

Analyzing Non-Functional Requirements of Mobile Applications: Usability, Reliability, Performance, and Supportability

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Abstract

Most people use mobile apps every day for a variety of purposes, including reading the news, checking social media, and shopping. Thus, these mobile apps must be thoroughly tested so that we can trust them to behave as intended when used in the field. The purpose of this study is to collect and analyze non-functional requirements (NFRs) for mobile apps from four perspectives to determine the success and quality of the applications from the perspective of usability, reliability, performance, and supportability. By focusing on these aspects of application development, developers can create applications that are consumer-friendly, reliable, fast, and easy to maintain, thus increasing user satisfaction and ensuring the long-term success of their products. According to the results of this study, of the 27 mobile applications that had been collected from the literature, 16 were able to meet the usability NFR, seven were able to meet the reliability NFR, 14 covered the performance NFR, and three were able to meet the supportability NFR. At the same time, three were unable to meet any NFRs. The results of the study showed that mobile application developers focused more on usability and performance than reliability and supportability. In contrast, reliability and supportability were used by a smaller percentage of developers in their development process.

Keywords

Mobile Apps, Non-Functional Requirements (NFRs), Usability, Reliability, Performance, Supportability, Literature Review Method

1. Introduction

Apps are software applications specifically designed for use on small, wireless computing devices, such as smartphones and tablets, and are not meant to be used on large, stationary computers such as desktops and laptops [1]. A mobile application (mobile Apps) can be categorized by whether it is web-based or native, depending on whether it is explicitly designed for a given platform or created from the ground up for that platform. Another type of app is a hybrid app, which is a combination of native and web apps [1]. It is critical to understand that functional and non-functional requirements (NFRs) play a crucial role in ensuring the product meets business requirements, such as speed, compatibility, localization, and capacity. According to [2], the mobile application lifecycle consists of four phases as shown in **Figure 1**. Each phase has several requirements, such as functional and non-functional requirements. Non-functional requirements (NFRs) play a crucial role in ensuring the success and satisfaction of mobile applications. These requirements go beyond the functionality of the app and focus on aspects such as usability, reliability, performance, and supportability. Understanding the consequences of analyzing functional and NFRs of mobile apps is essential for developers, designers, and stakeholders involved in mobile application development.

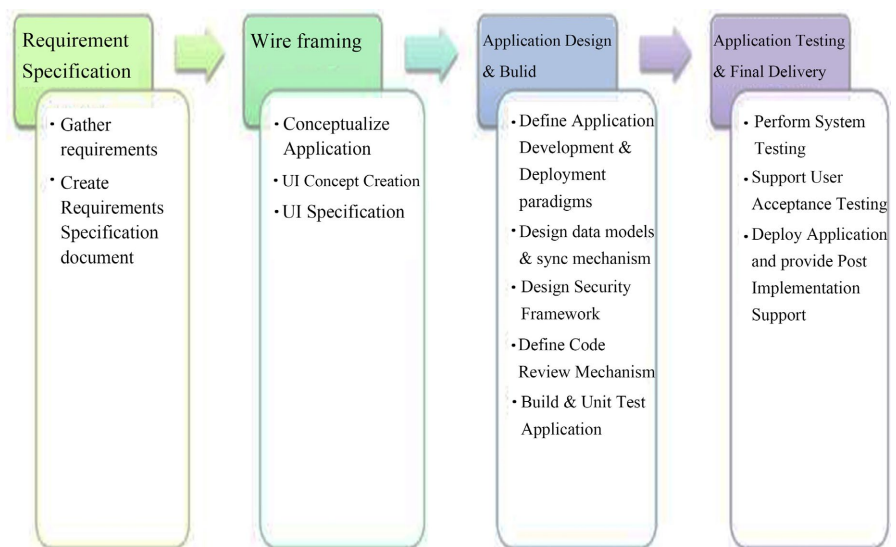


Figure 1. Mobile application lifecycle [2].

Hence, the purpose of this study is to analyse the four common NFRs of mobile Apps, which are usability, performance, reliability, and supportability, and to examine them in depth. The literature review method is used in this study. Thus, 27 mobile apps were collected and analysed based on the four NFRs of usability, performance, reliability, and supportability. Consequently, the authors found that 16 of the apps could meet the usability NFR, seven were able to meet the reliability NFR, fourteen covered the performance NFR, and three were able to meet the supportability NFR. At the same time, three were unable to meet any of the NFRs.

According to the study results, mobile application developers place a greater emphasis on usability and performance than reliability and supportability in the development process. In contrast, a smaller percentage of developers prioritize reliability and supportability in their development process. The definitions of usability, performance, reliability, and supportability are as follows:

1) Usability: This refers to how easily and intuitively users can interact with the mobile application. It encompasses aspects such as ease of learning, efficiency of use, memorability, error prevention, and user satisfaction. A highly usable app is easy to navigate, understand, and use for its intended purpose.

2) Performance: This relates to the responsiveness, speed, and efficiency of the mobile application. It includes factors like loading times, processing speed, resource consumption (battery, memory), and the ability to handle a high volume of users or data without degradation in service.

3) Reliability: This concerns the ability of the mobile application to perform its intended functions consistently without failure. It involves aspects like stability, accuracy, fault tolerance, recoverability, and the ability to maintain performance under various conditions.

4) Supportability: This refers to how easily the mobile application can be maintained, updated, and adapted to changing requirements or technologies. It encompasses factors like maintainability, testability, scalability, portability, and the availability of documentation and support resources

This article is structured as follows: the related works are discussed in Section I, and the methodology is presented in Section III. The results and discussion are displayed in Section VI, whereas the conclusion and future work are discussed in Section V.

2. Related Work

In the literature, there have been several models of mobile apps proposed for various purposes. The authors in [3] studied the usability of mobile applications within virtual environments based on several criteria, including the amount of time it took to complete the tasks, the number of errors the users made as well as the effectiveness and efficiency of their task completion. The authors in [4] conducted an empirical study, using a set of measures to assess the usability of mobile applications that are run on different mobile operating systems. A previous study, conducted by [5], aimed to determine the most essential characteristics that define mobile applications, to facilitate the delivery of practical, outstanding, and user-friendly mobile apps that meet the needs of users. According to [6], a systematic literature review was conducted to identify and collect the required evidence regarding the automated testing of mobile applications. Measuring the usability of a computer program requires considering three factors, namely effectiveness, efficiency, and satisfaction. The researchers at [7] designed a new usability model, namely, placing people at the centre of the mobile application development process. Additionally, they reviewed specific mobile applications to particular fields of study as well. Several

mobile applications have been developed by the authors, including those that can be used to monitor the symptoms of heart failure [8], cardiology [9], and diabetes [10], among others, according to a study carried out by [9], seven different strategies can be used when estimating and selecting applications related to health.

Furthermore, mobile applications are employed in the education sector, especially for the purpose of teaching/learning language [11] [12], m-learning [13] [14]. There are also smartphone applications that are used by undergraduate students [15]. Some applications exist for supporting the children suffering from autism spectrum disorders in a way to improve their capacities for understanding, interacting, and communicating with others with the use of the Arabic language [16].

Some other researchers have examined the role mobile applications in tourism [17] [18] and spiritual/religious services [19] [20]. Nevertheless, the literature lacks the review of mobile applications in terms of their use in process related to pilgrimage. Furthermore, several scholars have designed different mobile applications applicable to various Hajj and Umrah services. Several master's dissertations have been carried out on creating mobile applications that can guide Malaysian pilgrims [21]-[25]. In a masters' thesis, [26] proposed augmented reality aiming to guide pilgrims. In the studies of [26] [27], some mobile applications were designed, helping pilgrims to read Hajj and Umrah prayers and translating them into the pilgrims' native language. A new framework was suggested by [28], which serves as a crowd-sourcing platform defining the pilgrims' needs. It employs mobile sensory data and, this way, defines the users' contexts. The framework was employed for the development of a mobile application that could be used in numerous spatio-temporal services. In addition, [29] designed a mobile application serving as a dictionary for pilgrims who speak the Malay language. It has the capacity for translating three languages, *i.e.*, Malay, Arabic, and English, to each other. The authors [30] suggested the utilization of a mobile phone for tracking purposes. This strategy could aid the guides (Mutawwif) of pilgrimage groups in recognizing their movements and determining their locations. A dynamic signage system was designed by [31], which can be used as a mobile application that informs pilgrims regarding the crowd status around the Holy Ka'bah. Pilgrims can use this application to automatically count the number of Tawaf rounds performed. Another mobile application was designed by [32], which is capable of guiding pilgrims when doing Umrah. It can also serve as Tawaf counter and location tracker. The authors in [33] introduced a service for identifying exact location in Hajj. It was able to gather information about the pilgrims' locations to be used in identifying and tracking them. In another research, [34] offered a mobile translation application for the facilitation of communication among pilgrims. The advantage of this application is that it is accessible in numerous languages and uses technologies that recognize both text and voice to help pilgrims to correctly translate the target words. The "Al-Hajj" is a mobile application introduced by [35], helping pilgrims understand Hajj-related deeds. It can exhibit four interactive features, *i.e.*, map, checklist, motivational messages, and contact list. The authors [36] investigated how smartphone apps could be utilized to conduct surveys. They

concentrated upon the collection of relevant data and information during mass gatherings. This can significantly enhance public health through the reinforcement of the knowledge associated with disease prevention. An analytical research was carried out by [37] into the mobile applications related to the Hajj practices, which are offered on Google Play. The applications identified in this regard were analysed with considering the following criteria: supported languages, offered services, installation rates, and repetition of the services and names of the applications. The authors [38] developed an integrated classified model that illustrates mobile app usability from the high-ranking stage of “usability standards” to the middle level of “usability elements” to the comprehensive level of “usability elements” to evaluate the usability of present mobile apps from diverse classifications. [39] investigated the quality aspects that inspire students and lecturers’ usage of the Elearning. ZUJ mobile application at the Al-Zaytoonah University of Jordan. Additionally, the research revealed how well the quality aspects fit the desires of students and lecturers who applied the application during the academic year 2020 - 2021. The authors in [40] applied the fuzzy TOPSIS method to choose high-value and user skills of mobile education products for mathematics. They recognized the issues that are damaging the use of mobile mathematics education applications and proposed solutions to deal with such issues. The authors in [41] investigated how gamification may encourage user action and encouraging marketing results. They supplied several abstract and functional effects that can assist designers create more efficient gamified mobile apps. The authors in [42] identified stakeholder opinions on essential conditions for introducing mobile health schemes and appropriate consequences regarding reasonable and cost usefulness of effective mobile health schemes. The authors in [43] proposed and evaluated a novel hybrid model to examine the behavioural aims of young customers to utilize mobile apps. The authors in [44] introduced an emergency model of operating factors of consumer appointment in the context of selling mobile apps. The proposed model improved the existing literature of consumer commitment management that has been getting power lately within the field of online benefit study. The researchers in [45] introduced usability research that seeks to create a consistent, flexible, complete scale for categorization and measuring the features of health products.

On the other hand, several studies have discussed cybercrime, which may affect the privacy and security of the data in the mobile apps and their database [46]-[67].

Existing literature features a wide range of mobile apps for purposes like healthcare, education, tourism, and religious services. Research has examined usability models, automated testing methods, and domain-specific frameworks such as language learning and Hajj pilgrimage. However, there is a notable gap in the comprehensive review of these applications’ non-functional requirements (NFRs), especially regarding usability, reliability, performance, and supportability, along with some analysis of the related studies’ work. This paper addresses this gap by analyzing the NFRs across various mobile applications and industries. By empha-

sizing these critical quality attributes, the study aims to provide valuable insights for developers, designers, and stakeholders, fostering the development of more robust, user-friendly, and maintainable applications.

3. Methodology

To accomplish this objective, this study uses the literature review method [68] to go through all the different resources and collect and discover the mobile apps. In order to gather mobile app articles from different resources, five search engines have been identified in order to gather the articles. There are three keywords used in this study: “Mobile Apps”, “Mobile Applications” and “non-functional requirements”. The searching period identified from 2015 - 2024. Also, the inclusion and exclusion criteria are identified and listed as shown in **Table 1**. Then, based on the identified search rules, the data was gathered from the common search engines via the identified search engines. Based on the results of the search engines, there were 2091 articles found. Based on the criteria listed in **Table 1**, the 2091 articles gathered are filtered based on the inclusion and exclusion criteria, and then 27 articles for this study have been selected based on those criteria as shown in **Table 2**. **Figure 2** displays the methodology used.

Table 1. Summary of gathering data from common search engines.

Search Engine	Keywords	Total articles	Inclusion criteria	Exclusion criteria
IEEE Xplore	“Mobile Apps”, “Mobile Applications” and “non-functional requirements”.	250	Including only articles related to mobile apps and NFRs.	We excluded only articles that didn’t have anything to do with mobile apps and NFRs.
Scopus		390		
Web of Science		150		
Springer		301		
Google Scholar		1000		

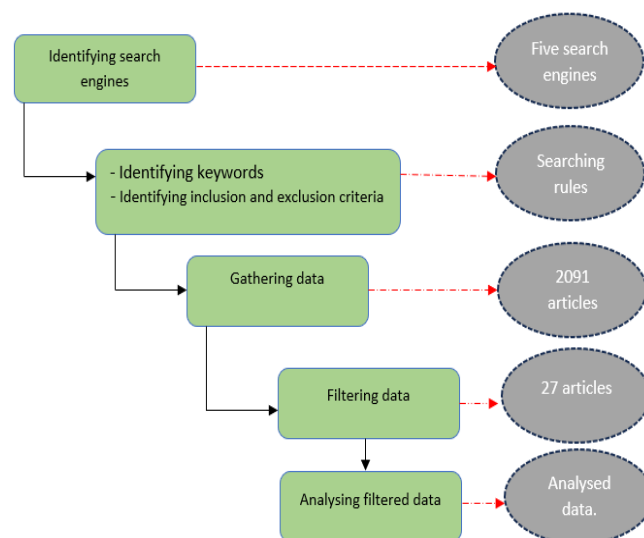


Figure 2. Adapted methodology.

Table 2. Selected mobile apps.

ID	Year	Ref	Non-functional Requirements			
			Usability	Reliability	Performance	Supportability
1	2007	[11]	☒	☑	☑	☒
2	2009	[19]	☑	☑	☑	☑
3	2009	[20]	☑	☑	☑	☑
4	2011	[10]	☑	☑	☑	☒
5	2011	[22]	☑	☑	☑	☑
6	2011	[24]	☑	☑	☑	☒
7	2011	[31]	☑	☒	☑	☒
8	2012	[27]	☑	☒	☑	☒
9	2012	[28]	☑	☒	☒	☒
10	2012	[29]	☑	☒	☒	☒
11	2013	[5]	☑	☒	☒	☒
12	2013	[25]	☑	☒	☒	☒
13	2013	[30]	☒	☒	☒	☒
14	2014	[17]	☒	☒	☑	☒
15	2015	[4]	☑	☒	☒	☒
16	2015	[14]	☑	☒	☑	☒
17	2015	[21]	☒	☒	☑	☒
18	2016	[2]	☑	☒	☒	☒
19	2016	[6]	☒	☒	☒	☒
20	2016	[8]	☒	☒	☒	☒
21	2016	[18]	☒	☒	☑	☒
22	2016	[32]	☒	☑	☒	☒
23	2016	[33]	☒	☑	☒	☒
24	2016	[34]	☒	☒	☑	☒
25	2017	[9]	☒	☒	☑	☒
26	2017	[44]	☑	☒	☒	☒
27	2018	[35]	☑	☒	☒	☒

Based on the mobile apps collected from the literature review, we obtained 16 out of 27 mobile apps that covered the usability NFR, 7 out of 27 mobile apps that covered the reliability NFR, 14 out of 27 apps that covered performance NFRs, and finally three out of 27 apps that covered supportability NFRs, whereas three out of 27 mobile apps no covering any NFRs. According to this analysis, most of the mobile Apps developers focused on the usability, and performance NFRs, while the reliability and supportability NFRs were the less used by the mobile Apps developers in their development process. **Figure 3** displays the usage of NFRs

among mobile Apps developers.

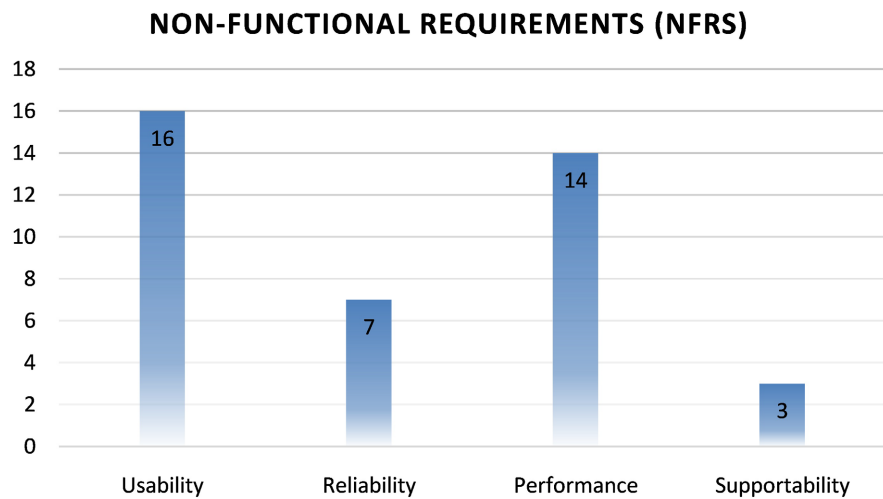


Figure 3. NFRs among mobile Apps developers.

According to this analysis, most of the mobile Apps developers focused on the usability, performance, and reliability NFRs, while the supportability NFR were the less used by the mobile Apps developers in their development process. The usability NFR refers to how easy and intuitive a mobile App is to use. Developers prioritize this NFR to ensure that users can easily navigate through the mobile app, find the information they need, and complete the desired tasks. By focusing on usability, developers aim to create a seamless and enjoyable user experience. Performance is another critical NFR that mobile developers consider. They ensure that a mobile apps responds quickly, loads data efficiently, and runs smoothly on different devices and network conditions. By optimizing the app's performance, developers aim to maintain a smooth and responsive user experience, regardless of external factors. Reliability is another crucial NFR that mobile developers prioritize. They ensure that a mobile apps consistently delivers the expected results and does not experience crashes or errors. By thoroughly testing the app and implementing robust error handling mechanisms, developers aim to maintain a high level of reliability, ensuring users trust the App and rely on it for their daily tasks. In contrast, supportability was found to be the less used NFR in the mobile apps development process. Supportability refers to how easily a mobile apps can be maintained, updated, and integrated with other systems. While developers understand the importance of supportability, they may focus more on the immediate needs of a mobile app's functionality rather than long-term maintenance.

Thus, most of the mobile apps developers emphasized usability, performance, and reliability as key NFRs during development. While supportability was considered important, it was generally less prioritized compared to the NFRs, likely due to its focus on long-term maintenance and integration.

In contrast, the 27 mobile apps that were included in the survey covered a variety of industries. There were some of these models that dealt with the health sec-

tor, some that dealt with the education sector, and so on. **Table 3** displays the outcome, methodology and variety of industries which covered by the 27 mobile apps. Furthermore, each mobile apps of the 27 has advantages and disadvantages as shown in **Table 4**.

Table 3. Existing mobile apps from the outcome, applied method, and focused perspectives.

Ref	Outcome	Applied Method	Focused
[11]	Integrated framework that combines the concepts from e-learning and mobile connectivity into application environments for mobile learning.	E-learning methods	Education sector
[19]	An application of mobile Hajj guide for Malaysian pilgrims	Spiral development method	Malaysian pilgrims
[20]	Mobile Application that can be interacting with customers by using wireless application protocol technology	Waterfall Methodology	Malaysian pilgrims
[10]	Mobile application for the language learning	Design Science approach (qualitative approach)	Technology-Centred Concepts
[22]	Mobile Application for Hajj and Umrah	Waterfall Methodology	Malaysian pilgrims
[24]	Proposed mobile pilgrim assistant prototype	Design science research	Religious section
[31]	Developed a system for pilgrim tracking and identification during Hajj in the Holy area using a mobile phone	Design science research	Religious section
[27]	Proposed dictionary targeted pilgrims to assist them to understand more about the principles of pilgrimage	Generic waterfall methodology	Religious section
[28]	Developed pilgrims tracking application	Design science approach	Religious section
[29]	Mobile Application Approach	User-centred design approach	Religious section
[5]	Designed a novel usability model, namely	Literature review and DSR	Technology-Centred Concepts
[25]	Proposed A mobile Dua and Zikr Application	Prototyping Approach	Religious section
[30]	M-Umrah application	Internet and smart phone technologies	Religious section
[17]	Methodological framework	a systematic study	Religious sector
[4]	Automated testing of mobile applications	systematic mapping and systematic literature review	Automation mobile apps
[14]	Application for Autism spectrum disorder for the children	systematic literature review	Autism for Children
[21]	Proposed Mobile Augmented Reality application	Qualitative method	Religious sector
[2]	Empirical framework	Qualitative method	Usability
[6]	Evaluation Framework	Systematic method	Health sector
[8]	Diabetes applications	A systematic and exhaustive critical review	Health sector

Continued

[18]	Mobile spiritual applications	Qualitative study	Religious and Spiritual Sector
[32]	A mobile translation application for Hajj	Prototyping Approach	Religious Sector
[33]	“Al-Hajj” mobile application	Prototyping	Religious Sector
[34]	Mobile application to prevent disease	Surveys	Healthcare sector
[9]	Mobile applications for education	Checklists, methodological frameworks, and Second Language Acquisition (SLA)	Education sector

Table 4. Advantages and disadvantages of mobile apps.

Ref	Advantages	Disadvantages
[11]	Provided a better understanding on the role of mobile technology in higher education	Due to the little sample size and restricted functionality of proposed application, this study cannot generalize the findings for all m-learning systems environments
[19]	Provide a flexibility and easy way to the Malaysian pilgrims to access anytime for their Hajj enquires.	Inability to provide time for pilgrims to do online search, and inability to provide pilgrims with the enquiry services in case of any question, and not being uploaded on the internet.
[20]	Provide a flexibility for Malaysian pilgrims to find information about hotels, streets, and restaurants during Hajj	Used only for the Malaysian pilgrims.
[10]	Illustrated the state of language learning applications, the devices they can be applied to, and how they are developed.	It's restricted for education sector only.
[22]	Assist pilgrims read Hajj and Umrah prayers and understand their meanings by translating them into the language of the pilgrims	Used only for the Malaysian pilgrims, where
[24]	It has provided high-quality services to pilgrims to ensure their safety during Hajj by avoiding problems. Makkah must catch up with technological city development due to its special status and the annual crowding and congestion in the city.	It lacks generalization. It focused only on the Arabic language
[31]	It was able to gather information about the pilgrims' locations to be used in identifying and tracking them	The tracking signal may get missing or damaged inside the big constructions
[27]	This study tried to introduce simple solution that might be used to minimize pilgrims' need to somebody else to help them.	It prepared only for Malay language
[28]	The system is more flexible since the system caters to a wide range of age groups, including children, youth, and the elderly. There are still some constraints on the system, however.	There is a possibility that the tracking signal could get lost or weakened within the building

Continued

[29]	<p>Informs pilgrims regarding the crowd status around the Holy Ka'bah. Pilgrims can use this application to automatically count the number of Tawaf rounds performed.</p>	<p>Losing track of the rounds' during Tawaf</p>
[5]	<p>The people who play an important role in the development of mobile applications</p>	<p>There is a need for further research into the usability of the proposed model</p>
[25]	<p>Allow pilgrims read Hajj and Umrah prayers and understand their meanings by translating them into the language of the pilgrims</p>	<p>The application proposed as guidance, however, it lacks generalisation.</p>
[30]	<p>It is permissible for pilgrims to perform Umrah. In addition to serving as a Tawaf counter and a location tracker, it can also be used for other purposes. Additionally, we are educating and training Hajj pilgrims and Umrah pilgrims who are performing Umrah as part of their pilgrimage of worship. Providing a complete guideline and procedure to help individuals perform Hajj and Umrah according to Sunni principles to achieve Umrah mabrur when they perform Hajj or Umrah.</p>	<p>This application is limited for the Malaysian hajj and umrah pilgrims.</p>
[17]	<p>Several different types of religious apps are available within the iTunes app store, each one with a different design function related to its primary purpose. In this study, a systematic study of all the religious apps available on the iTunes store is used to provide a nuanced classification of those currently available.</p>	<p>Focused on religious apps</p>
[4]	<p>In order to automate the app testing process, there are two major challenges, the first is developing an appropriate set of test cases and the second is selecting appropriate testing devices.</p>	<p>Only test automation is the focus of the study. A further limitation of their study is that no clear inclusion/exclusion criteria were included, resulting in biased selections.</p>
[14]	<p>It was the purpose of this presentation to present a usability evaluation of Arabic applications intended for children with autism spectrum disorders (ages 3-12), teachers, parents, and peers who do not have autism spectrum disorders.</p>	<p>The application supports only Arabic and emphasizes verbal communication in local dialects</p>
[21]	<p>Providing direction to lost pilgrims and assisting the Hajj authorities (staff and operators) with pilgrim movement between the ritual places. Additionally, it would alert the group guide to lost pilgrims and send them their location information.</p>	<p>Focused on Hajj sector only</p>
[2]	<p>Conduct a usability test on Android, iOS, and Symbian mobile applications.</p>	<p>The company is only focused on three operating systems (Android, iOS, and Symbian) now</p>

Continued

[6]	It is important to apply a rigorous methodological approach to the evaluation of apps and to use the MARS rating scale for evaluating apps.	Focused on evaluation mobi8loe Apps
[8]	There are very few diabetes apps available for the Arabic speaking population, which was successfully revealed by this study.	Our investigation focused only on Android and iOS operating systems; Microsoft and Blackberry were not studied due to limited adoption and usage in the MENA region. Due to their functions and high probability of adoption, diabetic apps that focused on diabetes and were in the Arabic language were the only ones studied.
[18]	Aid adults in reading and understanding Quran forms.	This study has no reviewed mobile applications for pilgrimage.
[32]	Communicate easily between pilgrims who speak different languages. Utilizing text and voice recognition technology, this application allows for the translation of the target words in a variety of languages	It's specific for religious sector.
[33]	Allow pilgrims to understand Hajj-related activities.	It's specific for religious sector.
[34]	Gathering relevant data and information during mass gatherings, which reinforce knowledge associated with disease prevention and contribute to improving public health.	It's centred on the public health sector
[9]	Insisting that all factors should be considered when evaluating an app could be misleading since apps are designed to serve different purposes for different learners.	Lack of comprehensive techniques which help in learning

4. Discussion and Analysis

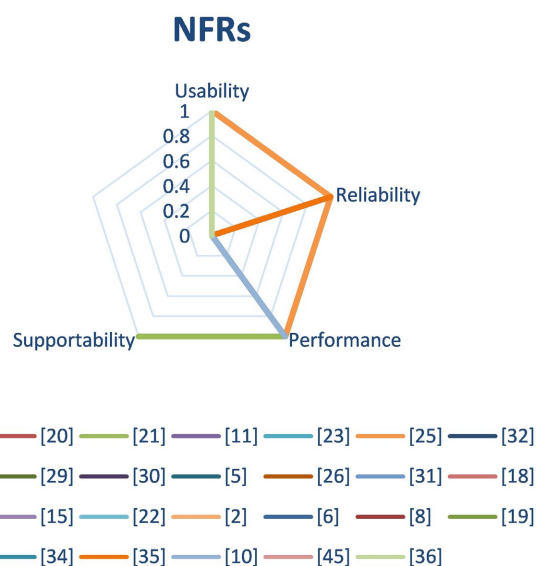


Figure 4. The diversity of the coverage provided by 27 mobile apps for the NFRs.

The purpose of this section is to provide a deep discussion and analysis of the study. Developing a mobile app is a crucial stage that requires empirical research to determine the development requirements. During the study, 27 mobile apps derived from such NFRs were collected and analyzed. Based on the results of the study, some of these apps covered whole NFRs, some covered partial NFRs, and some didn't cover any NFRs at all. As a result of the study, most of the mobile apps analyzed were focused primarily on usability and performance requirements. **Figure 4** shows the diversity of the coverage provided by 27 mobile apps for the NFRs.

Figure 4 shows that the developers of the mobile app focused primarily on the usability requirements and subsequently on performance requirements when it came to developing the mobile app. This decision was driven by a strong motivation, which was the need to develop an app that would be user-friendly and efficient, that would improve user satisfaction, increase user retention, optimize performance, and gain a competitive edge in the market. App development can be very successful when developers pay equal attention to usability and performance. By doing so, they can create an app that meets their users' expectations and remains relevant. This is in a market where mobile apps are constantly changing to remain relevant.

Nevertheless, most of the developers, as well as the majority of the authors, have not addressed the supportability requirement sufficiently, and only three of them have done so. It appears that this crucial component was ignored or neglected during the development process, which suggests that they overlooked or neglected it. In this case, it means that little attention was given to the requirements for the product's supportability, which means that nothing was done to ensure the product's long-term viability or to ensure that it can be maintained over time. Supportability is a crucial component of maintaining and updating software systems, and if this aspect is overlooked, there could be significant consequences for the product's stability and usability. Supportability must be prioritized and understood by developers as a key factor for ensuring the successful implementation of a product and its continued maintenance over the long term.

Functional requirements define *what* a mobile application does-the specific features and functionalities it offers to the user. These are typically described in terms of actions the system should perform, such as user login, data input, transaction processing, or information retrieval. Functional requirements are often the initial focus of development, as they form the core value proposition of the App. Without robust functional features, the App can't deliver on its intended purpose, regardless of its performance or usability. Therefore, developers often prioritize the implementation of these features to establish a working product as quickly as possible.

However, non-functional requirements (NFRs) determine how well the App performs these functions. They include qualities such as usability, reliability, performance, security, and supportability. While the App might technically fulfill

what it's supposed to do (meeting the functional requirements), poor NFRs can significantly harm the user experience and ultimately harm the App's success. For example, an e-commerce app with a detailed product catalog (functional) but slow loading times and frequent crashes (poor NFRs) will likely frustrate users and result in low conversion rates. Ignoring NFRs and focusing only on functional features is a common mistake that can lead to a technically correct but practically unusable or unsustainable application.

Ultimately, a successful mobile app requires a careful balance between functional and non-functional requirements. While functional requirements define the App's core capabilities, NFRs determine its overall quality, user satisfaction, and long-term viability. Ideally, development teams should consider both aspects simultaneously, refining both the features and qualities of the App throughout the development process. Focusing on only one at the expense of the other can result in a subpar product that does not meet user expectations or achieve its goals. This integrated approach ensures that the App is not only functional but also enjoyable, reliable, and easy to maintain. **Table 5** NFR Prioritization and Potential Driving Factors.

Table 5. Observed NFR prioritization and potential driving factors.

FR	Observed Prioritization (High/Low)	Potential Driving Factors
Usability	High	High user demand for intuitive, easy-to-use apps, coupled with competitive pressure to deliver a positive user experience. Usability testing methods are readily available, allowing immediate influence on user adoption and retention.
Performance	High	User expectations for speed and responsiveness, combined with competitive pressure to provide a seamless experience, highlight the importance of visibility into performance issues like crashes and slow loading times, which directly affect user satisfaction.
Reliability	Low	Underestimating the long-term impact of bugs and crashes, coupled with pressure to deliver features rapidly, often results in less direct user feedback on reliability issues compared to usability or performance concerns. These issues may be viewed as "fixable later."
Supportability	Low	Emphasize short-term gains and feature delivery, while recognizing the challenge in quantifying supportability ROI. There is limited awareness of long-term costs associated with poor maintainability, combined with pressure to reduce initial development expenses.

5. Conclusion

A variety of mobile apps are used every day by most people, including news apps, social media apps, and shopping apps. To ensure their reliability when used in the field, these mobile apps must be thoroughly tested. Usually, manual testing for mobile apps is extremely cost-prohibitive because it involves human effort in de-

fining tests and checking results, which can take a considerable amount of time. Developers must therefore conduct empirical studies on how nonfunctional requirements are treated by developers in mobile app development, and how they compare to functional requirements. According to this study, we examined the non-functional requirements (NFRs) of mobile apps from four perspectives: the usability of the mobile App, its reliability, its performance, and even its supportability. A survey of 27 mobile applications collected revealed that 16 out of 27 covered the usability NFR, 7 out of 27 covered the reliability NFR, 14 out of 27 covered the performance NFRs, and 3 out of 27 covered supportability NFRs; however, three out of 27 mobile apps did not meet any of the NFR criteria. As a result of this study, it has been discovered that mobile app developers focus primarily on usability and performance, while reliability and supportability are less deeply integrated into the process of developing apps for mobile devices. In the future work of this study, we will be analyzing mobile applications from the functional requirements and comparing them with our results, as well as developing a comprehensive framework that incorporates full functional requirements and non-functional requirements into a single framework that can be applied to mobile applications. Additionally, the primary study should include efforts to capture the latest trends and advancements in mobile app development.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Daniel, A.O., Precious, O.I., Oluwapelumi, O. and Ebenezer, O.F.O. (2023) Adaptive Multiple User-Device Interface Generation for Websites. *The IUP Journal of Computer Sciences*, vol. 17.
- [2] Pati, B. (2015) Mobile App Requirements Specification Creation. <https://community.sap.com/t5/technology-blog-posts-by-members/mobile-app-requirements-specification-creation/ba-p/13038979>
- [3] Delikostidis, I., Fechner, T., Fritze, H., Abdel Mouty, A.M. and Kray, C. (2013) Evaluating Mobile Applications in Virtual Environments. *International Journal of Mobile Human Computer Interaction*, 5, 1-19. <https://doi.org/10.4018/ijmhci.2013100101>
- [4] Moumane, K., Idri, A. and Abran, A. (2016) Usability Evaluation of Mobile Applications Using ISO 9241 and ISO 25062 Standards. *SpringerPlus*, 5, Article No. 548. <https://doi.org/10.1186/s40064-016-2171-z>
- [5] Flora, H.K., Wang, X. and Chande, S.V. (2014) An Investigation on the Characteristics of Mobile Applications: A Survey Study. *International Journal of Information Technology and Computer Science*, 6, 21-27. <https://doi.org/10.5815/ijitcs.2014.11.03>
- [6] Méndez Porras, A., Quesada López, C.U. and Jenkins Coronas, M. (2015) Automated Testing of Mobile Applications: A Systematic Map and Review. *CIBSE 2015—XVIII Ibero-American Conference on Software Engineering*, 195-208.
- [7] Harrison, R., Flood, D. and Duce, D. (2013) Usability of Mobile Applications: Literature Review and Rationale for a New Usability Model. *Journal of Interaction Science*,

- 1, Article No. 1. <https://doi.org/10.1186/2194-0827-1-1>
- [8] Masterson Creber, R.M., Maurer, M.S., Reading, M., Hiraldo, G., Hickey, K.T. and Iribarren, S. (2016) Review and Analysis of Existing Mobile Phone Apps to Support Heart Failure Symptom Monitoring and Self-Care Management Using the Mobile Application Rating Scale (MARS). *JMIR mHealth and uHealth*, **4**, e74. <https://doi.org/10.2196/mhealth.5882>
- [9] Martínez-Pérez, B., de la Torre-Díez, I., López-Coronado, M. and Herreros-González, J. (2013) Mobile Apps in Cardiology: Review. *JMIR mhealth and uhealth*, **1**, e15. <https://doi.org/10.2196/mhealth.2737>
- [10] Alhuwail, D. (2016) Diabetes Applications for Arabic Speakers: A Critical Review of Available Apps for Android and Ios Operated Smartphones. In: Sermeus, W., et al., *Studies in Health Technology and Informatics*, IOS Press, 587-591. <https://doi.org/10.3233/978-1-61499-658-3-587>
- [11] Rosell-Aguilar, F. (2017) State of the App: A Taxonomy and Framework for Evaluating Language Learning Mobile Applications. *CALICO Journal*, **34**, 243-258. <https://doi.org/10.1558/cj.27623>
- [12] Godwin-Jones, R. (2011) Mobile Apps for Language Learning. *Language Learning & Technology*, **15**, 2-11. <https://doi.org/10.64152/10125/44244>
- [13] Motiwalla, L.F. (2007) Mobile Learning: A Framework and Evaluation. *Computers & Education*, **49**, 581-596. <https://doi.org/10.1016/j.compedu.2005.10.011>
- [14] Pereira, O.R.E. and Rodrigues, J.J.P.C. (2013) Survey and Analysis of Current Mobile Learning Applications and Technologies. *ACM Computing Surveys*, **46**, 1-35. <https://doi.org/10.1145/2543581.2543594>
- [15] Bomhold, C.R. (2013) Educational Use of Smart Phone Technology: A Survey of Mobile Phone Application Use by Undergraduate University Students. *Program Electronic Library and Information Systems*, **47**, 424-436.
- [16] Lyan, A., Amjad, A., Shaden, A. and Khalid, A. (2015) A Usability Evaluation of Arabic Mobile Applications Designed for Children with Special Needs—Autism. *Lecture Notes on Software Engineering*, **3**, 203-209. <https://doi.org/10.7763/lnse.2015.v3.191>
- [17] Filofteia, T.M. (2016) Mobile Applications for Tourism. Study Regarding Their Use by Romanians. *Annals of the “Constantin Brâncuși” University of Târgu Jiu, Economy Series*, No. 4, 78-84.
- [18] Peretta, R. (2014) Evaluating Mobile Applications for Urban Tourism. *Almatourism—Journal of Tourism, Culture and Territorial Development*, **5**, 13-35.
- [19] Campbell, H.A., Altenhofen, B., Bellar, W. and Cho, K.J. (2014) There’s a Religious App for That! a Framework for Studying Religious Mobile Applications. *Mobile Media & Communication*, **2**, 154-172. <https://doi.org/10.1177/2050157914520846>
- [20] Ahmad, N.A., Zainal, A., Kahar, S., Hassan, M.A.A. and Setik, R. (2016) Exploring the Needs of Older Adult Users for Spiritual Mobile Applications. *Journal of Theoretical and Applied Information Technology*, **88**, 154-160.
- [21] Alssayh, A. (2009) Mobile Hajj Guide for Malaysian Pilgrims. Master’s Thesis, University Utara Malaysia.
- [22] Anad, M.M. (2009) A Mobile Application to Guide Hajj Pilgrims. Ph.D. Thesis, University Utara Malaysia.
- [23] Owaidah, A.A. (2015) Hajj Crowd Management via a Mobile Augmented Reality Application: A Case of the Hajj Event, Saudi Arabia. Ph.D. Thesis, University of Glasgow.

- [24] Makhzoom, S. (2011) The Four Basic Pillars of Hajj's Mobile System. Ph.D. Thesis, University Utara Malaysia.
- [25] Mantoro, T., Akhtaruzzaman, M., Mahmud, M. and Ayu, M.A. (2015) Design and Development of an Interactive Monitoring System for Pilgrims in Congregation of Hajj Ritual. *Journal of Convergence Information Technology*, **10**, 28-57.
- [26] Almasry, M.A. (2011) The Use of Augmented Reality as Assistive Services for Pilgrims. Master's Thesis, King Abdulaziz University.
- [27] Abdullah Al-Aidaroo, A.S., Zulkifli, A.N. and Che Mat, R. (2013) Development of Mobile Dua and Zikr for Hajj (MDZ4H). *TELKOMNIKA Indonesian Journal of Electrical Engineering*, **11**, 2723-2730. <https://doi.org/10.11591/telkomnika.v11i5.2509>
- [28] Ahmad, A., Rahman, M.A., Afyouni, I., Ur Rehman, F., Sadiq, B. and Wahiddin, M.R. (2014) Towards a Mobile and Context-Aware Framework from Crowdsourced Data. *The 5th International Conference on Information and Communication Technology for The Muslim World (ICT4M)*, Kuching, 17-18 November 2014, 1-6. <https://doi.org/10.1109/ict4m.2014.7020672>
- [29] Zeki, A.M., Alsafi, H., Nassr, R.M. and Mantoro, T. (2012) A Mobile Dictionary for Pilgrims. 2012 *International Conference on Information Technology and e-Services*, Sousse, 24-26 March 2012, 1-5. <https://doi.org/10.1109/icites.2012.6216620>
- [30] Amro, A. and Nijem, Q. (2012) Pilgrims "Hajj" Tracking System (e-Mutawwif). *Contemporary Engineering Sciences*, **5**, 437-446.
- [31] Hamhoum, F. and Kray, C. (2011) Supporting Pilgrims in Navigating Densely Crowded Religious Sites. *Personal and Ubiquitous Computing*, **16**, 1013-1023. <https://doi.org/10.1007/s00779-011-0461-6>
- [32] Mohamed, H.H., Arshad, M.R.H.M., Rashid, N.A., Zainol, Z., Husain, W., Majid, O.A., et al. (2013) M-Umrah: An Android-Based Application to Help Pilgrims in Performing Umrah. 2013 *International Conference on Advanced Computer Science Applications and Technologies*, Kuching, 23-24 December 2013, 385-389. <https://doi.org/10.1109/acsat.2013.82>
- [33] Mohandes, M. (2011) Pilgrim Tracking and Identification Using the Mobile Phone. 2011 *IEEE 15th International Symposium on Consumer Electronics (ISCE)*, Singapore, 14-17 June 2011, 196-199. <https://doi.org/10.1109/isce.2011.5973812>
- [34] Abdelazeez, M.A. and Shaout, A. (2016) Pilgrim Communication Using Mobile Phones. *Journal of Image and Graphics*, **4**, 59-62. <https://doi.org/10.18178/joig.4.1.59-62>
- [35] Shaout, A. and Khan, S. (2016) Alhajj "Hajj APP for IOS. *IJUM Engineering Journal*, **17**, 1-27. <https://doi.org/10.31436/ijumej.v17i1.528>
- [36] Alqahtani, A.S., BinDhim, N.F., Tashani, M., Willaby, H.W., Wiley, K.E., Heywood, A.E., et al. (2015) Pilot Use of a Novel Smartphone Application to Track Traveller Health Behaviour and Collect Infectious Disease Data during a Mass Gathering: Hajj Pilgrimage 2014. *Journal of Epidemiology and Global Health*, **6**, 147-155. <https://doi.org/10.1016/j.jegh.2015.07.005>
- [37] Khan, E.A. and Shambour, M.K.Y. (2018) An Analytical Study of Mobile Applications for Hajj and Umrah Services. *Applied Computing and Informatics*, **14**, 37-47. <https://doi.org/10.1016/j.aci.2017.05.004>
- [38] Huang, Z. and Benyoucef, M. (2022) An Empirical Study of Mobile Application Usability: A Unified Hierarchical Approach. *International Journal of Human-Computer Interaction*, **39**, 2624-2643.
- [39] Jaber, K., Abduljawad, M., Ahmad, A., Abdallah, M. and Alhindawi, N. (2021) E-

- learning Mobile Application Evaluation: Al-Zaytoonah University as a Case Study. *International Journal of Advances in Soft Computing and its Applications*, **13**, 89-99. <https://doi.org/10.15849/ijasca.211128.07>
- [40] Basaran, S. and Homsy, F.E. (2022) Mobile Mathematics Learning Application Selection Using Fuzzy Topsis. *International Journal of Advanced Computer Science and Applications*, **13**, 270-282. <https://doi.org/10.14569/ijacsa.2022.0130233>
- [41] Bitrián, P., Buil, I. and Catalán, S. (2021) Enhancing User Engagement: The Role of Gamification in Mobile Apps. *Journal of Business Research*, **132**, 170-185. <https://doi.org/10.1016/j.jbusres.2021.04.028>
- [42] Pai, R.R. and Alathur, S. (2021) Mobile Health Systems Affordability in India: Perspectives of Stakeholders. *Journal of Health Management*, **23**, 677-695. <https://doi.org/10.1177/09720634211050151>
- [43] Mehra, A., Paul, J. and Kaurav, R.P.S. (2020) Determinants of Mobile Apps Adoption among Young Adults: Theoretical Extension and Analysis. *Journal of Marketing Communications*, **27**, 481-509. <https://doi.org/10.1080/13527266.2020.1725780>
- [44] Ho, X.H., Nguyen, D.P., Cheng, J.M.S. and Le, A.N.H. (2022) Customer Engagement in the Context of Retail Mobile Apps: A Contingency Model Integrating Spatial Presence Experience and Its Drivers. *Journal of Retailing and Consumer Services*, **66**, Article ID: 102950. <https://doi.org/10.1016/j.jretconser.2022.102950>
- [45] Feroz, I., Ahmad, N. and Iqbal, M.W. (2019). Usability Based Rating Scale for Mobile Health Applications. 2019 *International Conference on Engineering and Emerging Technologies (ICEET)*, Lahore, 21-22 February 2019, 1-7. <https://doi.org/10.1109/ceet1.2019.8711845>
- [46] Ngadi, M., Al-Dhaqm, R. and Mohammed, A. (2012) Detection and Prevention of Malicious Activities on RDBMS Relational Database Management Systems. *International Journal of Scientific & Engineering Research*, **3**, 1-10.
- [47] Alhussan, A.A., Al-Dhaqm, A., Yafooz, W.M.S., Razak, S.B.A., Emara, A.M. and Khafaga, D.S. (2022) Towards Development of a High Abstract Model for Drone Forensic Domain. *Electronics*, **11**, 1168. <https://doi.org/10.3390/electronics11081168>
- [48] Al-Dhaqm, A.M.R., Othman, S.H., Abd Razak, S. and Ngadi, A. (2014) Towards Adapting Metamodelling Technique for Database Forensics Investigation Domain. 2014 *International Symposium on Biometrics and Security Technologies (ISBAST)*, Kuala Lumpur, 26-27 August 2014, 322-327. <https://doi.org/10.1109/isbast.2014.7013142>
- [49] Al-Dhaqm, A., Othman, S.H., Yafooz, W.M.S. and Ali, A. (2023) Review of Information Security Management Frameworks. In: Yafooz, W.M.S., Al-Aqrabi, H., Al-Dhaqm, A. and Emara, A., Eds., *Kids Cybersecurity Using Computational Intelligence Techniques*, Springer, 69-80. https://doi.org/10.1007/978-3-031-21199-7_5
- [50] Salem, M., Othman, S.H., Al-Dhaqm, A. and Ali, A. (2023) Development of Metamodel for Information Security Risk Management. In: Yafooz, W.M.S., Al-Aqrabi, H., Al-Dhaqm, A. and Emara, A., Eds., *Kids Cybersecurity Using Computational Intelligence Techniques*, Springer, 243-253. https://doi.org/10.1007/978-3-031-21199-7_17
- [51] Al-Dhaqm, A., Yafooz, W.M.S., Othman, S.H. and Ali, A. (2023) Database Forensics Field and Children Crimes. In: Yafooz, W.M.S., Al-Aqrabi, H., Al-Dhaqm, A. and Emara, A., Eds., *Kids Cybersecurity Using Computational Intelligence Techniques*, Springer, 81-92. https://doi.org/10.1007/978-3-031-21199-7_6
- [52] Saleh, M., Othman, S.H., Driss, M., Al-dhaqm, A., Ali, A., Yafooz, W.M.S., et al

- (2023) A Metamodeling Approach for IoT Forensic Investigation. *Electronics*, **12**, Article 524. <https://doi.org/10.3390/electronics12030524>
- [53] Al-Dhaqm, A.M.R. (2019) Simplified Database Forensic Investigation Using Meta-modeling Approach. Ph.D. Thesis, University Teknologi Malaysia.
- [54] Kebande, V.R. and Ray, I. (2016) A Generic Digital Forensic Investigation Framework for Internet of Things (IoT). 2016 *IEEE 4th International Conference on Future Internet of Things and Cloud (FiCloud)*, Vienna, 22-24 August 2016, 356-362. <https://doi.org/10.1109/ficloud.2016.57>
- [55] Kebande, V. and Venter, H. (2016) Requirements for Achieving Digital Forensic Readiness in the Cloud Environment Using an NMB Solution. *11th International Conference on Cyber Warfare and Security: ICCWS*, Boston, 17-18 March, 2016, 399.
- [56] Al-Dhaqm, A., Razak, S., Ikuesan, R.A., R. Kebande, V. and Hajar Othman, S. (2021) Face Validation of Database Forensic Investigation Metamodel. *Infrastructures*, **6**, Article 13. <https://doi.org/10.3390/infrastructures6020013>
- [57] Al-Dhaqm, A., Razak, S.A., Ikuesan, R.A., Kebande, V.R. and Siddique, K. (2020) A Review of Mobile Forensic Investigation Process Models. *IEEE Access*, **8**, 173359-173375. <https://doi.org/10.1109/access.2020.3014615>
- [58] Al-Dhaqm, A., Razak, S.A., Dampier, D.A., Choo, K.R., Siddique, K., Ikuesan, R.A., *et al.* (2020) Categorization and Organization of Database Forensic Investigation Processes. *IEEE Access*, **8**, 112846-112858. <https://doi.org/10.1109/access.2020.3000747>
- [59] Al-Dhaqm, A., Razak, S.A., Siddique, K., Ikuesan, R.A. and Kebande, V.R. (2020) Towards the Development of an Integrated Incident Response Model for Database Forensic Investigation Field. *IEEE Access*, **8**, 145018-145032. <https://doi.org/10.1109/access.2020.3008696>
- [60] Kebande, V.R., Ikuesan, R.A., Karie, N.M., Alawadi, S., Choo, K.R. and Al-Dhaqm, A. (2020) Quantifying the Need for Supervised Machine Learning in Conducting Live Forensic Analysis of Emergent Configurations (ECO) in IoT Environments. *Forensic Science International: Reports*, **2**, Article ID: 100122. <https://doi.org/10.1016/j.fsir.2020.100122>
- [61] Al-Dhaqm, A., Razak, S. and Othman, S.H. (2018) Model Derivation System to Manage Database Forensic Investigation Domain Knowledge. 2018 *IEEE Conference on Application, Information and Network Security (AINS)*, Langkawi, 21-22 November 2018, 75-80. <https://doi.org/10.1109/ains.2018.8631468>
- [62] Aldhaqm, A., Abd Razak, S., Hajar Othman, S., Ali, A. and Ngadi, A. (2016) Conceptual Investigation Process Model for Managing Database Forensic Investigation Knowledge. *Research Journal of Applied Sciences, Engineering and Technology*, **12**, 386-394. <https://doi.org/10.19026/rjaset.12.2377>
- [63] Ali, A., Razak, S.A., Othman, S.H. and Mohammed, A. (2017) Extraction of Common Concepts for the Mobile Forensics Domain. In: Saeed, F., Gazem, N., Patnaik, S., Saed Balaid, A. and Mohammed, F., Eds., *Recent Trends in Information and Communication Technology*, Springer, 141-154. https://doi.org/10.1007/978-3-319-59427-9_16
- [64] Ali, A., Razak, S.A., Othman, S.H. and Mohammed, A. (2015) Towards Adapting Meta-Modeling Approach for the Mobile Forensics Investigation Domain. *1st International Conference on Innovation in Science and Technology*, Kuala Lumpur, 20 April 2015, 364-367.
- [65] Saleh, M.A., Hajar Othman, S., Al-Dhaqm, A. and Al-Khasawneh, M.A. (2021) Common Investigation Process Model for Internet of Things Forensics. 2021 *2nd International Conference on Smart Computing and Electronic Enterprise (ICSC EE)*,

Cameron Highlands, 15-17 June 2021, 84-89.

<https://doi.org/10.1109/icscee50312.2021.9498045>

- [66] Alshammari, A. (2023) Detection and Investigation Model for the Hard Disk Drive Attacks Using FTK Imager. *International Journal of Advanced Computer Science and Applications*, **14**, 767-774. <https://doi.org/10.14569/ijacsa.2023.0140784>
- [67] Ullah, F., Pun, C., Kaiwartya, O., Sadiq, A.S., Lloret, J. and Ali, M. (2023) Hide-healthcare IoT Data Trust Management: Attribute Centric Intelligent Privacy Approach. *Future Generation Computer Systems*, **148**, 326-341. <https://doi.org/10.1016/j.future.2023.05.008>
- [68] Lloyd, K. (2017) Benefits of Art Education: A Review of the Literature. *Scholarship and Engagement in Education*, **1**, Article 6.