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Development of A New Model for the Usability Evaluation of M-commerce Applications

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Abstract

The acceptance of Mobile commerce (M-commerce) applications has become a way of life for business professionals and mobile shoppers. The global acceptance and increase in its usefulness have resulted in concerns about the availability of a suitable model for its usability evaluation. In order to fill this literature gap, the study introduced the MObile Shoppers Application Development (MOSAD) usability model to address the limitations in current usability models when applied in the context of M-commerce applications. The proposed model in this study incorporates different essential attributes from widely accepted usability models, which helped develop a more detailed usability model for M-commerce applications. The attributes in the proposed model are not entirely new; however, the current and widely accepted usability models failed to consider some of them. This neglect could lead to usability evaluation flaws and affect the outcomes of usability evaluations of M-commerce applications.

I. INTRODUCTION

The popularity of mobile devices has promoted the widespread development of mobile applications which mobile users can access anytime and anywhere [1]. In most cases, mobile device developers fail to consider that interactions with mobile devices will sometimes occur while individuals are on the move [2].

Recent research has shown that ascertaining essential attributes in the usability evaluation is vital in improving the adoption and user experience of Mobile commerce (M-commerce) applications [3]. Mobile devices and M-commerce applications are significantly sensitive to the impacts of identifying essential attributes because they are utilised in different task settings. The identification of essential attributes of the usability model has not been well researched in present usability models. The developed models are often used for applications in the mobile context [4].

The current research proposes the MObile Shoppers Application Development (MOSAD) usability model for M-commerce applications. This model determines appropriate attributes that directly benefit the adoption and result in an improved user experience of M-commerce applications. Therefore, this research will address the question: What are the essential attributes of the usability model that can enhance user experiences in the context of M-commerce applications? This research work examined a general list of usability attributes which occurred in usability evaluations contained in various published research studies between 2008 and October 2021, as well as attributes proposed in the MOSAD model. The authors present a literature review to validate the MOSAD model's development.

II. LITERATURE REVIEW

A. Usability of M-commerce Applications

Generally, usability is a term that comprises system aspects like user-friendliness and ease of use of user interfaces. Over time, usability has been defined in different ways. These definitions are not contradictory but can instead be viewed as complementary. Usability thus involves the context of use, the users and the goal suitable to specific circumstances [5].

Other researchers, such as Alghamdi, Al-Badi, Alroobaea, and Mayhew [3], considered usability as the quality of performing required tasks easily by any user interacting with a website. Different definitions of usability are presented in terms of different standards and various ways.

Most recently, the International Standards Organisation (ISO) [6, p. 16] defined usability as:

"…the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use…"

Therefore, this research adopts the ISO [6] standards' definition of usability, as presented above, which identifies satisfaction, efficiency and effectiveness as usability attributes. The current research argues that, for users to achieve high levels of satisfaction with M-commerce interfaces, there is an urgent need to identify appropriate attributes to evaluate M-commerce applications.

M-commerce has some specific features absent in traditional E-commerce, including ubiquity, personalisation, flexibility and dissemination [7]. An earlier study suggested

that M-commerce applications should be complementary to E-commerce as a shopping medium and not a direct alternative [8]. Table 1 lists common M-commerce challenges as well as their corresponding solutions.

Table 1
M-commerce Challenges and Potential Solutions (adapted from [9]–[11]).

Challenges/Problems	Solutions
Increasingly demands users' attention	Less interface attention
Real-life users' environment	Provision for context-awareness
Usability and limitations of mobile devices	New and flexible I/O modalities
Security and privacy concerns	Biometrics
Safety	Strong legislation and safety-enabled design
Societal concern	Strong societal norms and law enforcement

Therefore, to establish a successful M-commerce environment, there are particular prerequisites that developers of M-commerce applications and usability professionals must adhere to. The simple conversion of a successful E-commerce business to an M-commerce cannot guarantee success. Thus, Kaur [11] stated that merely translating and copying the contents of an E-commerce application onto an M-commerce application, using a step-by-step approach, would not yield good results.

Mobile technology is here to stay, and it promises to have a very bright future. Therefore, this research seeks to identify M-commerce usability attributes by reviewing several mobile empirical usability studies. In addition, this research aims to determine the essential attributes of the MOSAD model for M-commerce applications.

B. Description of Previous Usability Models

Various usability models are discussed in the literature. The earliest usability models were presented between 1991 and 1999 [3]. However, the ISO standards and Nielsen models are the common and widely cited usability models found in the literature [12]–[16]. Consequently, these models serve as baselines for this research work. Nielsen identified the following five significant attributes of usability:

- Efficiency: "Resources are expended in relation to the accuracy and completeness with which users achieve goals" [17, p. 26].
- Satisfaction: Comfortable feeling and positive attitude of users when engaging with the product.
- Learnability: Users should be able to start and finish tasks easily without learning task processes repeatedly.
- Memorability: The system should allow users to recall their previous experiences, even if they did not utilise the system for an extended period.
- Errors: The system should present minimal errors while users interact. If errors do occur, users should be able to address them easily. Also, the system should be free from catastrophic errors.

In selecting usability attributes, specific attributes are considered more important than others. Cáliz and Alamán [18] categorised usability attributes according to their importance: efficiency, effectiveness, satisfaction, learnability, accessibility, operability, memorability, acceptability and flexibility. Based on the application, different usability attributes play different critical roles. For example, memorability is a critical aspect of software which is not used frequently. Efficiency and minimal errors are more critical in applications which require a short processing time [2]. Determining which attributes to include in the usability evaluation of mobile and M-commerce applications is critical. Prior study shows that identifying essential attributes in usability evaluation plays a vital role in adopting and facilitating improved user experiences of M-commerce applications [3].

The ISO definition identifies three important factors when conducting usability evaluations.

- Users: The "person who interacts with a system, product or service" [6]. An earlier study indicates that users' demographics (education, gender and/or age), as well as physical and sensory characteristics (visual and auditory, handedness and body dimensions), can also affect usability [19].
- Goal: An "intended outcome" [6] refers to the expected outcome of user interaction with the product. In addition, it can be described as any responsibility capable of affecting user interface usability [19].
- Context of use: The "combination of users, goals and tasks, resources, and environment" [6]. This factor consists of tasks or activities, users, technologies (software, hardware and materials) and psychosocial, social and physical environments in which the system or product is being used [20].

These factors impact product design and development, which, in turn, explicitly influences user interactions with the product or system [21]. The ISO standards suggest three measurable attributes which are linked to the usability of any product [6]:

- Effectiveness: The "accuracy and completeness with which users achieve specified goals".
- Efficiency: The "resources used in relation to the results achieved". The "typical resources include time, human effort, costs and materials".
- Satisfaction: The "extent to which the user's physical, cognitive and emotional responses that result from using a system, product or service meet the user's needs and expectations".

Unlike the attributes of usability identified by Nielsen, the ISO standards do not include memorability, learnability and error rate as product usability attributes. It can be suggested, though, that they are implicitly contained in satisfaction, effectiveness and efficiency definitions. For example, learnability, memorability and error rates can be argued to have an overall effect on a user's effectiveness and efficiency.

C. Limitations of the Existing Models for Mobile Applications

The attributes discussed in the previous section were traditionally tailored to desktop applications; their applicability to mobile applications is limited [20]. For example, Nielsen's study focuses on the design and development of telecommunication systems which differ from the computer software. The emergence of mobile devices presents more significant challenges for usability

professionals as these devices are difficult to evaluate and align with traditional usability models [22].

Furthermore, the usability of mobile applications differs from traditional software applications in terms of screen size, limited processing capability and power, context, text and data entry methods and connectivity [23].

Most of the literature reviewed indicated that existing usability models fail to consider the need for mobility and other essential attributes appropriate to M-commerce applications and the consequences on user experiences. This complicates the work of usability professionals who need to explicitly define task model inclusion in the mobility of mobile devices. The following section provides an overview of the proposed usability model for M-commerce applications.

D. Techniques Used in the Review of Research Resources

This study examined the general list of usability attributes and methods which form part of usability evaluations as presented in different published research studies dated 2008 to 2021. In order to assimilate the relevant research resources in the areas of mobile and M-commerce applications to be used in the current research work, the authors reviewed the literature on selected resources. The resources reviewed in this study were obtained from academic and non-academic sources (statistical data compilations and publications), as indicated by literature references [24]. The authors explored different sources by using keywords [25]. Sources accessed included, amongst others: Google Scholar search engine, Emerald, SpringerLink, ScienceDirect, the Association for Computing Machinery (ACM) database, the Institute of Electrical and Electronics Engineers (IEEE) database, the UNISA subject databases and other Human-Computer Interaction (HCI) database sources.

Amongst the keywords used to search for relevant articles were: usability attributes, mobile E-commerce usability, E-commerce usability attributes, mobile commerce usability attributes, usability methods, E-commerce usability, E-commerce usability methods, E-commerce usability problems, mobile usability issues, mobile usability problems, mobile usability, mobile usability methods, E-commerce usability issues, mobile E-commerce usability issues, mobile E-commerce usability problems, mobile E-commerce usability, mobile E-commerce usability methods, E-commerce usability, usability theory, usability engineering, usability studies and heuristic evaluation method.

The resources selected for this research work are based on specific selection criteria, which formed the basis for the inclusion and exclusion of research resources [26]. Research resources included were those published between 2008 and 2021. The selection criteria are contingent upon whether the research resource:

- Performed an evaluation of mobile applications.
- Contained software components (e.g. paper prototype) which allow users to interact with it.
- Focused on users' interactions with the applications or devices and also conducted an evaluation.

The method suggested by Randolph [27] subscribes to the view that electronic searches cannot yield 100% of the total research resources required for a literature review. The residual percentage can be identified by reviewing the reference list containing the research resources which had already been retrieved. The authors determined which among these were deemed relevant by using the included selection criteria outlined above.

Table 2
Total Number of Research Papers Used in the Literature Review

Name of Database / Search Engine	Step 1: Total of publications found via Search strings	Step 2: Initial selection decision after reading abstracts	Step 3: Sub-total of papers selected after applying selection criteria	Step 4: Sub-total of papers selected via list of references of papers selected in Step 3	The final total of papers selected
IEEEXplore	256	188	17	15	32
ACM Portal	466	376	220	168	388
Science Direct	130	111	6	3	9
Emerald	270	189	125	12	137
Google Scholar	210	134	66	38	104
Springer Link	144	89	9	6	15
Total	1476	1087	443	242	685

Table 2 depicts the total number of research resources identified in each database source. Initially, a total of 1476 research resources were retrieved by using the search strings and reading through the titles of the research resources. A total of 1087 research resources were chosen after reading their abstracts. The authors then applied the three selection criteria, reducing the total to 443 research resources. The authors adopted the strategy proposed by Randolph [27] and revisited the reference lists of the research resources which had already been retrieved and passed the selection criteria. Using this approach, a total of 242 additional research resources were identified. The authors repeated this process until no relevant research resources were found. Therefore, a total of 685 research resources adhered to the selection criteria and were consequently included in the literature review of the current study.

To validate the MOSAD usability model, the current study seeks to answer the research question to establish the importance of each attribute in the proposed MOSAD model in the context of M-commerce applications. The research question seeks to discover the types of attributes commonly used in the usability evaluation of M-commerce applications and their corresponding metrics.

E. The Prominence of Usability Attributes

Previous research by Baharuddin et al. [28] identified 18 usability dimensions, while Coursaris and Kim [29] identified 11 and 28 usability attributes commonly evaluated in mobile applications. However, based on the literature review conducted on 685 relevant and selected studies, this research work identified 32 usability attributes in the context of mobile applications.

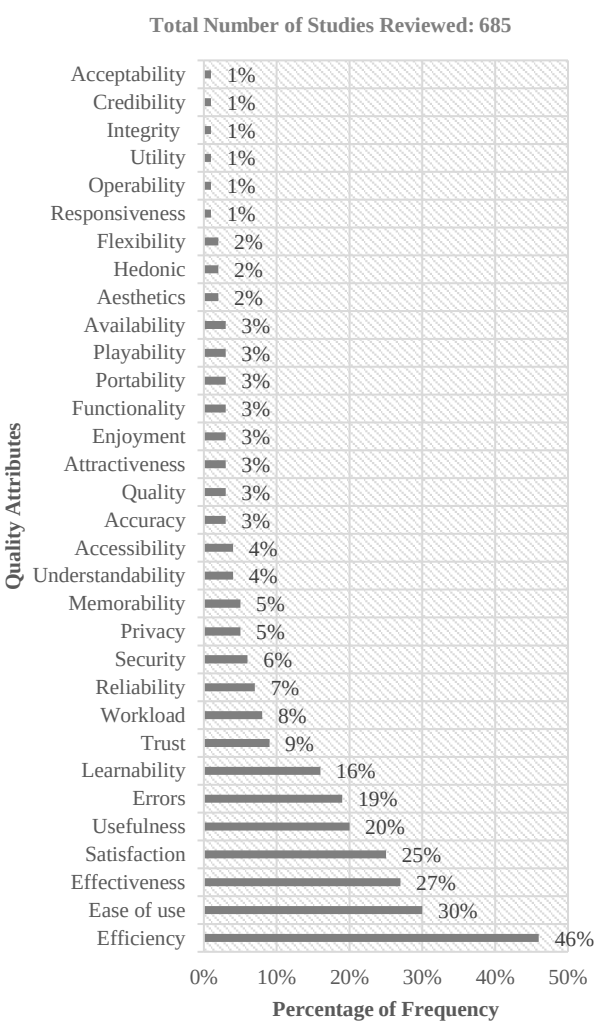

Figure 1. Frequency of Attributes Utilised in the Reviewed Studies

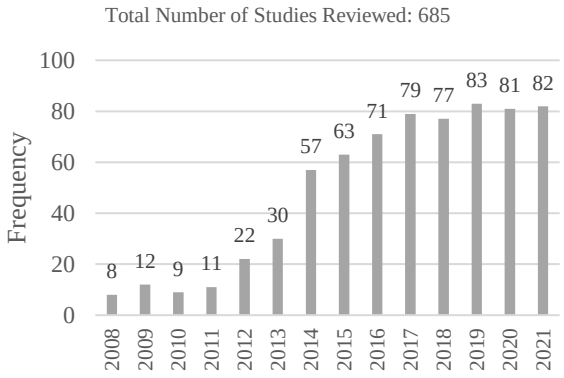

Figure 2. Frequency of Empirical Mobile Usability Evaluation Studies

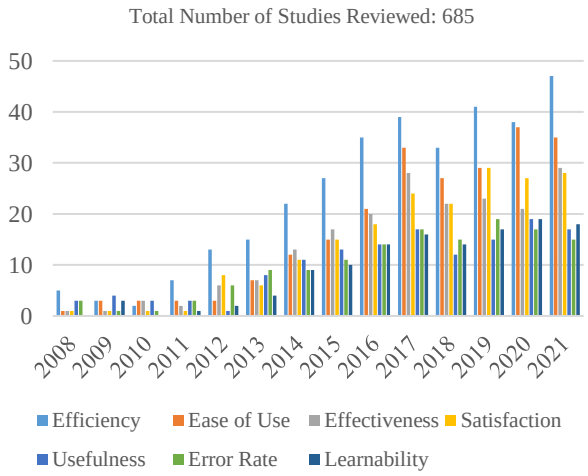

Figure 3. Frequency of Attributes evaluated within Mobile Usability Studies

Figure 1 illustrates the frequency percentage of general attributes, as identified in the literature review of mobile empirical usability evaluation studies. The attributes of efficiency (48%), ease of use (29%), effectiveness (27%), satisfaction (25%), usefulness (22%), error rate (21%) and learnability (13%) are most frequently evaluated in the literature dated between 2008 and 2021. Figure 2 shows the frequency of empirical mobile usability evaluation studies done between 2008 and 2021. The findings reveal a significant increase in the frequency of mobile usability studies from 2012 to 2021. The increase is not accidental but can be ascribed to mobile applications (native mobile applications) becoming more prominent in 2012 [30].

Figure 3 presents statistical data regarding attributes with at least a 10% frequency of use in the usability evaluation of the reviews of mobile empirical usability studies, as per Figure 1. As seen in Figure 3, efficiency is considered the most frequently evaluated usability attribute as it appears in 12 of the 14 years of studies reviewed. Furthermore, the domain of usability attributes was most frequently addressed between 2012 and 2021.

Ease of use is an attribute which indicates how easy it is for a user to learn how to operate a system. In addition to acquiring mobile applications to perform intended tasks, clarity in interaction, the ability to become more skilful in the use of the application and the ease with which the task is performed are considered significant [31]–[37]. In addition, usefulness as an attribute is defined as a constituent of perceived ease of use [38]. Satisfaction is described as pleasantness [39]–[45]. A perceived degree of comfort is associated with users' use of the software [46].

The proposed MOSAD model is aimed at addressing the shortcomings evident in current usability models when attempting to evaluate M-commerce applications. Existing theories in usability studies serve as a foundation for the proposed MOSAD model for M-commerce applications. In addition, a prior study proposed a new model for mobile applications, People At the Centre of Mobile Application Development (PACMAD) [46]. PACMAD applies to mobile applications in general and does not adequately address specific mobile applications, including M-commerce and Mobile health.

The PACMAD is an extension of Nielson's model, but it includes cognitive load as an essential characteristic of mobile applications. The PACMAD fails to address imbalances in the existing mobile applications, and the model has not been empirically validated in the context for which it was proposed. In addition, PACMAD does not afford guidance and metrics regarding what? And how? in

measuring each identified attribute in the model [47]. This study contends that each mobile application possesses its unique characteristics. Mobile applications differ, to some extent, under the context for which they were developed. Mobile health, mobile games and M-commerce applications, amongst others, have distinctive attributes unique to each of them [48], [49]. Consequently, specifically tailored usability models for M-commerce applications should be developed to address these specific attribute(s) as they significantly impact overall user experiences.

After careful consideration and at the hand of specific selection criteria, the authors decided which attributes should be included in the MOSAD model. The attributes included in the MOSAD model had to adhere to three selection criteria which formed the basis for including or excluding attributes. The three selection criteria are:

- The attributes must have been uncovered in the review of mobile empirical usability evaluation studies, as per Figure 1.
- The attributes must have at least a 10% frequency of use in the usability evaluation of the reviews of mobile empirical usability studies, as per Figure 1.
- The attributes must have been incorporated in the ISO Standards or Nielsen's usability model.

Thus, in this research work, the initial attributes included in the mobile usability evaluation are identified based on the above selection criteria. The study identified the following seven initial usability attributes per the above criteria and their prominence in mobile applications: *efficiency, ease of use, effectiveness, satisfaction, usefulness, error rate and learnability*. The following section discusses the method used to validate the seven initial attributes of the proposed MOSAD usability model by usability professionals.

III. METHODS

Based on the extensive study and critical analysis of relevant literature, the attributes proposed by ISO and Nielsen models were used as a baseline for developing the proposed MOSAD model for M-commerce applications. In addition, this research adopted and used the popular guidelines used by a prior study in developing a model for mobile applications [46]. The research uncovered seven initial attributes that apply to the usability evaluation of M-commerce interfaces. The proposed set of attributes was subjected to review by users' experience and HCI professionals. This approach is in accordance with prior studies in validating a newly developed set of models for the usability evaluation of user interfaces [5, 6, 30, 59]. The authors contacted 167 user experience professionals to participate in the review process. The professionals were contacted via the LinkedIn social media experts groups. The experts were required to review the attributes of the proposed model using a five-point Likert scale, which was placed below each attribute on a customised online survey. The first author performed the analysis and refined the qualitative and quantitative data obtained from the usability professionals, who participated in the review process. Additional areas for experts' comments were provided to obtain qualitative data. The description of the professional usability survey for validating the initial attributes of the MOSAD model is stated in the following subsection.

IV. USABILITY PROFESSIONAL SURVEY

The usability professionals reviewed the seven initial attributes through a customised online survey. Before the commencement of the survey, the selected professionals were informed about the literature gap that informed the development of a new model for M-commerce applications.

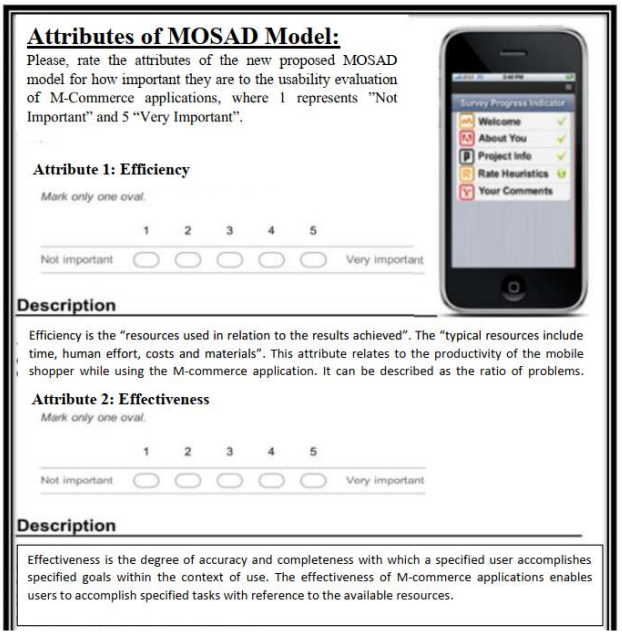

Figure 4. Sample of Usability Professional Survey

The selected usability professionals are required to rate each of the seven initial attributes of the proposed MOSAD model with the aid of a five-point Likert Scale (1: Not important to 5: Very important) as presented in Fig. 4. Additional areas were provided in order to get the experts' comments for qualitative data. One hundred and forty out of the total of one hundred and sixty-seven usability experts from different countries participated in the review process; ninety-nine of the reviewers were user experience professionals while the rest were HCI researchers from different universities.

V. PROFESSIONAL USABILITY SURVEY RESULTS

The selected usability professionals could provide detailed reviews of the seven initial attributes of the proposed MOSAD model. The provided text comment options were adequately utilised and helpful in the review process. Table 3 provides the rating scores for seven initial attributes obtained from the usability professionals. The authors used the standard stacked bar chart and removed the Likert Scale of 3 (Neutral) to show the review results [58]. Analysing the remaining negative and positive feedback enabled the visualisation of the complete results [52]. The Likert Scale results are used to judge the relevance of each attribute to the proposed MOSAD model in the usability evaluation of M-commerce applications. Table 3 shows that each efficiency, effectiveness, satisfaction and error rate has a modal score of 5, learnability has a modal score of 4, while the rest has 3 each. Therefore, attributes with modal scores of either 4 or 5 are considered relevant.

Table 3
Modal Score for the Proposed Heuristics

M-commerce Heuristics	Modal Score (1: Not important to 5: Very important)
Efficiency	5
Effectiveness	5
Satisfaction	5
Usefulness	3
Ease of use	3
Error rate	5
Learnability	4

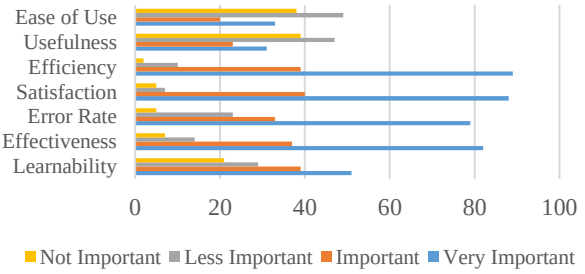

Figure 5. Quantitative Data from Usability Survey

In addition, Figure 5 shows that most usability professionals rated the attributes as either "Very Important" or "Important" However, usefulness and ease of use were rated less useful, with little or no modifications. Therefore, the required modifications were made to the descriptions of the seven initial attributes based on the usability professionals' comments from the review process.

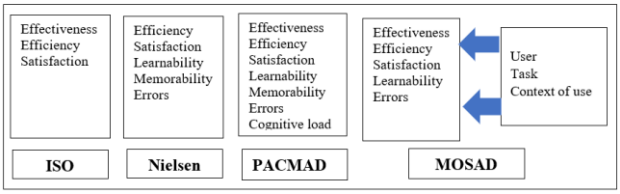

Figure 6. Comparing Attributes of Usability Models

The authors ensured that the attributes included have at least a modal score of either 4 or 5 as reviewed by the usability professionals, as per Table 3. Therefore, *efficiency, effectiveness, satisfaction, error rate and learnability* were found to adhere to the condition. Consequently, they were included as the final attributes of the MOSAD model for usability evaluation of M-commerce applications, as presented in Figure 6.

VI. DESCRIPTION OF THE MOSAD USABILITY MODEL

Figure 6 compares the ISO, Nielsen, PACMAD and MOSAD models. The MOSAD model includes attributes found in the earlier and authoritative ISO standards and Nielsen usability models.

The MOSAD model for M-commerce applications suggests certain factors (user, task and context of use) which should be considered when developing M-commerce applications. These factors are not new but need to be re-addressed in the context of M-commerce applications as they had previously been discussed in terms of ISO standards and Nielsen's model in desktop-based applications.

A. Factors of the MOSAD Usability Model

The MOSAD model incorporates three factors that affect the general usability of M-commerce applications: task, user and context of use. The models developed by ISO [6] and Nielsen [17] suggest that these factors significantly impact the overall success of the application's usability. However, these models fail to address the factors in the context of mobile and M-commerce applications. For mobile and M-commerce applications, the context of use serves as a common ground because the mobile application may be used in different contexts. The factors (User, Task and Context of use) are discussed:

1. User: In the M-commerce application development process, it is essential to consider the end-users or mobile shoppers. Since M-commerce applications are a subset of mobile applications that are designed and developed to be small in size, physical desktop and laptop input methods like mouse and keyboard are not applicable [50], [51]. Therefore, designers of M-commerce applications must identify and employ alternative input methods. Many mobile shoppers may encounter difficulties using these input methods because of their physical limitations. Alternative inputs, like Swype and SwiftKey, afford mobile smartphone users certain benefits as they facilitate a similar typing speed comparable to that of a physical computer keyboard [50].
2. Task: For this study, the goal which the mobile shopper seeks to accomplish when browsing M-commerce applications is referred to as a task. In the development of M-commerce applications, it is expected that additional features might be added to enable mobile shoppers to accomplish more goals. The inclusion of additional features may directly affect the usability of M-commerce applications. The additional features may make the application increasingly complex, ultimately affecting the accomplishment of the user's intended goal/s [52]. The factors which characterise the dynamic context of M-commerce applications are task difficulty, time to complete the task, complexity of the task, task completion rate and dependency between tasks [20].
3. Context of use: The context of M-commerce applications denotes the environment in which mobile shoppers will use the application. This study differentiates the context of use in terms of both the task and the user. The context of use can be viewed in terms of the physical (auditory, co-location, visual and experiment type), psychosocial and social conditions. However, different social and cultural factors affect the context of use and the users' experiences while interacting with the products [53]. As mobile devices have a portable characteristic which enables their use in any location, the context of use cannot be viewed apart from the device. This means that mobile application

users often, via their mobile devices, perform tasks in random locations and at random times [54].

B. Attributes of the MOSAD Usability Model

The MOSAD model identifies five initial attributes, which cover the usability of M-commerce applications, as discussed in Figure 4. These attributes are efficiency, effectiveness, satisfaction, error rate and learnability and are discussed in the following section.

1. Efficiency: Efficiency is the "resources used in relation to the results achieved". The "typical resources include time, human effort, costs and materials" [6]. This attribute relates to the productivity of the mobile shopper while using the M-commerce application. It can be described as the ratio of problems identified and the speed, or time, required to detect them [31]. In contrast, the effectiveness of M-commerce applications enables users to accomplish specified tasks regarding the available resources [7]. Examples of the metrics used to measure efficiency are task completion time and counting mouse clicks or the number of keystrokes used to complete a specified task.
2. Effectiveness: Effectiveness is the "accuracy and completeness with which users achieve specified goals" [6]. Alternatively, effectiveness is the degree of accuracy and completeness with which a specified user accomplishes specified goals within the context of use [55]. Typically, effectiveness evaluates whether or not the test participant can accomplish the intended tasks. Generally, a supervisor computes successful and unsuccessful tasks by counting the number of mistakes made by the participant whilst performing certain tests [56].
3. Satisfaction: Satisfaction is the "extent to which the user's physical, cognitive and emotional responses that result from the use of a system, product or service meet the user's needs and expectations" (ISO 9241-11, 2018). It is the degree of pleasantness and comfort users achieve while using particular software. This reflects the user's attitudes, feelings, perceptions and opinions regarding the software [57]. Satisfaction is a subjective usability attribute; therefore, its perception differs for each user. Qualitative tools, like questionnaires, typically measure the user's attitude when engaging with software applications. The System Usability Scale (SUS), a questionnaire tool, is a 10-item data collection method that provides usability overviews regarding effectiveness, efficiency and satisfaction [58].
4. Learnability: Learnability is the ease with which users, during their first use, achieve intended tasks on the software application [59]. However, Kenteris et al. [60] define learnability as a situation where the user of the application improves his/her task performance on the second attempt. In this research, learnability is defined as the ease with which users of M-commerce applications gain some proficiency. There are many available mobile applications, and if users find anyone difficult to use, they may switch to another. Ease of learning is considered a usability attribute which allows users to accept applications [61]–[64]. For this reason, the MOSAD M-commerce model includes learnability, as the Nielsen usability model proposed. To measure learnability, usability professionals observe participants performing tasks and measure how long it takes them to achieve a pre-determined level of proficiency [48], [65].
5. Error: The MOSAD M-commerce model broadens the error description initially suggested by Nielsen to include errors made by mobile application users when using their mobile devices. Thus, mobile application developers can uncover problematic areas of an application, and necessary improvements can be made during successive iterations of the development process. For mobile users with a limited attention span, a reduced error rate is critical to the acceptance of the M-commerce application. It is impractical for mobile users to continually encounter errors when executing their intended tasks [55], [66], [67]. The MOSAD M-commerce model considers the characteristics of errors and the number of times they occur. Through a proper understanding of the characteristics of the errors committed, M-commerce application developers can prevent the occurrence of these errors in subsequent versions of the application.

VII. CONCLUSION

Though still in its infancy, the empirical usability evaluation of M-commerce applications is expanding rapidly. The processing power of mobile phones and devices (tablets, smartphones and iPhones) is rapidly increasing along with the services available. Furthermore, the usability of mobile applications differs from traditional software applications. The widely cited ISO and Nielsen usability models fail to capture M-commerce applications' unique nature and interaction complexities. Therefore, this research study presents the proposed MOSAD model in the context of M-commerce applications, incorporating existing usability models. To justify the conceptual model, a thorough literature review was conducted. The review shows the extent and frequency at which attributes included in the MOSAD model are evaluated within the context of mobile and M-commerce applications. Therefore, identifying the essential attributes of the MOSAD model for the usability evaluation of M-commerce applications addresses the research question of this current study.

REFERENCES

[1] C. C. Kulpa and F. G. Amaral, "Evaluation of Tablet PC Application Interfaces with Low Vision Users: Focusing on Usability," in International Conference of Design, User Experience, and Usability, 2014, pp. 273–284. Accessed: Feb. 26, 2015. Available: http://link.springer.com/chapter/10.1007/978-3-319-07668-3_27

[2] C. K. Coursaris, K. Hassanein, M. M. Head, and N. Bontis, "The impact of distractions on the usability and intention to use mobile devices for wireless data services," Computers in Human Behavior, vol. 28, no. 4, pp. 1439–1449, 2012, doi: 10.1016/j.chb.2012.03.006.

[3] A. S. Alghamdi, A. H. Al-Badi, R. S. Alroobaea, and P. J. Mayhew, "A Comparative Study of Synchronous and Asynchronous Remote Usability Testing Methods," International Review of Basic and Applied Sciences, vol. 1, no. 3, pp. 61–97, 2013.

[4] I. Muslukhov, Y. Boshmaf, C. Kuo, J. Lester, and K. Beznosov, "Know your enemy: the risk of unauthorised access in smartphones by insiders," in Proceedings of the 15th international conference on Human-computer interaction with mobile devices and services, 2013, pp. 271–280. Accessed: May 01, 2014. Available: http://dl.acm.org/citation.cfm?id=2493223

[5] E. Chalkia, J. B. M. Colomer, S. de los Rios, and I. C. Rojo, "Evaluating the Global Public Inclusive Infrastructure: Cloud4all Evaluation Framework," in Proceedings of the 8th International Conference on

Universal Access in Human-Computer Interaction. Design for All and Accessibility Practice, 2014, pp. 358–367. Accessed: Feb. 26, 2015. Available: http://link.springer.com/chapter/10.1007/978-3-319-07509-9_34

[6] ISO 9241-11, "Ergonomics of human-system interaction -- Part 210: Human-centred design for interactive systems," 2018. Accessed: May 24, 2018. Available: https://www.iso.org/standard/52075.html

[7] W. Oyomno, P. Jäppinen, E. Kerttula, and K. Heikkinen, "Usability study of ME2.0: User interface design for mobile context enhanced personalisation software," Personal and Ubiquitous Computing, vol. 17, no. 2, pp. 305–319, 2013, doi: 10.1007/s00779-011-0495-9.

[8] A. A. Ozok and J. Wei, "An empirical comparison of consumer usability preferences in online shopping using stationary and mobile devices: results from a college student population," Electronic Commerce Research, vol. 10, no. 2, pp. 111–137, 2010, doi: 10.1007/s10660-010-9048-y.

[9] T. Feng, N. DeSalvo, L. Xu, X. Zhao, X. Wang, and W. Shi, "Secure Session on Mobile: An Exploration on Combining Biometric, TrustZone, and User Behavior," in 6th International Conference on Mobile Computing, Applications and Services, Austin, USA, 2014, pp. 206–215. doi: 10.4108/icst.mobicase.2014.257767.

[10] L. Gitau and D. Nzuki, "Analysis of Determinants of M-Commerce Adoption by Online Consumers," International Journal of Business, Humanities and Technology, vol. 4, no. 3, pp. 88–94, 2014.

[11] M. Kaur, "A brief study of usability principles for mobile commerce," International Journal of Computational Engineering Research, vol. 4, no. 8, pp. 20–25, 2014.

[12] A. Hussain and E. Ferneley, "Usability metric for mobile application: A goal question metric (GQM) approach," in Proceedings of the 10th International Conference on Information Integration and Web-based Applications & Services, 2008, pp. 567–570. Accessed: May 02, 2014. Available: http://dl.acm.org/citation.cfm?id=1497412

[13] N. A. bt Mohd and Z. F. Zaaba, "A Review of Usability and Security Evaluation Model of Ecommerce Website," Procedia Computer Science, vol. 161, pp. 1199–1205, 2019, doi: 10.1016/j.procs.2019.11.233.

[14] K. Benmoussa, M. Laaziri, S. Khoulji, M. L. Kerkeb, and A. E. Yamami, "Evaluating the Usability of a Moroccan University Research Management Web Platform," Procedia Manufacturing, vol. 32, pp. 1008–1016, 2019, doi: 10.1016/j.promfg.2019.02.315.

[15] K. Ishaq, F. Rosdi, N. Azan, and A. Abid, "Usability and Design Issues of Mobile Assisted Language Learning Application," IJACSA, vol. 11, no. 6, 2020, doi: 10.14569/IJACSA.2020.0110611.

[16] A. Hussain and A. Mohamed Omar, "Usability Evaluation Model for Mobile Visually Impaired Applications," Int. J. Interact. Mob. Technol., vol. 14, no. 05, p. 95, Apr. 2020, doi: 10.3991/ijim.v14i05.13349.

[17] J. Nielsen, Usability Engineering, 1st ed. Morgan Kaufmann, USA, 1994. Accessed: Apr. 20, 2015. Available: http://www.amazon.com/Usability-Engineering-Interactive-Technologies-Nielsen-ebook/dp/B0029ZBK80

[18] D. Cáliz and X. Alamán, "Usability Evaluation Method for Mobile Applications for the Elderly: A Methodological Proposal," in Annual Conference on Human Factors in Computing Systems, Italy, 2014, pp. 252–260. Accessed: Feb. 26, 2015 Available: http://www.bookmetrix.com/detail/chapter/2802f3c2-2b1b-40df-9577-99f9c2e3cbf1#downloads

[19] N. Bevan, "Using the Common Industry Format to Document the Context of Use," in Human-Computer Interaction. Human-Centred Design Approaches, Methods, Tools, and Environments, Berlin, Heidelberg, 2013, vol. 8004, pp. 281–289. doi: 10.1007/978-3-642-39232-0_32.

[20] S. Hörold, C. Mayas, and H. Krömker, "Guidelines for Usability Field Tests in the Dynamic Contexts of Public Transport," in International Conference on Human-Computer Interaction, 2014, pp. 489–499. Accessed: Feb. 26, 2015. Available: http://link.springer.com/chapter/10.1007/978-3-319-07233-3_45

[21] P. Ponce, D. Balderas, T. Peffer, and A. Molina, "Deep learning for automatic usability evaluations based on images: A case study of the usability heuristics of thermostats," Energy and Buildings, vol. 163, no. 1, pp. 111–120, 2018, doi: 10.1016/j.enbuild.2017.12.043.

[22] A. De Lima Salgado and A. P. Freire, "Heuristic Evaluation of Mobile Usability: A Mapping Study," in Proceedings of the 16th International Conference on Human Computer Interaction, M. Kurosu (Ed.)., Crete, Greece: Springer, 2014, pp. 178–188. Accessed: Feb. 26, 2015. Available: http://link.springer.com/chapter/10.1007/978-3-319-07227-2_18

[23] M. S. Al-Razgan, H. S. Al-Khalifa, and M. D. Al-Shahrani, "Heuristics for Evaluating the Usability of Mobile Launchers for Elderly People," in A. Marcus (Ed.): International Conference of Design, User Experience, and Usability. Theories, Methods, and Tools for Designing the User Experience, Crete, Greece, 2014, pp. 415–424. Accessed: Feb. 26, 2015. Available: http://link.springer.com/chapter/10.1007/978-3-319-07668-3_40

[24] G. R. Howard, "Investigating good usability consistency within and across the South African super 14 rugby franchise web sites," University of South Africa, South Africa, 2009. Accessed: Jun. 02, 2015. Available: http://uir.unisa.ac.za/handle/10500/3885

[25] L. I. González-Pérez, M. S. Ramírez-Montoya, F. J. García-Peñalvo, and J. E. Q. Cruz, "Usability evaluation focused on user experience of repositories related to energy sustainability: A Literature Mapping," in Proceedings of the 5th International Conference on Technological Ecosystems for Enhancing Multiculturality - TEEM 2017, Cádiz, Spain, 2017, pp. 1–11. doi: 10.1145/3144826.3145385.

[26] T. Álvarez, C. Rusu, F. Álvarez, E. Benítez-Guerrero, and A. Esparza, "Applying usability evaluation methods with blind users: a systematic mapping study," in Proceedings of the XVIII International Conference on Human Computer Interaction - Interacción '17, Cancun, Mexico, 2017, pp. 1–4. doi: 10.1145/3123818.3123829.

[27] J. J. Randolph, "A guide to writing the dissertation literature review," Practical Assessment, Research and Evaluation, vol. 14, no. 13, pp. 1–13, 2009.

[28] R. Baharuddin, D. Singh, and R. Razali, "Usability dimensions for mobile applications—A review," Research Journal of Applied Sciences, Engineering and Technology, vol. 5, no. 6, pp. 2225–2231, 2013.

[29] C. Coursaris and D. Kim, "A qualitative review of empirical mobile usability studies," 2006, pp. 1–14. Accessed: Feb. 14, 2015. Available: http://aisel.aisnet.org/cgi/viewcontent.cgi?article=1900&context=amcis2006

[30] R. Budiu, "Mobile: Native Apps, Web Apps, and Hybrid Apps," Nielsen Norman Group, Sep. 2013. http://www.nngroup.com/articles/mobile-native-apps/ (accessed Apr. 23, 2015).

[31] L. Rivero, G. Kawakami, and T. U. Conte, "Using a Controlled Experiment to Evaluate Usability Inspection Technologies for Improving the Quality of Mobile Web Applications Earlier in their Design," 2014, pp. 161–170. doi: 10.1109/SBES.2014.24.

[32] A. Nathoo, G. Bekaroo, T. Gangabissoon, and A. Santokhee, "Using tangible user interfaces for teaching concepts of internet of things: Usability and learning effectiveness," ITSE, vol. 17, no. 2, pp. 133–158, Jun. 2020, doi: 10.1108/ITSE-09-2019-0061.

[33] N. A. Nik Ahmad, N. I. M. Hamid, and A. Mohd Lokman, "Performing Usability Evaluation on Multi-Platform Based Application for Efficiency, Effectiveness, and Satisfaction Enhancement," Int. J. Interact. Mob. Technol., vol. 15, no. 10, p. 103, May 2021, doi: 10.3991/ijim.v15i10.20429.

[34] R. Alturki and V. Gay, "Usability Attributes for Mobile Applications: A Systematic Review," in Recent Trends and Advances in Wireless and IoT-enabled Networks, M. A. Jan, F. Khan, and M. Alam, Eds. Cham: Springer International Publishing, 2019, pp. 53–62. doi: 10.1007/978-3-319-99966-1_5.

[35] P. Weichbroth, "Usability of Mobile Applications: A Systematic Literature Study," IEEE Access, vol. 8, pp. 55563–55577, 2020, doi: 10.1109/ACCESS.2020.2981892.

[36] N. Andriamilanto and T. Allard, "BrFAST: a Tool to Select Browser Fingerprinting Attributes for Web Authentication According to a Usability-Security Trade-off," in Companion Proceedings of the Web Conference 2021, Apr. 2021, pp. 701–704. doi: 10.1145/3442442.3458610.

[37] E. O. C. Mkpojiogu, O. E. Okeke-Uzodike, and E. I. Emmanuel, "Quality Attributes for an LMS Cognitive Model for User Experience Design and Evaluation of Learning Management Systems:," presented at the 3rd International Conference on Integrated Intelligent Computing Communication & Security (ICIIC 2021), Bangalore, India, 2021. doi: 10.2991/ahis.k.210913.029.

[38] Y. Liu and H. Li, "Exploring the impact of use context on mobile hedonic services adoption: An empirical study on mobile gaming in

China," Computers in Human Behavior, vol. 27, no. 2, pp. 890–898, 2011, doi: 10.1016/j.chb.2010.11.014.

[39] R. Koci, X. Franch, P. Jovanovic, and A. Abello, "A Data-Driven Approach to Measure the Usability of Web APIs," in 2020 46th Euromicro Conference on Software Engineering and Advanced Applications (SEAA), Portoroz, Slovenia, Aug. 2020, pp. 64–71. doi: 10.1109/SEAA51224.2020.00021.

[40] R. Alexander, N. Thompson, T. McGill, and D. Murray, "The Influence of User Culture on Website Usability," International Journal of Human-Computer Studies, vol. 154, p. 102688, Oct. 2021, doi: 10.1016/j.ijhcs.2021.102688.

[41] A. Amiruddin, R. S. Dewi, and E. Widodo, "Structural modeling for usability attributes on technology acceptance model for smart parking mobile application," IOP Conf. Ser.: Mater. Sci. Eng., vol. 1072, no. 1, p. 012024, Feb. 2021, doi: 10.1088/1757-899X/1072/1/012024.

[42] R. Kumar, A. Irshad Khan, Y. B. Abushark, M. M. Alam, A. Agrawal, and R. A. Khan, "An Integrated Approach of Fuzzy Logic, AHP and TOPSIS for Estimating Usable-Security of Web Applications," IEEE Access, vol. 8, pp. 50944–50957, 2020, doi: 10.1109/ACCESS.2020.2970245.

[43] H. M. Alotaibi, "Computer-Assisted Translation Tools: An Evaluation of Their Usability among Arab Translators," Applied Sciences, vol. 10, no. 18, p. 6295, Sep. 2020, doi: 10.3390/app10186295.

[44] I. K. R. Arthana, I. M. A. Pradnyana, and G. R. Dantes, "Usability testing on website wadaya based on ISO 9241-11," J. Phys.: Conf. Ser., vol. 1165, p. 012012, Feb. 2019, doi: 10.1088/1742-6596/1165/1/012012.

[45] T. Rupere and M. Jakovljevic, "Usability and user evaluation of an integrated multimedia e-learning management system," Knowledge Management & E-Learning: An International Journal, vol. 13, no. 3, pp. 334–366, 2021, doi: 10.34105/j.kmel.2021.13.018.

[46] R. Harrison, D. Flood, and D. Duce, "Usability of mobile applications: Literature review and rationale for a new usability model," Journal of Interaction Science, vol. 1, no. 1, pp. 1–16, 2013.

[47] A. Saleh, R. Ismail, and N. Fabil, "Evaluating Usability for Mobile Application: A MAUEM Approach," in Proceedings of the 2017 International Conference on Software and e-Business - ICSEB 2017, Hong Kong, China, 2017, pp. 71–77. doi: 10.1145/3178212.3178232.

[48] J. Xu, X. Ding, K. Huang, and G. Chen, "A Pilot Study of an Inspection Framework for Automated Usability Guideline Reviews of Mobile Health Applications," in Proceedings of the Wireless Health 2014 on National Institutes of Health, 2014, pp. 1–8. Accessed: Feb. 26, 2015. Available: http://dl.acm.org/citation.cfm?id=2669585

[49] A. Thorpe, K. Nesbitt, and A. Eidels, "Assessing Game Interface Workload and Usability: A Cognitive Science Perspective," in Proceedings of the Australasian Computer Science Week Multiconference on - ACSW 2019, Sydney, NSW, Australia, 2019, pp. 1–8. doi: 10.1145/3290688.3290749.

[50] T. Page, "Usability of text input interfaces in smartphones," Journal of Design Research, vol. 11, no. 1, pp. 39–56, 2013.

[51] A. R. Façanha, W. Viana, M. C. Pequeno, M. de Borba Campos, and J. Sánchez, "Touchscreen Mobile Phones Virtual Keyboarding for People with Visual Disabilities," in Human-Computer Interaction. Applications and Services, Springer, 2014, pp. 134–145. Accessed: Feb. 26, 2015. Available: http://link.springer.com/chapter/10.1007/978-3-319-07227-2_14

[52] B. Poulcheria and V. Costas, "A context management architecture for m-commerce applications," Central European Journal of Computer Science, vol. 2, no. 2, pp. 87–117, 2012.

[53] F. Gündüz and A.-S. K. Pathan, "On the Key Factors of Usability in Small-sized Mobile Touch-Screen Application.," International Journal of Multimedia and Ubiquitous Engineering, vol. 8, no. 3, pp. 115–138, 2013.

[54] M. Quaresma and R. Gonçalves, "Usability Analysis of Smartphone Applications for Drivers," in Design, User Experience, and Usability. Theories, Methods, and Tools for Designing the User Experience, Springer, 2014, pp. 352–362. Accessed: Feb. 26, 2015. Available: http://link.springer.com/chapter/10.1007/978-3-319-07668-3_34

[55] L. Olsina, L. Santos, and P. Lew, "Evaluating Mobileapp Usability: A Holistic Quality Approach," in International Conference on Web Engineering, 2014, pp. 111–129. Accessed: Feb. 26, 2015. Available: http://link.springer.com/chapter/10.1007/978-3-319-08245-5_7

[56] F. Lettner and C. Holzmann, "Automated and unsupervised user interaction logging as basis for usability evaluation of mobile applications," in Proceedings of the 10th International Conference on Advances in Mobile Computing & Multimedia, 2012, pp. 118–127. Accessed: Feb. 26, 2015. Available: http://dl.acm.org/citation.cfm?id=2428983

[57] G. Orlandini, G. A. Castadelli, and L. M. P. Braccialli, "Ergonomics and Usability in Sound Dimension: Evaluation of a Haptic and Acoustic Interface Application for Mobile Devices," in International Conference of Design, User Experience, and Usability, 2014, pp. 193–202. Accessed: Feb. 26, 2015. Available: http://link.springer.com/chapter/10.1007/978-3-319-07626-3_18

[58] R. Ravendran, I. MacColl, and M. Docherty, "A comparative usability study of a tag-based interface in the mobile banking context," in Proceedings of the 13th International Conference of the NZ Chapter of the ACM's Special Interest Group on Human-Computer Interaction, 2012, pp. 80–83. Accessed: Feb. 26, 2015. Available: http://dl.acm.org/citation.cfm?id=2379269

[59] R. Ivanov, "Blind-environment interaction through voice augmented objects," Journal on Multimodal User Interfaces, vol. 8, no. 4, pp. 345–365, Oct. 2014, doi: 10.1007/s12193-014-0166-z.

[60] M. Kenteris, D. Gavalas, and D. Economou, "An innovative mobile electronic tourist guide application," Personal and Ubiquitous Computing, vol. 13, no. 2, pp. 103–118, 2009, doi: 10.1007/s00779-007-0191-y.

[61] A. S. Ajibola, "Usability Attributes and Evaluation Methods for M-Commerce Websites," PhD Thesis, University of South Africa, Pretoria, South Africa, 2019. Available: https://uir.unisa.ac.za/bitstream/handle/10500/29006/thesis_ajibola_as.pdf?sequence=1

[62] A. S. Ajibola and L. Goosen, "Development of heuristics for usability evaluation of m-commerce applications," in Proceedings of the South African Institute of Computer Scientists and Information Technologists, Thaba Nchu, South Africa, 2017, pp. 1–10. doi: 10.1145/3129416.3129428.

[63] S. A. Ajibola and L. Goosen, "Information Systems Architecture and Technology Security Aspects Relating to the Usability Attributes and Evaluation Methods of Mobile Commerce Websites," in 40th International Conference Information Systems Architecture and Technology, Wrocław, Poland, 2019, pp. 40–53.

[64] D. Nyumbeka and J. Wesson, "Using Mobile Computing to Support Malnutrition Management in South Africa," in Proceedings of the Southern African Institute for Computer Scientist and Information Technologists Annual Conference on Empowered by Technology, 2014, pp. 352–360. doi: 10.1145/2664591.2664622.

[65] S. A. Ajibola and L. Goosen, "Development of Landscape of Usability Evaluation Methods for Mobile Applications," International Journal of Computer Science Engineering, vol. 8, no. 2, pp. 89–102, 2019.

[66] A. S. Ajibola and L. Goosen, "Missed Opportunities in Mobile E-Commerce Usability," International Journal of Scientific & Engineering Research, vol. 5, no. 6, pp. 954–956, 2014.

[67] A. S. Ajibola and L. Goosen, "Trends of Mobile E-Commerce Usability in South Africa," South Africa, p. 3, 2013.