuries, or property damage caused by such hazards. Hazard analysis refers to the process of closely examining the details of analytical approaches using both inductive and deductive methodologies. Various tactics can be employed to investigate the causes of injuries and illnesses resulting from hazards. Various solutions have been devised and implemented on a global scale (Goetsch, 2015).

1) Failure Mode and Effects Analysis (FMEA) is a methodology widely used in several industries to identify and assess potential failure modes and their corresponding effects (Liu et al., 2013).
2) Hazard and Operability Review (HAZOP) is mostly utilized within the chemical industry.
3) Technique of Operations Review (TOR) is a methodological approach used to evaluate and analyze the operations of an organization.
4) Human Error Analysis (HEA).
5) Fault Tree Analysis (FTA) is a systematic and analytical method used to assess and analyze potential failures or faults in a system. It is a graphical representation that depicts the logical relationships between various events and conditions that could lead to the occurrence of a specific fault (Arslan et al., 2018).
6) Risk Analysis.
7) Risk Assessment. The comprehensive procedure of identifying hazards, doing risk analysis, and evaluating the associated risks is undertaken to analyze the potential risks that may occur from the identified hazards (Canadian Centre for Occupational Health and Safety, 2017).

Of the above methods, the last one is the most used approach (Hughes and Ferrett, 2015).

Risk assessment

The risk assessment process reveals the significant risks present in a workplace and identifies appropriate management measures that should be implemented. The primary aim of risk assessment is to ascertain the necessary actions an organization must take to adhere to pertinent health and safety laws. Consequently, this measure aids in reducing the incidence of occupational accidents and injuries. There exist two types of risk assessments, namely qualitative and quantitative. The initial component, the qualitative risk assessment, involves determining the amount of risk, which can be categorized as high, medium, or low. To mitigate the risks effectively, it is essential to implement the right corrective measures. Specifically, high-risk operations are recommended to undergo daily review, medium-risk activities are evaluated weekly, and low-risk activities are reviewed monthly. A quantitative risk assessment aims to provide numerical values to the amount of risk, which refers to the probability of an incident occurring and the resulting repercussions. A risk assessment matrix (RAM), is a technique for quantifying both the likelihood and the consequences of a risk (Baker, 2022). Some examples of the levels of likelihood include almost certain, likely, possible, unlikely, or rare. Consequences can include catastrophic, major, moderate, minor, or negligible. Activities considered both likely-almost certain and catastrophic would be regarded as extremely high risk, while activities that are both unlikely-rare and negligible would be regarded as low risk. A comprehensive analysis of multiple risk matrices is provided in extensive detail (Azadeh-Fard et al., 2015; Ristić, 2013).

Luko (2014) evaluated the reviews of standards and associated literature on risk assessment approaches. Risk assessment can be executed by employing a series of five sequential steps. The initial stage of the risk assessment involves providing a comprehensive description of the work at hand. Visual information such as videos or photographs are important as they visualize issues such as worker's postures. The second step in the risk assessment would be collecting technical information, including all the physical measurements needed, such as using a measuring tape for length, a scale for weight, etc. Any other related information that is required in the risk assessment tool will be collected at this stage. The third step in the risk assessment would be identifying the risk factors whilst using the appropriate risk assessment tool to fill in the relevant RAM with information. RAM could be completed with the visual information and technical data already gathered. An indication of the risk levels for each hazard would be present and reflect any dangerous issues. The fourth step in the risk assessment would be recognizing the improvements to be implemented. Appropriate measures should be applied to reduce or eliminate the risk of injury. These measures will be effective and practical to address the ergonomic risk factors. Additionally, it would be advantageous to maintain a documented duplicate of the safety manual, which encompasses the safety policy and arrangements. To ensure the production of a comprehensive report, it is vital to incorporate key elements such as identifying significant risks, assessing initial risk levels, determining necessary conclusions, delineating groups affected by the hazards, documentation of existing control measures, and evaluation of their effectiveness. Moreover, it is essential that the study's findings clearly outline any additional measures or protocols that need to be implemented, along with a specified timeline for their approval. The evaluation of the effectiveness of the improvements constitutes the fifth and ultimate stage of the risk assessment approach. Periodic reviews should be conducted to determine whether the recommended improvements have been implemented and if they effectively address the identified risk factors. This is particularly important in cases where major changes have occurred since the last assessment was conducted. For instance, the condition undergoes alterations due to implementing novel procedures or introducing new personnel, machinery, or risks. Additionally, novel legislation or updated data about the presence of hazardous compounds may exist. Furthermore, a risk assessment review can serve as a valid justification for an incident, accident, or a sequence of minor occurrences, commonly called post-accident risk assessment. The risk assessment tool has the potential to be utilized once more to compare the levels of risk associated with each criterion both before and after the implementation of the improvements (Health and Safety Authority, 2019).

2.2. Unified modeling language and mobile application development

UML is a widely used and continuously expanding modeling language within software engineering. Rumbaugh et al. (Rumbaugh et al., 2005) introduced UML as a collection of design representations that quickly established itself as the widely accepted standard language for software design. UML offers software engineers a range of essential skills including, many interrelated design views and semi-formal semantics expressed as a UML model. Additionally, UML expresses formal logical constraints on design elements. In addition to design, UML helps analyze software systems, ensuring that all aspects of the system are understood before development begins. Using UML diagrams, developers can identify potential issues, optimize system architecture, and ensure that requirements are met. This comprehensive analysis helps in creating efficient mobile applications that meet user expectations. Moreover, UML assists in bridging the communication gap between stakeholders, developers, and designers. It provides a clear and concise representation of the system's requirements, making it easier for all parties to understand and agree on the project's scope and objectives. This clarity is essential in mobile application development, where requirements are often complex. By using UML, teams can have a shared understanding of the system, reducing the risk of misunderstandings and ensuring that the final product aligns with the initial vision. Furthermore, UML's analytical capabilities allow continuous assessment and improvement throughout the development lifecycle. The requirements gathering phase identifies and documents stakeholders' needs and expectations. This phase involves interviews, surveys, and workshops to collect detailed information about what the system should achieve. This phase is crucial for creating accurate and comprehensive models from a UML perspective. In this phase, UML diagrams, like the Use Case and Class Diagram, capture functional requirements and outline the system's structure. Sequence Diagram also visualizes interactions between different system components. These diagrams help ensure that all requirements are clearly understood and communicated.

Dehlinger and Dixon (2011) described mobile application issues encompassing the design of a universal user interface, the facilitation of context-aware applications, and the delicate balance between agility and the specification of needs in the face of insecurity. Additionally, they highlighted the importance of enhancing user interface design, implementing preemptive reprocessing during the initial stages of mobile application development, and considering context awareness and sensitivity in identifying requirements to handle uncertainty effectively within existing mobile application development approaches. To foster greater interest in mobile applications by incorporating context awareness and design for self-adaptation, mobile application developers must embrace established methodologies for specifying requirements of self-adaptive systems, such as RELAX (Whittle et al., 2010). Incorporating the RELAX framework into mobile application software engineering enables developers to systematically consider how an application can adapt when faced with suboptimal environmental conditions or activities. Moreover, Whittle et al. (2010) introduced a "requirements" definition language known as RELAX. The RELAX framework's purpose is to tackle the challenge of uncertainty in identifying activities inside dynamically adaptive systems. Furthermore, the authors presented the formal semantics of RELAX using fuzzy logic, enabling a rigorous handling of requirements involving uncertain elements. Moreover, the authors elucidated the utilization of the RELAX framework in the context of smart home applications and analyzed many notable advantages associated with its implementation.

Vitello et al. (2015) presented a mobile application associated with a workflow-enabled context to perform imagining and data analysis on datasets of distributed computing infrastructures (DCI). The authors showed the usage of the large-scale, multi-dimensional DCI's datasets on workflow-driven applications, exploiting science gateway technologies. Explained features allow the researchers to share data examination responsibilities as workflows. Furthermore, the obtained results are shared in an obvious and user-friendly manner.

Mobile applications for occupational safety and health area

There are mobile applications for occupational safety and health areas to deliver help and guidance. Some of the top-rated safety-related mobile applications can be summarized as follows. The "Occupational Health and Safety" mobile application focuses on increasing awareness for workplace safety training. Another application named "The USW Chemical Safety" informs you how to avoid harmful exposure to toxic chemicals. Another popular mobile application called "Safety First" gives safety solutions to inquiries being asked. "Oil and Gas Safety Management" mobile application conducts oil and gas inspections by bringing crucial resources together, stores all collected data, and prepares reports. Another mobile application named "HSE Observation" allows users to report hazard issues by taking images and detailing the situation to the organization's safety management to take the necessary actions to prevent incidents or unsafe acts in the future. The "Safety JSA" mobile application helps to conduct workplace hazard analysis by incorporating occupational safety health principles into a task or job.

In addition to the aforementioned highly regarded applications, numerous research centers and scholars have conducted investigations into frameworks for the creation and evaluation of mobile applications intended for use in occupational safety and health domains (Flor-Unda et al., 2023; Hossain et al., 2023; Karlsen et al., 2022; Kasap et al., 2019). Some researchers are focused on the oil and gas field for occupational safety and health (Blauhut and Seip, 2018; Jiao et al., 2020; Rahim and Dom, 2023; Worthmann and Esterhuyse, 2022). Like the oil and gas field, many other areas have mobile application designs and developments, such as health, construction, and agriculture. In a study by Scott et al. (2015), researchers identified safety aspects and risks associated with evaluating mobile health applications. In another study, researchers have built a dependable quality evaluation method for testing, classifying, and evaluating mobile health applications (Stoyanov et al., 2015). Al-Shatti and Kasap (2017) developed a mobile application for type-1 diabetic kids. The study by Rodder et al. (2018) focused on integrating m-health into the current inter-professional nutrition curriculum by utilizing mobile applications for analyzing significant health issues and safety concerns. An extensive review and meta-analysis of mobile application acceptance for users in the health area are studied by Binyamin and Zafar (2023). Researchers presented a mobile application for monitoring contagious illness with the aim of helping the public and government know the zone's status among green, yellow, and red zones in various regions in Indonesia (Bas et al., 2024). The presented application was designed based on Web Application Programming Interface (API) data and configured on the Google Map API to determine the user's coordinates in a particular zone. The authors used the prototype method to help users understand the application. Moreover, the application supports crowd offense reporting, forum contact, and infection disease expert system features. For the construction sector, a safety inspection by developing a mobile computing framework for the construction industry is explained in detail by Zhang et al. (2017). A prototype development and usability test results of a mobile application to manage on-site information for the construction sector are given in the study of Nourbakhsh et al. (2012). Slips, trips, and falls (STF) are the reason for some of the most common occupational accidents in generally construction areas, and a mobile application for STF averting in construction sites is developed by assessing STF risk exposure (Hsiao, 2014). In another study by Harirchian and Lahmer (2019), hazards, natural disasters such as earthquakes, and safety assessment of buildings are proposed by using a mobile application. Another disaster risk reduction by using mobile apps is proposed by Paul et al. (2021). A study by Zubil and Zaki (2023) focused on household emergency preparedness and proposed a mobile application for this preparation. For instance, a scholarly work by Reyes et al. (2016) proposes the utilization of a mobile application as an assessment instrument within the agricultural health and safety sector. The article by Rodriguez et al. (2018) provides a comprehensive account of the development, deployment, and evaluation of a mobile learning platform that utilizes tablets to enhance safety awareness among dairy farm workers in the United States. Gumbi et al. (2023) conducted a systematic review to summarize the research that has been undertaken regarding digital agriculture ecosystems, including mobile applications.

3. Methodology

This section presents the features and design steps of the developed mobile application for safety engineers. Moreover, this study explores the potential of utilizing UML as an initial framework for integrating architectural modeling into a broader scope of industrial applications. UML suits the task because it provides a comprehensive, valuable, and adaptable collection of predefined constructs. Additionally, it possesses the potential for substantial tool support and is rooted in knowledge derived from widely accepted development methodologies. In a scientific context, UML use cases are employed to model user and system interactions. This provides a detailed and systematic approach to capturing functional requirements and ensuring that all user scenarios are considered. A deeper understanding of the relationship between UML models and an application's features allows developers to accurately map out how different components interact and function within the system. This insight ensures that the application's design aligns with its intended functionality, leading to more efficient development and a higher-quality end product. In the process of developing this mobile application, we implemented a 10-step approach that was derived from Rastogi (2017).

Step 1: Imagination of application of the proposed mobile device: To extract expertise, knowledge, and opinion about the requirements and features of the application, an opinion poll was performed among safety engineers in Kuwait, and the results of this poll will be given in the following section. The following three features were considered when developing the prototype. The first feature is that the application comprises various workplace hazards, such as electrical, noise, chemical, radiation, and pressure. A notable feature of our application is an emergency call button, which will be seamlessly connected to a dedicated safety engineer hotline, enabling prompt assistance in urgent situations. The third feature is the provision of a guideline for Personal Protective Equipment (PPE).

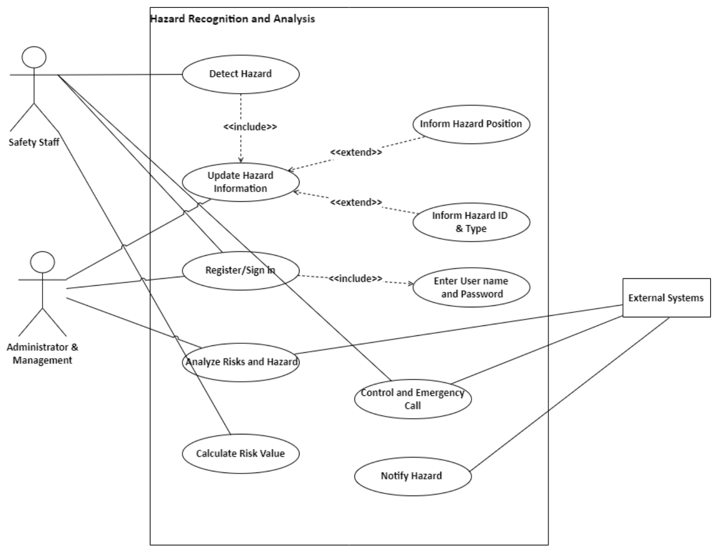


Figure 1. High-level modeling-UML use case diagram for the developed mobile application.

Step 2: Find out the application's target users, platforms, and digital devices: As mentioned before, the target users for the mobile application are safety engineers or safety staff. They can use mobile application devices such as iPhones, iPads, iPod touch, and iOS. **Figure 1** shows a high-level use case diagram in the application. UML use case diagrams show actors (safety staff, administrators and management, and external systems) and dependencies between use cases (such as detect hazard, update hazard information, registration/sign-in, risk analyze risks and hazard, risk value calculation, etc.). "External systems" send information to other external systems (e.g., traffic control systems and emergency response systems). UML use case diagrams are helpful in communication from phase-to-phase information technology project management.

Step 3: Design your application and create UML diagrams: The UML class diagram for the developed mobile application is given in **Figure 2**. In this diagram, key classes such as hazard, message, safety staff, environment, and report are identified to represent the system's components. All attributes and methods are identified and demonstrated in the UML diagram. These classes are connected through relationships like associations and data flow, illustrating how the components collaborate to perform hazard detection and alerting within the system. In **Figure 3**, the sequence diagram contains the participating actors (safety staff, users), design objects (external systems, application), and messages between them. UML sequence diagram shows message communications between objects in software. The sequence diagram validates the logic of the spatial database for hazard identification and information. **Figure 4** shows the UML activity diagram for the developed mobile application. This activity diagram details the workflow from start to finish and the many decision paths in the progression of events contained in the activity.

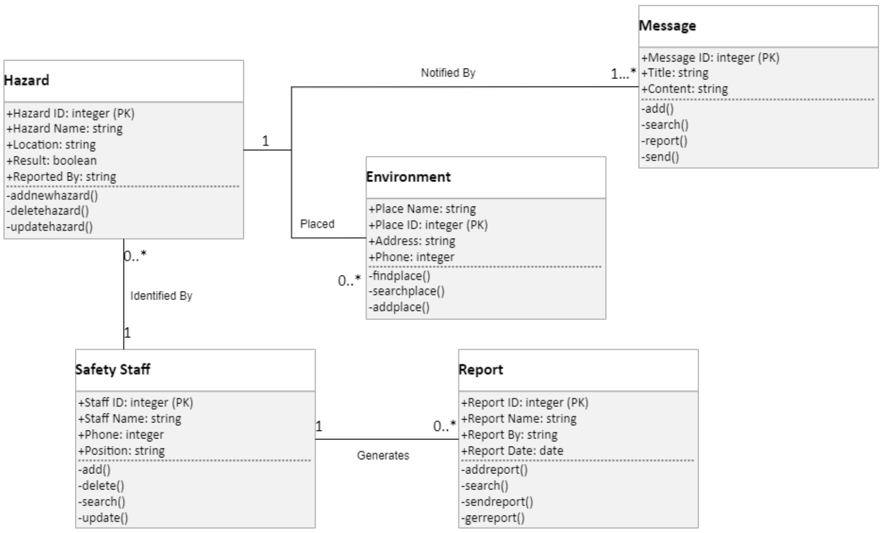


Figure 2. Object modeling-UML class diagram for the developed mobile application.

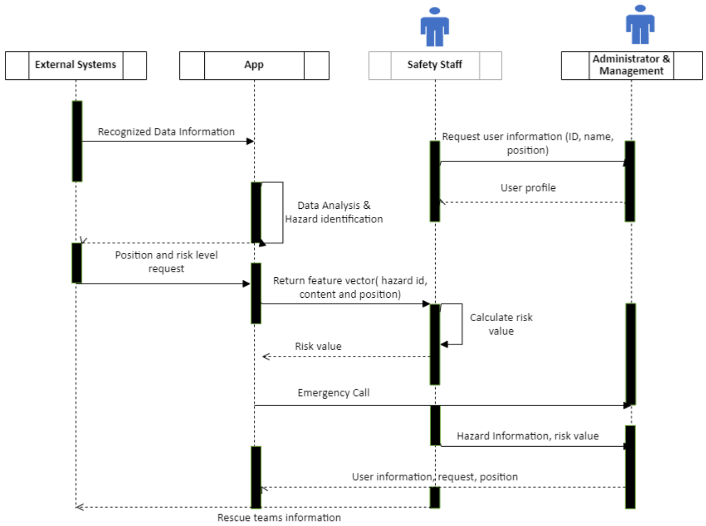


Figure 3. UML sequence diagram for the developed mobile application.

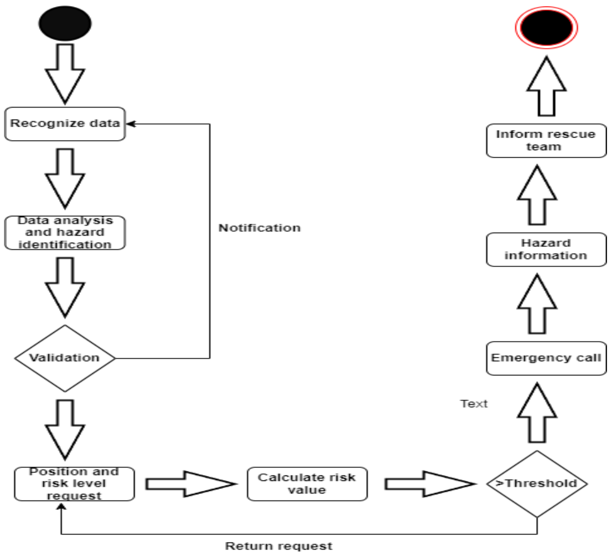


Figure 4. UML activity diagram for the developed mobile application.

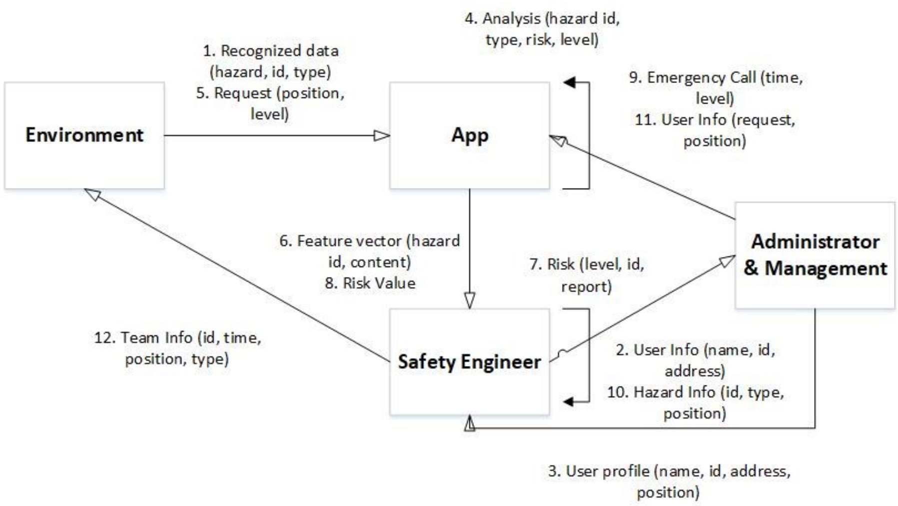


Figure 5. UML communication diagram for the developed mobile application.

Figure 5 is a communication diagram that shows the message order between objects in the sequence diagram. The safety engineer object calculates the risk and sends ID, level, and address information to the object users. The application object calculates the feature vector and risk value and sends it to the safety engineer. In this diagram, the reception's order differs from the order of sending a given set of messages.

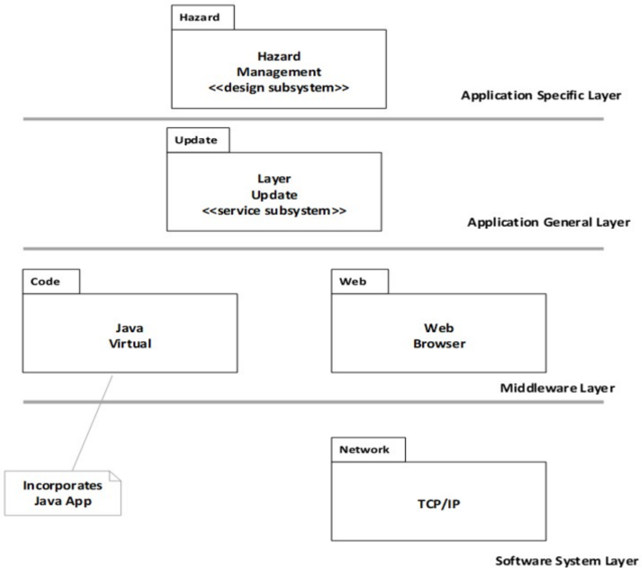


Figure 6. UML diagram showing subsystem packages in the developed mobile application, middleware and system software layers.

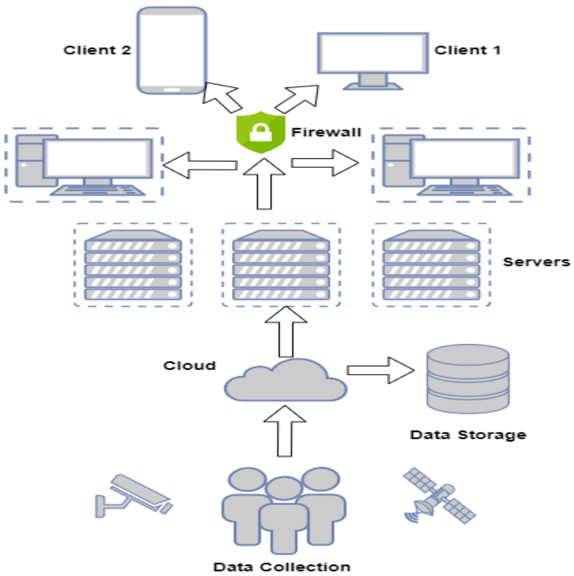
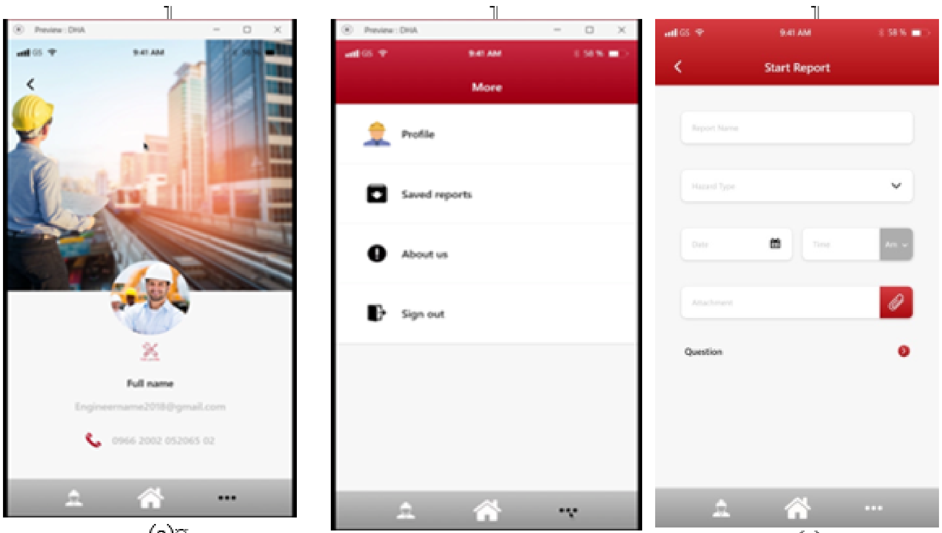


Figure 7. UML architecture (client-server configuration) diagram for the developed mobile application.

Step 4: Approach selection for mobile application development: Three distinct methodologies exist for the development of mobile applications: traditional, internet-based, and hybrid. The traditional method has been chosen for constructing this mobile application due to its ability to provide an optimal user experience. Furthermore, it has robust application visibility and exceptional performance (Klubnikin, 2017). The package diagram given in **Figure 6** identifies corresponding subsystems within the whole design pattern. The developed mobile application functionalities are based on middleware later, such as the database, software development, and graphical user interface (GUI). Web browsers are for uploading web information, and in the software system layer, Transmission Control Protocol/Internet Protocol (TCP/IP) is for internet communication. **Figure 7** shows the client-server configuration in the mobile application for hazard analysis. Both a wide-area and a local-area network are used in the development. This architecture allows managers to recognize, retrieve, and map hazard information. In this study, workstations, servers, databases, and networks are the system's main parts.

Step 5: Agile mobile application prototype development: After determining the mobile application's features and acquiring all necessary information and statistics, a prototype is constructed to manifest the design concepts into tangible form. This prototype serves as a rudimentary manifestation of the application's core functionalities, employing agile software design principles and prototyping techniques. Once the features of the mobile app have been identified and all the necessary information has been gathered, a prototype is constructed to implement the design ideas. This prototype encompasses the fundamental functionalities of the application, presented in two stages: sketches and a functional prototype. **Figure 8 a–c** illustrates prototype pages such as the user profile page, user profile, and start report pages.



(a) (b) (c)

Figure 8. Some sample pages of the prototype of mobile application for hazard analysis. **(a)** user profile page; **(b)** more on user profile page; **(c)** start report page.

Step 6: Integration of data collection and analytics tool: The mobile application for hazard analysis data collection and analytics tool is included to gather information and statistics of user behavior and then analyze user behavior. This will facilitate the advancement and adaptation of requirements for the mobile application. We used the Apple dashboard for risk data collection and analytics. It has very promising accuracy and high performance for iOS systems. In addition, it provides all types of information about the environment, such as the number of people, type of hazard, and frequency of visits.

Step 7: Identify beta-testers: As potential users from the region, safety engineers are chosen to enter data and test our prototype to test software, get their feedback, and integrate needed ones into the system. Note that this step is not the scope of this paper.

Step 8: Software closure-release/deploy the mobile application: The developed mobile application is available to download and use at application stores.

Step 9: Find out the metrics for mobile application hazard analysis inputs: This step will be considered later once enough data is obtained. At this point, the plan is to consider the following usability metrics along with what aspects of the mobile application are catching the attention of users and seeing the emergent conduct of the consumer base. Usability metrics measure users' effectiveness, efficiency, and satisfaction with this mobile application. For effectiveness, the focus will be on simplicity (ease of inputting the data, ease of using output, ease of installation, and ease of learning) and accuracy. For efficiency, the focus will be on features such as - support/help, input options, hazard types, report outputs, automatic updates, etc. For satisfaction, the focus will be on attractiveness through user interfaces. Several methods are used to measure mobile applications obtained from web analytics. The following input metrics should be considered: (1) The measurement of public sharing points to the aspects of the mobile application that catch users' attention. (2) Relationship between the demographics and user behavior or language. (3) Awareness of the contexts in which the mobile application is used by tracking location and time. (4) Capturing the emergent behavior of the user's base.

Step 10: Reengineering-upgrade your mobile application with improvements and new features: It is necessary to determine application performance and upgrade with developments and innovative features. Stakeholder involvement is crucial in software development, especially in understanding the application requirements, design phase, and system testing. Based on the stakeholder's suggestions, we can add some new features or improve the current ones. We measure software performance using the Apple Developer program cause of the iOS platform. Performance measurement is essential to determine missing parts or requirements from actual users.

After implementing the mobile application for hazard analysis, the following explanation will clearly explain its usage. First, a welcome page will appear once the user clicks on the mobile application. To secure from unauthorized access a login page will appear. After logging in, the safety engineer has to select the hazard category and a tool for data collection based on the need. For instance, if the workplace suffers from hazardous chemical particles that surpass the threshold limit, the user will select the hazard category for the risk assessment. After choosing the hazard category, this category suggests distinctive questions for distinctive hazards based on the usual occupational protection and health standards. Until now, no agency-related facts have been specified, but preferred questions for all classes have been provided. When a company, such as a customer company, is selected, unique questions for all categories based on the company's sector, including oil, chemical, service, industrial, etc., can be addressed. The mobile application will automatically generate a report once the safety engineer completes the risk assessment, as shown in **Table 1**. In addition, if any video, picture, or voice record is taken in the evaluation, these items will be attached and saved.

Table 1. Risk assessment at workplace environment template.

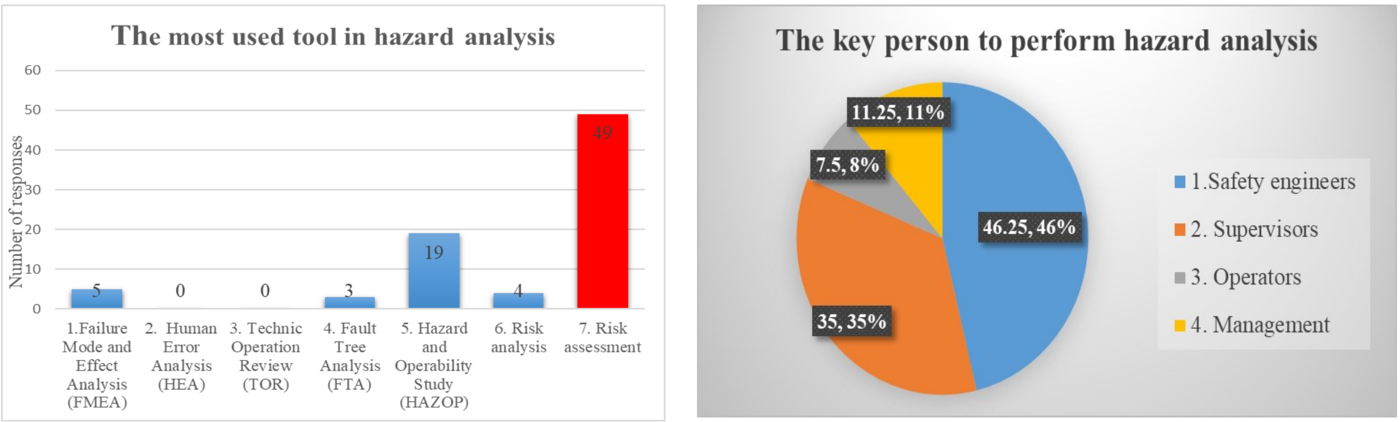
Person's first and last name: **Person's title:** **Date:**					
Action	**Possible Hazards**	**Risks at workplace**	**Calculate Risk Value (Priority)**	**Controls (Include Engineering, Administrative and PPE)**	**Are Controls in the Workplace? If not, how and when?**
• Find out all types of tasks done in the environment. • (Work breakdown structure. Some of the tasks might be broken down into small tasks to use in hazard and risk analysis.)	• Find out all recognized and possible hazards for each work breakdown structure tasks. • (Also, we should consider possible long-term health problems.)	• Find out all possible risks related to each hazard. • (Possible risks in workplace which affect anyone and company itself.)	• For each possible risk in your table assign label Low, Medium, or High. • We can use likelihood or severity if risk value is not clear. Likelihood (1 – 5) Severity (1 – 5) Risk Level (L × S) = Low, Medium High)	• Find out possible risks to eliminate in workplace. • When you find out reducible risks, it should be easily practicable. • Part of harm reduction is suitable provision of first aid. • Do suggested solutions and controls meet the legislative requirements? • If we compare our control mechanism, how is the success compared to best practices?	• Find out first high-risk hazards and deal with them. • Then decide who will take the action, and how long it will take to complete.

4. Results and discussion

To extract the knowledge and opinions of experts regarding the application's effectiveness, requirements, and features, a five-question opinion poll was created and performed among safety engineers in Kuwait. A total of 80 safety engineers responded. The poll results are analyzed and summarized below. Note that these results are used during the requirement gathering phase of the mobile application design and development.

First Question: What is the most used tool in hazard analysis? This question is asked to help us choose the hazard analysis technique for the developed mobile application. Participants were asked to select one of seven methods described in section 2.1. As shown in **Figure 9a**, the most commonly used procedure is risk assessment. The results show that 49 out of 80 participants agreed on it. Moreover, it shows the significance of using this method, as was pointed out before. The following most used hazard analysis method is HAZOP, where 19 out of 80 participants preferred it. Other preferred methods are FEMA, Risk analysis, and FTA.

Second Question: Who is the key person in performing hazard analysis at the work site? This question is asked to help us identify target users. As illustrated in **Figure 9b**, 46.25% of the participants responded that safety engineers, and 35.35% responded that supervisors are the key people to perform hazard analysis. This result extends the target users to safety engineers and supervisors. A few percent of participants said that operators and management people can also perform hazard analysis.

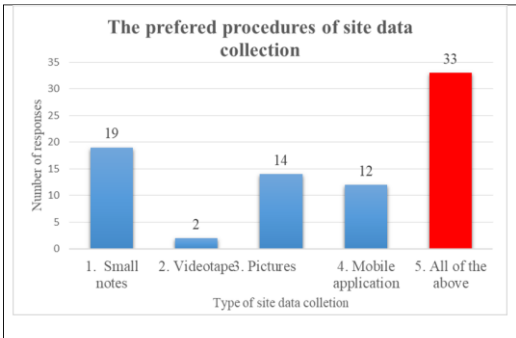


(a) **(b)**

Figure 9. (a) Results of the questions 1 of the opinion poll; **(b)** results of the questions 2 of the opinion poll.

Third Question: If a mobile application can take pictures and videos and transfer them into a ready template, would it reduce paperwork and save time in hazard analysis? This question was asked to help consider target users' opinions regarding the possible features we add to the mobile application. The results of this question are summarized as follows: 71% of the participants agreed on using the mobile application for hazard analysis, and 18% were neutral. The safety engineers needed a tool to reduce the paperwork and time necessary for hazard analysis. Around 10% of participants disagreed, and they stated that mobile phones are unsafe during work and should not be used.

Fourth Question: What do you prefer to use to collect data when performing hazard analysis on-site? This question helped us understand the preferred data collection method, so we added it as a feature to the mobile application we developed. As shown in **Figure 10a** "all of the options" was the most selected data collection procedure during hazard analysis. The small notes took second place. The remaining options, using pictures, mobile tools, and videotaping, are the less preferred options. Since most of the alternatives have been chosen, a feature for selecting a data collection tool has been added to increase the performance of the safety engineers for the mobile application we developed.



Mobile features	Tools	User-friendly	Hazard analysis techniques
Video recording	Checklist	Systematic and well guided	Risk assessment
Voice to text transformation	Observation sheet	Should not be complicated	Risk rate and probability
Photograph	Graphical illustration	Easily searchable	Near miss reporting
Notepad	HSE documents	Old document retrieval	FMEA

(a) **(b)**

Figure 10. (a) Results of the question 4 of the opinion poll; **(b)** Results of the question 5 of the opinion poll.

Fifth Question: What features do you expect to see in the mobile application for hazard analysis? The purpose of this open-ended question is to collect diverse opinions and views on what kind of features a mobile tool for hazard analysis should have based on the expertise and knowledge of safety engineers. The answers gathered are organized into four groups: mobile features, tools, user-friendliness, and hazard analysis techniques. **Figure 10b** recapitulates the results for each of the four groups.

After analyzing opinion poll results, one can conclude that some safety engineers agree with using mobile applications (a)during hazard analysis, and some do not. The poll results supported the proposed features of the mobile application for hazard analysis, such as a voice recorder, video, camera, and notes. Converting collected data to a complete report facilitated the users' support and approval of the mobile application. Alternatively, there were non-positive comments, such as mobile phones being distracting while performing duties.

5. Conclusion

This study presents a comprehensive architecture for a mobile application designed to assist safety engineers in conducting hazard analysis across various industrial settings. The mobile technology that has been suggested aims to reduce reliance on physical documents and streamline the process of reporting hazard analysis findings, hence optimizing time efficiency. The intended users of the proposed mobile application, which utilizes a risk assessment technique, are safety engineers and supervisors. The application must provide the required information through a series of responses. These responses provided by the user will undergo an automated process to generate a comprehensive risk assessment report based on the occupational health and safety policy of the organization/company. The data collection is facilitated through voice notes, photos, and videos, enabling users to engage in a more convenient alternative to manual note-taking. Manually recording information necessitates significant cognitive exertion and captures the attention of safety engineers. The hazard analysis requires a concentrated effort on observation, data collection, and report composition. The aforementioned vital actions are performed while safety engineers actively monitor potential threats. The mobile application that has been presented aims to streamline the job of safety engineers by efficiently converting their observations into reports in a timely and organized manner, thereby minimizing the time and paperwork involved in the process. The proposed mobile application significantly reduces information processing time while digitalizing information and intends to make workplace interventions during a hazard analysis of occupational safety and health. Reducing the process control time after hazard analysis will also positively affect occupational health and safety policy.

The existing body of research on the current topic enlightens the significance of hazard analysis for enhancing safety policies and protocols. However, to date, few to no mobile applications have employed UML to develop an efficient tool for safety engineers to improve the risk assessment process in a streamlined, timely, and organized manner. Integrating a mobile platform into hazard analysis can create a mobile application that can be a valuable tool for safety engineers when performing risk assessments. With this integration, more efficient time management can be achieved by adopting a systematic approach. The development of the mobile application, which is done in the current study, can facilitate the risk assessment process by making it easier to collect data and create instant reports, thus eliminating the need for paperwork. In the design phase, future researchers could explore innovative user interface (UI) and user experience (UX) strategies explicitly tailored for safety engineers, ensuring that the application is intuitive and enhances their workflow. This could include studying the impact of various design elements on usability and efficiency in high-stress environments. During the development phase, research could focus on integrating advanced technologies such as augmented reality (AR) (Abdeen et al., 2024) and machine learning (ML) to provide real-time hazard detection and risk assessment. This would involve evaluating the effectiveness of these technologies in improving safety outcomes and reducing incidents, which could be studied further in future studies.

Therefore, developing this mobile application to assist safety engineers in performing risk assessments is very important. The study derives its relative significance by creating an innovative UML-based approach for proposing a mobile application-based hazard analysis framework. Also, the study has broader implications for practitioners in the field as the framework applies to many different mobile application developments.

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