FACTOR VALUE AND SYSTEM USABILITY SYSTEM BASED PARAMETERS FORMULATION FOR EVALUATING MOBILE BANKING APPLICATIONS USABILITY

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Abstract
Usability and user experience are a major preoccupation of software services or products. Inept content and design of interface have contributed to issues of mobile apps usability and accessibility issues. The proliferation of mobile devices and smartphones had enabled the mobile marketplace to provide diverse kinds of mobile banking around the world. Interface usability on the part of customers, financial fraud, and design defects are unending challenges of mobile apps adoption in the banking and financial management. Consequent upon these, mobile apps users have rejected and disapprove shortly after their launch. To overcome these problems, this paper formulated a three-tier based parameters for evaluating usability of the mobile banking applications rather than user perception alone. Firstly, the content analysis approach was adopted in selecting 26 relevant attributes from the various usability standards, heuristics and models obtained from the literature. Secondly, the factor value method was used to select and weight the eventual parameters by the different mobile application user-tiers of m-banking products/applications, that is, user, developers/experts and administrators. The outcomes showed that, the factor value of 7.4 out of 9.0 for first-tier went for 10 usability factors: efficiency, satisfaction, effectiveness, ease of use, cognitive load, memorability, trustworthiness, learnability, user-friendliness, and pleasurable. At Factor value of 2.57 out of 9, second-tier went for four usability factors including: quality-in-use (or learnability), satisfaction, security, and efficiency. Whereas the tier 3 chose the seven usability factors at 5.73 out of 9 including: user efficiency, learnability, productivity, security, universality, satisfaction, and privacy. Also, further experts' reviews on the identified usability parameters revealed that, at 4.00 out 5.00 selection threshold, the most preferred m-banking app usability factors are the ease of use, user-friendly, trustworthiness, efficiency, satisfaction, pleasurable, effectiveness, attractiveness, security, portability, and satisfaction. Therefore, the formulated usability parameters can be used effectively to evaluate local m-banking apps in Nigeria.

Keywords: Usability Factors, M-banking, Mobile Apps, Finance, Software Quality**.**

Introduction
In Human Computer Interaction (HCI), the ease of use is often used to describe usability of applications. A number of components have been identified when conducting usability assessments of applications including: memorability, user satisfaction, efficiency, general accuracy, and learning (Asghar *et. al.,* 2022). Presently, user experience and technology acceptance are important considerations in measuring usability of mobile and website banking applications (Shetty *et. al.,* 2022). The efforts are on-going to enable desktop applications run on mobile devices and web browsers for better experiences at anytime and anywhere. The number of Internet users, such as children, adults, and older adults, are increasing which put new constraints on developers to provide diverse functionalities and roles across mobile applications. Mobile apps are a common place for ubiquitous information access (Khowaja, *et al.,* 2019).

Generally, usability was described by the International Organization for Standardization (ISO) (1998) as comprising three scopes: effectiveness (the capability of system to support

completion of users' tasks qualitatively), efficiency (resources consumed by tasks), and satisfaction (subjective reactions of user the system use) (ISO 9241-11) (Vlachogianni & Tselios, 2021).

Usability and user experience are a major preoccupation of software products. Inept content and design of interface have contributed to issues of mobile apps usability. Consequently, mobile apps users reject and disapprove products shortly after their launch. In particular, mobile context of use, connectivity or network, smaller size of screen, diverse resolution, minimal processing capacity, and data entry approach are reoccurring problems of mobile apps. The process of conducting usability attempts to detect flaws, bugs and possible functionality problems for the developers before eventual release to the app marketplace. In addition to that, it enables the developers to check the conformance of mobile apps to the goals and objectives (Othman *et al.,* 2018).

Usability heuristics empowers HCI experts to investigate intricate problems areas for potential users about mobile applications prior to their actual releases (Joyce et al., 2017). Other usability evaluation on the basis of the ISO 92411-11 have been developed in the past, which considers the efficiency, effectiveness and satisfaction of mobile apps users. The proliferation of mobile devices and smartphones and increased high-speed wireless network interconnectivity had motivated diverse kinds of mobile banking globally. Aside the huge revenue generation benefit, mobile banking offers convenient, all-inclusive electronic and ubiquitous transactions consummation.

In spite of the several benefits, the adoption of mobile technologies and innovation in mobile banking is still low and lagging among developing economies like Nigeria. The reasons can be adduced to lack of familiarity, ever changing technology, low literacy levels, poor understanding of the technology, and unattractiveness and lack of enthusiasm about the technology (Msweli & Mawela, 2020). Recently, there are more attentions on m-banking methods and their usability evaluations from the part of customers and the industry stakeholders (Abubakar *et al.,* 2015).

This paper attempts to formulate m-banking apps usability parameters considering three-tiers to increase adoption across the financial value chain in developing economies. The remaining sections of this paper include: the related work is in the section two, section three is the methodology, section four discusses the results, and the conclusion is in the last section.

Related Work

Nielsen (1994) itemised several usability heuristics for evaluating mobile apps based on ten heuristic criteria. These include: system status visibility; matching of system and the real-life scenarios; freedom and control of user; standards and consistency; prevention of error; recall not recognition; Efficiency and flexibility of use; aesthetic and minimalist design; users' guide must identify, analyse, and recuperate from errors; and documentation and help.

Later, Bertini *et. al.,* (2006) created ten(10) new mobile application usability heuristic. According to Joyce et al. (2014), the process of ascertaining the usability of mobile apps involves a number of criteria and metrics known as the SMART criteria. These describe the general practice of mobile application, to perform re-evaluation with another established heuristics, then, the different participants are expected to follow through on all the specified tasks again. thereafter, new issues identified at the stage of the evaluation were assigned by the participants in accordance its severity rate (Sauro, 2013). The severity ratings include: the minor causes certain irritation or hesitation; the moderate causes infrequent failure of task in

case of group of users or resulting in delays and moderate irritation; and the critical causes extreme irritation or leads to failure of tasks.

Bashir & Farooq (2019) introduced the Extending Usability Heuristics for Smartphone Application (EUHSA) including: SH1. The visibility of system status; SH2. Matching system with the real-world settings; SH3. Realistic error management; SH4. User guide and help; SH5. Performance and efficiency of use; SH6. Aesthetic and minimalistic design; SH7. Flexibility and efficiency of use; SH8. Focus on various context of use in mobile environments; SH9. Controls of fingertip dimensions and ergonomics; SH10. Effective design to minimize workload of user; SH11. Recall rather than recognition; SH12. User control and obviousness; and SH13. Consistency and standards.

Gomez *et. al.,* (2014) heuristic evaluation includes: System status [Visibility], [Match] between system and the real-life, User freedom and [control], Standards and [Consistency], Prevention of [Error], [Recognition] rather than recall, Efficiency of use and [Flexibility], [Minimalist] and Aesthetic design, Assist users identify, analyse, and [recover] from errors, User guide and [documentation], [Skills], Pleasurable and respectful [interaction] with the user, [Privacy].
WCAG 2.0 accessibility guidelines include: Text [Alternatives], [Time]-based Media, [Adaptable], [Keyboard] Accessible, [Enough] Time, [Distinguishable], Seizures and Physical Reactions [S and PR], [Readable], [Predictable], [Navigable], Input [Assistance], [Compatible].

Khowaja *et. al.,* (2019) adopted the collection of Heuristics developed by (Gomez *et. al.,* 2014), and Web Content Accessibility Guidelines (WCAG 2.0) accessibility guidelines to perform the virtually impaired mobile app interface.

The mostly utilised usability attributes in the measure and evaluation for mobile applications are presented in Table 1.

Table 1: Top-most mobile applications usability attributes measure and methods

S/N	References	Attributes	Prior Standards/Methods
1.	Asghar et al. (2022)	Efficiency, effectiveness, ease of use, learnability, memorability, cognition and consistency.	HCI usability criteria/Machine learning classification and clustering models (Genetic Algorithm and Support Vector Machine)
2.	Shetty et al. (2022)	Behavioural intention, dependability, efficiency, perspicuity.	Technology Acceptance Model/ structural equation models.
3.	Hamid et al. (2022)	Effectiveness, learnability, memorability, satisfaction, truthfulness, efficiency.	Software application usability models.

4.	Weichbroth (2020)	Satisfaction, efficiency, effectiveness, cognitive load, learnability, errors, memorability, ease of use, simplicity.	ISO 9241-11
5.	Msweli & Mawela (2020)	Usability, user-friendliness, accessibility, trustworthiness, satisfaction.	A systematic literature review of m-banking apps user's preferences.
6.	Khowaja et al. (2019)	Pleasurable, Skills, privacy and respectful interaction of user.	Nielsen heuristics and accessibility guidelines.
7.	Bashir & Farooq (2019)	Efficiency, user's cognitive, interaction, user control and support, and information presentation- based heuristics.	Traditional usability heuristic of smartphones interfaces.
8.	Hussain, Thamer, & Matcharan (2018)	Satisfaction, ease of use of functionalities, suitability.	User's satisfaction of banking mobile app interface measured through set of activities.
9.	Abubakar et al. (2015)	Efficiency, effectiveness, trustfulness, learnability, and user satisfaction.	Usability factors and criteria matching.
10.	Sabao & Lacorte (2019)	Functionality, reliability, efficiency, portability, maintainability, and usability.	Characteristics of ISO 9126 software evaluation.
11.	Hussain et al. (2018)	Effectiveness, learnability, memorability, efficiency, and satisfaction.	Jacob Nielsen usability qualities for Amila pregnancy app.
12.	Shah & Chiew (2019)	-Quality model: Understandability, operability, learnability, and attractiveness as quality-in-use to measure usability. -Sub-characteristics: user interface	ISO 9241-11 and ISO/IEC 25010 for developing pain management mobile app.

		aesthetics, appropriateness, learnability, operability, recognizability, user error protection, and accessibility	
13.	Medina et al. (2019)	User Efficiency, learnability, and satisfaction.	Traditional and empirical methods for remote monitoring of user experience with mobile apps users.
14.	Gupta et al. (2017)	Productivity, security, effectiveness, memorability, satisfaction, efficiency, and universality.	Fuzzy hierarchical usability model from HCI and software models.

Table 1 reveals a number of adaptations from existing standards and heuristics usability of software products, systems and applications cutting across the mobile devices, desktops and specific application areas. The criteria, factors and attributes have been utilised measuring usability target groups of participants from the developers/administrators, end-users /customers, and expert reviewers.

In the context of mobile applications, previous works have adopted the usability definition of the ISO 9241-11 standard. Usability is described as the degree to which a product, system, or service can be put to use by particular group of users in order to attain set objectives of efficiency, effectiveness, and satisfaction in a given context of use (Othman *et al.,* 2018; Weichbroth & Baj-rogowska, 2019). In addition to the three attributes mentioned earlier, other works have enlisted certain attributes such as learnability, memorability, cognitive load, errors, ease of use, navigation and operability (Pallud, 2017). Considering user's experience, which is one's responses and perceptions occasioned from the use and/or expected a product use, service or system are a major concern. Several subfactors can be derived from user's experience dimension including: aesthetics, enjoyment, hedonics, trust, support, engagement, discomfort and frustration. It follows that usability can be interpreted from the user's perspective of personal goals, which involves perceptual and emotional aspects usually associated with user's experience. Therefore, usability criteria can elicit useful means of evaluating certain parts of user's experience (Othman *et al.*, 2018; Weichbroth & Baj-rogowska, 2019).

The development of m-banking applications needs the complete involvement and iterative evaluation of potential consumers and usability experts. The process of assessing usability entails: ascertaining the rate to which an interactive system may be utilised by expected end-users in order to attain set goals with efficiency, effectiveness, and satisfaction in an identified context of use (Medina *et al.,* 2019).

Methodology

Proposed Usability Parameters Formation

Suppose that, the mobile applications usability and accessibility are considered to be a parallel condition composed of independent contextual factors of end users' activities or interactions. The paper introduces three-tier usability parameters formulation for m-banking apps by leveraging on *Factor*$_{value}$ and System Usability Scale (SUS) with the Firefly (deep learning) method to model the mobile applications resource utilization which is considered to be a parallel condition composed of independent contextual factors of end users' activities or interactions at the distinct tiers. The selection function is to be solved as individual mobile user for all the contextual factors understudied. The paper assumes that firefly set is M, the location of (x_j, y_j) of the quantity j firefly relates to the selection function $h(x_j, y_j)$ and value of Luciferin of the firefly is V_j, and the updating equation upon consideration of all possible factors is given by Equation 1:

$$D_j = h(x_j, y_j) \times \varphi \frac{V_j}{N^{h-t}} \quad 1$$

The aggregate usability weight or index for the given time, *t,* and contextual factors for all the parallel firefly set (*M*) or end use nodes (that is, the influence matrix) are given by Equation 2:

$$Y = D_j \otimes V_j = \left[\frac{\left(h(x_j, y_j) \times \varphi \frac{V_j}{N^{h-t}} \right)}{\frac{\max_{j=1} D_j \times M}{N}} \right]_{j=1}^{t} \times Z_{j=1}^{M} \quad 2$$

where,

Z is the influence matrix or impact factor for firefly set, *M*, for the mobile application on the basis of individual Luciferin value,

V_j for the parallel mobile end users' activities of the applications.

The usability assessment aggregate index is *Y* for the various activities and history φ.

The number of instances is denoted by *N.*

The factors determination involved the rating of each usability parameter by an individual measuring the m-banking app usability in order of magnitude using mapping scale of 0-9, the probability is described as the degree of event happening or otherwise. The *Factor*$_{value}$ can be expressed using Equations 3 and 4.

$$P(factor) = \frac{Number\ of\ matched\ factors\ with\ value\ of\ 1}{Total\ number\ of\ matched\ factors} \quad 3$$

$$Factor_{value} = P(factor) * Max_{mapping\ scale\ value} \quad 4$$

where,

$P(factor)$ = probability of a factor of mobile apps usability models,

$Factor_{value}$ = the realised from each factor of mobile apps usability models,

Max_{value} = the maximum value of the mapping scale (that is, 9).

The attributes scoring using ascending order of weights is defined by the appropriate fitness function given by Equation 5.

$$F = P(factor) + T \quad 5$$

where, if and only if (iff) for an exact solution, and $T \rightarrow 0$, and $F \rightarrow 1$.

The value of F defines the score of each attribute of evaluation performed by individuals. This implies that, larger residue value decreases the fitness one.
Also, the factors are subjected to the SUS approach in which users are required to rate their preference from the bag of factors generated as illustrated by Equation 6.

$$U(factor) = \{s: s0 \leq f \geq sn\} \quad 6$$

where,
U is the universal set or bag of factors containing highly and lowly influential,
s is the aggregated average factors from the original bag of considered by users,
$s0$ is the lowly influential factors,
sn is the highly influential factors,
f is the objective function for selecting the best fit and influential factors of usability evaluation.

The resultant factors or parameters are determined using combinations of factors realized from $P(factor)$, and the SUS methods, which is expressed by Equation 7.

$$Rf = \{U(factor) \cap P(factor)\} \quad 7$$

where,
Rf is the final/resultant factors for evaluating the usability of m-banking apps, and
$\cap$ is the overlapping function between factors generated from the two methods illustrated in Equations 6 and 7.

The context of environment measures the tools and appraisal of generalizability, attribute coverage and quality of m-banking mobile applications. This is the usability expert side of the proposed model in which the usability heuristics parameters are adopted.

sThe context of interaction measures the mobile apps user's capability to attain certain tasks and operations with satisfaction, effectiveness and efficiency. This is to be accomplished by the end-users of the m-banking apps by adopting the Nielson's usability parameters.

The context of accessibility refers to the remote monitoring of mobile apps users regarding ease of accessing content, and their behavioural characteristics. This is to be achieved by the administrators of the m-banking apps through the usability heuristics parameters adoption. In this paper, twenty-six (26) usability parameters were initially identified for measuring the m-banking apps usability as realized from the ISO standards, HCI, and heuristics. These parameters are illustrated in Table 2.

Table 2:The usability parameters with matching the three tiers of m-banking apps.

Tier	Parameters	Methodology
1 – Customer	Efficiency, satisfaction, effectiveness, ease of use, cognitive load, memorability, trustworthiness, learnability, user-friendliness, pleasurable, errors, and attractiveness.	System Usability Scale (SUS) of User experience.
2 – Expert/Developer	Quality-in-use (understandability, operability, learnability, and attractiveness), user interface aesthetics, appropriateness, satisfaction, learnability, recognizability, user error protection, accessibility, security, and efficiency.	Analytical usability evaluation method.
3 – Administration	User efficiency, learnability, productivity, security, universality, satisfaction, information presentation, ease of use of functionality, maintainability, portability, and privacy.	Remote monitoring with machine learning. Empirical usability evaluation method.

Table 2 describes the methodology deployed for the different tiers of usability evaluation as follows: User Experience: This entails the capability of an interface to enable users to achieve tasks efficiently and quickly as specified in the ISO 9241 definition (part 210): the emotions, preferences, beliefs, physical, perceptions, and psychological responses, behaviours, and activities of users that happen prior, at the time of use, and post usage. Often, SUS is a 10-point measuring instrument for ascertaining the perception of website, mobile apps or product' usability. Empirical evaluation method: It entails observing user's effort at tasks on an interface (website, app, or product) to detect issues (formative) or to appraise its ease of use with factors or attributes (summative). Analytic usability evaluation method: It uses a collection of experts in evaluating an interface with a given criteria for the purpose of revealing the possible issues for users. This makes use of heuristic appraisal in which the assessors appraise an interface in accordance with a collection of universal design principles and heuristics for m-banking apps.

B. Usability Parameters Determination

The distinct models utilised for explaining the concept m-banking and general mobile apps with associated usability parameters are specified in Table 5. On the basis of the reviewed usability models, the value of 1 is assigned to models containing matching factors or attributes, while the models excluding matching factors or attributes are assigned 0. The mapping scale of 0-9 is used for validating the proposed model by means of probability as defined in Equation 5 (Gupta et al., 2017).

C. Description Data Collection Procedure

This survey targets a population of 20 participants (End-user, Developer, and Administrator) non-randomly selected with experiences of top-five m-banking apps. Since the sampling frame was hard to obtain due to the Personal Information Protection Act that restricts financial institutions from disclosing personal data about users, a non-random sampling method was adopted for data collection. The voluntary respondents were recruited through a physical contact interview and questionnaire drawn on the selected participants like in comparable studies. The sampled size breakdown is as follows: End-users = 10; Developers = 5; and Administrators = 5.

D. The research instrument construction

This paper constructed structured questionnaire for the purpose of gathering the data useful for formulating new m-banking app usability evaluation parameters of the money deposit banks mobile applications. The lists of criteria used with their descriptions for developing the questionnaire and content analysis with associated nominal scale (1 – 5) of m-banking usability evaluation. The participants with history of five m-banking apps usage in the last one year were recruited for the survey across five top banks by e-Transaction profit margin for H1, Year 2023 including: GTCO, ZENITH, FBNH, ACCESS HOLDINGS, and UBA. The survey respondents were within Nigerian Cities of Abuja (15) and Minna (5), and Lagos (5).

Results and Discussion

A. Model Validation Outcomes

Table 3 (a, b, c) presents the analysis of the factors value computations of the comparable m-banking apps usability models against the proposed usability parameter, which were formulated across the three-tiers. Accordingly, the value of 1 is assigned whenever an existing model had a matching factor; otherwise, the score of 0 is assigned for no matching factor. These values are used to formulate the valid factor scores required in the formulated m-banking apps usability evaluation. Similarly, in the Table 3(a, b, c), the $P(factor)$ and $Factor_{value}$ are computed for all the factors across the three tiers by summating the scores of each existing model. For instance, in Table 3(a), the total count of the proposed factors for tier 1=12

(adapted from Table 2), the factor: efficiency has total score = 3, P(factor)=3/12, the highest-ranking scale = 9, and $Factor_{value}$ = ((9*3)/12) = 2.25. Therefore, the new usability parameters had a p(factor) score of 0.8333, and a $Factor_{value}$ of 7.5. By leveraging on three tiers of participants, the proposed usability model's parameters, its corresponding factors, and mapped factor values on the scale of 0-9 are presented in Table 3(a, b, c).

Table 3: (a). Mapped factor values of the usability models on the scale of 0-9 for Tier 1.

Factors	Weichbroth (2020)	Msweli & Mawela (2020)	Khowaja et al. (2019)	Bashir & Farooq (2019)	Abubakar et al. (2015)	New usability parameters
Efficiency	1	0	0	1	1	1
Satisfaction	1	1	0	0	1	1
Effectiveness	1	0	0	0	1	1
Learnability	1	0	0	0	1	1
Ease of use	1	0	0	0	0	1
Cognitive load	1	0	0	1	0	1
Memorability	1	0	0	0	0	1
Trustworthiness	0	1	0	0	1	1
User-friendliness	0	1	0	0	0	1
Pleasurable	0	0	1	0	0	1
Errors	0	0	0	0	0	0
Attractiveness	0	0	0	0	0	0
Total score	7	3	1	2	5	10
p(factor)	0.5833	0.25	0.0833	0.1667	0.4167	0.8333
Factor(value)	5.25	2.25	0.75	1.5	3.75	7.5

From Table 3(a), the new usability parameters had 10 factors including: efficiency, satisfaction, effectiveness, ease of use, cognitive load, memorability, trustworthiness, learnability, user-friendliness, and pleasurable. The $Factor_{(value)}$ for the new model is the best at 7.5 out 9, which is closely followed by 5.25, 3.75, and 2.25 for (Weichbroth, 2020), (Abubakar et al., 2015), and (Msweli & Mawela, 2020) respectively.

Table 3: (b). Mapped factor values of the usability models on the scale of 0-9 for Tier 2.

Factors	Msweli & Mawela (2020)	Hussain et al. (2018)	Sabao & Lacorte (2019)	Hussain, et al. (2018)	Gupta et al. (2017)	Abubakar et al. (2015)	New usability parameters
Quality-in-use	X	X	X	X	X	X	X
Understandability	0	0	0	0	0	0	0
Operability	0	0	0	0	0	0	0
Learnability	0	1	0	0	0	1	1
Attractiveness	0	0	0	0	0	0	0
User interface aesthetics	0	0	0	0	0	0	0
Appropriateness	0	0	0	0	0	0	0
Satisfaction	1	1	1	1	1	1	1
Operability	0	0	0	0	0	0	0
Recognizability	0	0	0	0	0	0	0
User error protection	0	0	0	0	0	0	0
Accessibility	1	0	0	0	0	0	0
Security	0	0	0	0	1	0	1
Efficiency	0	0	1	0	1	1	1
Total score	2	1	1	1	3	3	4
p(factor)	0.1429	0.0714	0.0714	0.0714	0.2143	0.2143	0.2857
Factor(value)	1.29	0.64	0.64	0.64	1.93	1.93	2.57

In Table 3(b), the proposed model has four factors including: quality-in-use (learnability), satisfaction, security, and efficiency. The $Factor_{(value)}$ for the new usability parameters is the best at 2.57 out 9, which is closely followed by 1.93 (Gupta et al, 2017), (Abubakar et al., 2015), and 1.29 (Msweli & Mawela, 2020) respectively.

Table 3: (c). Mapped factor values of the usability models on the scale of 0-9 for Tier 3.

Factors	Shah & Chiew (2019)	Medina, et al. (2019)	Khowaja et al. (2019)	Gupta et al. (2017)	New usability parameters
User efficiency	0	1	0	0	1
Learnability	1	1	0	0	1
Productivity	0	0	0	1	1
Security	0	0	0	1	1
Universality	0	0	0	1	1
Satisfaction	0	1	0	1	1
Information Presentation	0	0	0	0	0
Ease of use of functionality	0	0	0	0	0
Maintainability	0	0	0	0	0
Portability	0	0	0	0	0
Privacy	0	0	1	0	1
Total score	1	3	1	4	7
p(factor)	0.0909	0.2727	0.0909	0.3636	0.6364
Factor(value)	0.82	2.45	0.82	3.27	5.73

Table 3(c) shows the proposed model as having seven factors including: user efficiency, learnability, productivity, security, universality, satisfaction, and privacy. The $Factor_{value}$ for the new usability parameters is the best at 5.73 out 9, which is closely followed by 3.27, and 2.45 for (Gupta et al., 2017) and (Medina et al., 2019) respectively. The m-banking apps usability evaluation covers twenty-six (26) parameters cutting across the three-tiers. The Tier-1 has the highest usability index of 7.5, followed by the Tier-3 by 5.73, and the Tier-2 by 2.57. The outcomes showed the indispensability of the end-users and administrators during usability evaluation processes in terms of offering more realistic, contextual and highly sensible

feedback. It follows that the concept emphasized in this paper, that interaction and context of environment are a key in usability assessments of m-banking apps.

The resultant usability factors and context of evaluation of m-banking apps after the complete process of factors selection are presented in Table 4.

Table 4: The usability parameters and context of evaluation of m-banking apps.

Tier	Usability Parameters	Context of Evaluation
1.	Efficiency, satisfaction, effectiveness, ease of use, cognitive load, memorability, trustworthiness, learnability, user-friendliness, pleasurable, errors, and attractiveness.	Interaction
2.	Quality-in-use (understandability, operability, learnability, and attractiveness), user interface aesthetics, appropriateness, satisfaction, learnability, recognizability, user error protection, accessibility, security, and efficiency.	Environment
3.	User efficiency, learnability, productivity, security, universality, satisfaction, and privacy.	Accessibility

Table 4 depicts the overlapping usability parameters from the various context of evaluation as well as tiers presented in Table 2. These include: efficiency, satisfaction, effectiveness, memorability, learnability, attractiveness, and security. These outcomes are in accordance with the previous works' contributions on usability parameters and measures of m-banking apps when compared to the initial usability parameters defined by ISO, Heuristic, HCI, and other standards/studies.

B. Mobile Usability Parameters Selection using System Usability Scale Method

The weights of usability factors for m-banking apps through survey approach measured with SUS technique whose steps are presented as follows:

Step 1: The respondents' responses are collected and tallied for each of the m-banking applications usability evaluation factors as shown in Table 5.

Table 5: Respondents' responses on preferred m-banking apps usability parameters.

Usability Parameter	End-user Weight	Admin Weight	Expert Weight	Aggregated Average Weight
Efficiency	4.08	4.40	4.10	4.19
Satisfaction	4.08	4.30	4.10	4.16
Effectiveness	4.00	4.30	4.10	4.13
Ease of use	4.25	4.50	4.20	4.32
Cognitive load	3.54	4.30	3.50	3.78
Memorability	3.96	4.00	4.00	3.99
Trustworthiness	4.00	4.40	4.30	4.23
User-friendly	4.13	4.50	4.20	4.28
Pleasurable	4.13	4.30	4.00	4.14
Errors	2.75	3.10	2.70	2.85
Attractiveness	4.08	4.30	3.80	4.06
Quality in use	3.58	3.80	3.60	3.66
User interface aesthetics	3.58	3.70	3.80	3.69
Appropriateness	3.63	3.80	3.80	3.74
Learnability	3.67	4.20	3.80	3.89
Recognizability	3.75	3.80	3.80	3.78

User error protection	3.13	3.50	3.20	3.28
Accessibility	3.79	3.80	4.10	3.90
Security	3.83	4.10	4.10	4.01
Productivity	3.75	4.00	3.90	3.88
Information presentation	3.67	3.70	3.70	3.69
Éase of use of functionality	3.58	3.70	3.80	3.69
Maintainability	3.58	3.60	3.70	3.63
Portability	3.92	4.10	4.00	4.01
Privacy	3.88	4.20	3.60	3.89

Step 2: The ranking of the average aggregate weight of usability parameters using descending order of magnitude for the three-tiers of respondents as presented in Table 6.

Table 6: Ranking of aggregated weights of preferred m-banking apps usability parameters.

Usability Parameter	Aggregated Average Weight	SUS Score (%)
Ease of use	4.32	86.40
User-friendly	4.28	85.60
Trustworthiness	4.23	84.60
Efficiency	4.19	83.80
Satisfaction	4.16	83.20
Pleasurable	4.14	82.80
Effectiveness	4.13	82.60
Attractiveness	4.06	81.20
Security	4.01	80.20
Portability	4.01	80.20
Memorability	3.99	79.80
Accessibility	3.90	78.00
Privacy	3.89	77.80
Learnability	3.89	77.80
Productivity	3.88	77.60
Recognizability	3.78	75.60
Cognitive load	3.78	75.60
Appropriateness	3.74	74.80
Universability	3.74	74.80
User interface aesthetics	3.69	73.80
Éase of use of functionality	3.69	73.80
Information presentation	3.69	73.80
Quality in use	3.66	73.20
Maintainability	3.63	72.60
User error protection	3.28	65.60
Errors	2.85	57.00

From Table 6, the most influencing usability parameters for evaluating m-banking apps are realised through the average aggregate weights and SUS score of the selected parameters. Accordingly, the study considered parameters with average aggregated weights with 4.00 (SUS score of 80.00%) or more as having high weighting score. Consequently, the overlapping usability parameters from the survey conducted for the three tiers include: ease of use, user-friendly, trustworthiness, efficiency, satisfaction, pleasurable, effectiveness, attractiveness, security, portability, and satisfaction.

Conclusion

The quest to realise distinct user's behaviours can be done in two ways: dynamic and static personalization. The dynamic personalization involves user activity logs that offer feedback to the personalized tool available on the mobile applications. In addition, predictive analytics are utilised in predicting the usage behaviour (such as machine learning schemes) with proactively situate the application for the user. The process of evaluating m-banking apps requires contextual interaction, contextual environmental, and contextual accessibility. This study delineated the entire procedure of conducting usability assessment along these three-tiers: consumer, expert, and administrator.

There are twenty-six (26) parameters identified for m-banking mobile applications covering existing standards, heuristics and models of usability evaluation. The outcomes reveal that significant number of activities have been assigned to diverse participants for accuracy, speed and reliability. Also, this paper adopted the SUS model with selection criteria of 4.0 for treatment of experts' survey responses that realized the following usability parameters: ease of use, user-friendly, trustworthiness, efficiency, satisfaction, pleasurable, effectiveness, attractiveness, security, portability, and satisfaction.

The future works, the proposed usability parameters can be used to evaluate financial products/apps to predict continuous usage or otherwise. Also, multicriteria decision-making (MCDM) approaches can be adopted in the selection and refinement of the m-banking apps usability factors like fuzzy hierarchical process model.

References

Abubakar, H. I., Hashim, N. L., & Hussain, A. (2015). Modelling subjective measurements for usability evaluation of m-banking application interface. *International Journal of Emerging Technologies in Computational and Applied Sciences,* 87–92.

Abubakar, H I., Nor, L. H., & Hussain, A. (2015). Verification process of usability evaluation model for m-banking application. *17th International Conference on Mathematical and Computational Methods in Science and Engineering*. *WSEAS Transactions on Computers*.

Asghar, M., Bajwa, I. S., Ramzan, S., Afreen, H., & Abdullah, S. (2022). A genetic algorithm-based support vector machine approach for intelligent usability assessment of m-learning applications. *Mobile Information Systems*, 2022*,* 1609757, 1-20. https://doi.org/10.1155/2022/1609757

Bashir, M. S., & Farooq, A. (2019). EUHSA: Extending usability heuristics for smartphone application. *IEEE Access, 7*, 100838–100859.

Bertini, E., Gabrielli, S., & Kimani, S. 2006. Appropriating and Assessing Heuristics for Mobile Computing. In *Proceedings of Working Conference on Advanced Visual Interfaces*.

Yanez-Gomez, R., Cascado-Caballero, D., & Sevillano, J. L. (2014). Heuristic evaluation on mobile interfaces: A New Checklist. *The Scientific World Journal, 2014*(1), 434326.

Gupta, D., Ahlawat, A. K., & Sagar, K. 2017. Usability prediction & ranking of SDLC models using fuzzy hierarchical usability model. *DE Gruyter Open Eng., 7*, 161–168. https://doi.org/10.1515/eng-2017-0021

Hamid, K., Iqbal, M. W., Muhammed, H. A. B., Fuzail, Z., Ghafoor, T. Z., & Ahmad, S. 2022. Usability evaluation of mobile banking applications in digital business as emerging economy. *International Journal of Computer Science and Network Security, 22*, 2 (2022): 250–260.

Hussain, A., Mkpojiogu, E. O. C., Fadzil, N., Hassan, N., & Zaaba, Z. F. 2018. A mobile usability evaluation of a pregnancy Application. *Journal of Telecommunication, Electronic and Computer Engineering*, 10, 1 (2018): 13–18.

Hussain, A., Thamer, A., & Matcharan, A. 2018. The challenges of mobile banking application on novice users the challenges of mobile banking application on novice users. In *AIP Conference Proceedings, 2016*, 1 (2018), 020050.

International Organization for Standardization (1998). ISO 9241-11: Ergonomic requirements for office work with visual display terminals (VDTs): Part 11: Guidance on usability. https://doi.org/10.3403/01822507

Joyce, G., Lilley, M., Barker, T., & Jefferies, A. 2017. Mobile application usability heuristics: decoupling context-of-use. *DUXU 2017, Part I, LNCS, vol. 10288,* pp. 410–423. Springer, Cham. https://doi.org/10.1007/978-3-319-58634-2

Joyce, G., & Lilley, M. 2014). Towards the development of usability heuristics for native smartphone mobile applications. In Marcus, A. (ed.) *DUXU 2014, LNCS, vol. 8517, pp. 465–474*. Springer, Cham. https://doi.org/10.1007/978-3-319-07668-3_45

Khowaja, K., Al-thani, D., Aqle, A., & Banire, B. (2019). Accessibility or usability of the user interfaces for visually impaired users? A Comparative Study. In *International Conference on Human-Computer Interaction,* 267-283. Springer, Charm. https://doi.org/10.1007/978-3-030-23560-4

Kortum, P., & Sorber, M. 2015. Measuring the usability of mobile applications for phones and tablets. *International Journal of Human-Computer Interaction*, 31 (8), 518–529.

Medina, J. L. P., Acosta-Vargas, P., & Rybarczyk, Y. (2019). A Systematic review of usability and accessibility in tele-rehabilitation systems. In *Assistive and Rehabilitation Engineering,* 1357633X2098603. IntechOpen.

Msweli, N. T., & Mawela, T. (2020). Enablers and barriers for mobile commerce and banking services among the elderly in developing countries: A Systematic Review. In *Conference on e-Business, e-Service and e-Society*, 319-330. Springer, Charm.

Nielsen, J., & Molich, R. (1990). Heuristic evaluation of user interfaces. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems: Empowering People*.

Nielsen, J. 1994. *Heuristic evaluation*. In Nielsen, J., Mack, R.L. (eds.), Usability inspection methods. Wiley, New York.

Othman, M. K., Sulaiman, M. N. S., & Aman, S. (2018). Heuristic evaluation: Comparing generic and specific usability heuristics for identification of usability problems in a living museum mobile guide Application. *Advances in Human-Computer Interaction*, *2018*, 1518682 (2018): 1–13.

Pallud, J. (2017). Impact of interactive technologies on stimulating learning experiences in a museum. *Information and Management, 54*, 4 (2017), 465–478.

Sabao, J. S., & Lacorte, A. M. (2019). Cloud-based real-time bulletin board posting using angularjs framework. *International Journal of Simulation-Systems, Science & Technology*, *20*, 1–10.

Sauro, J. (2013). Rating the severity of usability problems. *Measuring Usability*. Accessed on December 28, 2021.

Shah, U. M., & Chiew, T. K. (2019). SS symmetry A systematic literature review of the design approach and usability evaluation of the pain. *Symmetry*, *11*, 400 (2019): 1–24.

Shetty, D. K., Bhagawati, J., Shetty, S., Rodrigues, L. L. R., Kumar. A., Tilwani, P., Vanahalli, K., Kishore B., Namesh, M., Chaabra, S., Makkithaya, K., & Nair, N. N. (2022). Enhancing technology acceptance through user experience evaluation: Comparative Analysis of Banking Websites Versus Mobile Application. *Engineered Science, 19*, 154 – 166.

Vlachogianni, P., & Tselios, N. (2021). Percieved Usability evaluation of educational technology using system usability scale (SUS): A Systematic Review. *Journal of Research on Technology in Education,* 1-19. https://doi.org/10.1080/15391523.2020.1867938

Weichbroth, P. (2020). Usability of mobile applications: A Systematic Literature Study. *IEEE Access*, *8*, 55563–55577.

Weichbroth, P., & Baj-rogowska, A. (2019). Do online reviews reveal mobile application usability and user experience? The case of whatsapp. In *Proceedings of the Federated Conference on Computer Science and Information Systems*, *18*, 747–754.

Yeratziotis, A., & Zaphiris, P. (2017). A heuristic evaluation for deaf web user experience (HE4DWUX). *International Journal of Human-Computer Interaction, 34,* 3 (2017): 195–217.