JCBI
Journal of Computing & Biomedical Informatics
ISSN: 2710 - 1606
Volume 07 Issue 02
2024

*Research Article*
https://doi.org/10.56979/702/2024

# Enhancing User Experience: Cross-Platform Usability in Digital Banking Apps

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**Received:** March 02, 2024 **Accepted:** May 01, 2024 **Published:** September 01, 2024

**Abstract:** Word is a Global village so banking services are performing vital role in the modern world to manage the trades, but still there is a problem to intercommunication between different banking services. Digital banking, ensuring uniform User Experiences (UX) across diverse platforms which is also a significant challenge. Through a review of existing literature on UX design principles, platform-specific considerations, and measurement methodologies, a structured framework is synthesized to assess the consistency and seamlessness of interactions within digital banking apps across web browsers, mobile devices, and desktop applications. The proposed model Cross-Platform Usability Measurement (CPUM) addresses a comprehensive measurement model tailored to evaluate cross-platform uniformity in digital banking applications. Includes both qualitative and quantitative metrics, focusing on key dimensions such as visual consistency, navigation fluidity, feature parity, and responsiveness. Leveraging principles from usability engineering, human-computer interaction, and cognitive psychology, the model provides a robust methodology for evaluating design strategies aimed at harmonizing UX across diverse platforms. Additionally, we offer a practical guidelines and best practices for digital banking app developers, and designers. Highlighting to optimizing cross-platform consistency to enhance user satisfaction, trust, and engagement. By establishing a systematic approach to measuring and improving cross-platform uniformity, this aims to empower stakeholders in the digital banking industry to deliver seamless interactions, ultimately fostering greater user loyalty and retention in a competitive market.

**Keywords:** Usability; User Experience (UX); Cross-Platform; Interactions; Apps

## 1. Introduction

Mobile applications have become ubiquitous in contemporary digital interactions, with users relying on various platforms for diverse purposes, including banking, entertainment, and productivity. However, achieving a consistent and seamless user experience across different platforms remains a significant challenge for developers and designers. This study introduces a research endeavor that aims to contribute to the field of user experience design by crafting a measurement model specifically tailored for cross platform uniformity in mobile app interactions. In the realm of mobile app development, iOS and Android stand as the dominant platforms with significant market share.

However, the landscape is evolving, and the prevalence of cross platform technologies remains crucial, with numerous app development frameworks available. The industry's interest appears to be centered on solutions that are both straightforward and customizable. This inclination is exemplified in minor patents, such as those detailing the customization of a mobile application through a web-based interface [1].

1.1. Android and iOS Experience

Cross platform development is a widely discussed concept that proves advantageous in various scenarios, allowing for the inclusion of key platforms such as Android and iOS [2]. Since 2014, there has been a rapid global increase in the usage of mobile devices across various platforms, including Android, iOS, and Windows [3]. In the current digital landscape, users expect a fluid and consistent experience whether they are using a mobile app on iOS, Android, or other platforms. However, variations in design, functionality, and overall user experience often hinder this uniformity. This research seeks to address this challenge by developing a comprehensive measurement model that evaluates and guides the creation of cross platform experiences that are not only visually harmonious but also functionally seamless. Keeping abreast of the ever-evolving landscape of cross platform frameworks poses an inherent challenge to academic research due to the swift release, updates, and deprecation cycles. Despite this challenge, it remains crucial to stay informed about the latest developments and technical advances. However, the continuous emergence of new frameworks brings with it the promise of addressing existing challenges, necessitating thorough assessment and scrutiny [4]. As more devices connect, there's a growing need for services that work smoothly across them all. The idea of "Inter-usability" or cross platform usability, coined by Karsenty and Denis, captures how easily users can switch between devices while still using their skills. To make this seamless, multiservice services must follow the continuity principle, ensuring a consistent user experience. This highlights the importance of evaluating usability when users perform tasks across different platforms. A consistent design in cross platform services is key, allowing users to effortlessly use their skills on any platform. Cross platform development frameworks have been popular due to the heterogeneity of the top mobile platforms in terms of user interfaces, user experience, programming language, and ecosystem. These facilitate the development of mobile apps that can run on the target platforms (usually Android and iOS) with little or no platform specific code. Researchers and practitioners alike are interested in the underlying technologies because of the cost and timesaving opportunities presented by using such a framework [5].

1.2. Digital Banking

In today's digital age, banking has evolved from traditional in-person interactions to seamless digital experiences. Digital banking apps have become integral to modern financial management, offering users the convenience of managing their finances across various devices. However, ensuring a consistent and smooth user experience across different platforms presents unique challenges that developers must address to maintain customer satisfaction and loyalty. Cross-platform usability in digital banking apps is about delivering a seamless and consistent user experience, no matter the device or platform being used. It involves designing apps that eliminate friction points and provide intuitive navigation for fundamental tasks such as checking balances, transferring funds, and making payments. This consistency is essential as it allows users to switch between devices and smartphones, tablets, or desktops: without relearning the app's interface or functionalities. By carefully considering and optimizing each platform's unique characteristics, developers can create a unified and intuitive user experience. The concept of cross-platform usability hinges on the ability of digital banking apps to offer a seamless experience across various devices. Whether a user accesses the app on a smartphone during a commute, on a tablet at home, or on a desktop at work, the app must deliver similar levels of usability and functionality. This seamless experience is crucial because it ensures that users do not face interruptions or a learning curve when switching between devices, which could lead to frustration and a poor user experience. Consistency in usability fosters trust and convenience, encouraging users to engage with their digital banking app more frequently and with greater confidence [6].

1.3. Cross-Platform Adaptability

In practical terms, achieving cross-platform usability means that the navigation and functionality of the app remain consistent across all platforms. This consistency includes the uniform placement of navigation elements, a cohesive design language, and the assurance that all essential features are accessible and functional on every device. For instance, users should be able to find and use features like balance checking or fund transfers in the same way, regardless of whether they are on a mobile app or a web-based platform. By maintaining this uniformity, developer’s help users perform tasks efficiently, enhancing their overall satisfaction with the app. While maintaining consistency, cross-platform usability also requires adapting the app's design and functionality to the unique characteristics of each platform. For example, a smartphone app must accommodate smaller screens while providing an intuitive and visually appealing interface. In contrast, a desktop version may take advantage of larger screen real estate to display more

information or offer additional features. This adaptation ensures that the app not only looks good but also performs well on each platform, providing an optimized user experience tailored to the specific device being used [7].

At the heart of cross-platform usability is the goal of eliminating user friction by removing barriers to accessing and using banking services across different platforms. This involves streamlining processes, minimizing load times, and optimizing interactions to ensure a smooth and hassle-free user experience. By focusing on reducing user effort and simplifying interactions, developers can create digital banking apps that users find easy to use and reliable, regardless of the platform. This approach not only enhances user satisfaction but also promotes greater engagement and loyalty to the banking app.

1.4. Motivation of the Study

The motivation behind this study stems from the growing reliance on digital banking services and the increasing demand for seamless cross-platform experiences. As consumers engage with banking services through a variety of devices, financial institutions face the challenge of maintaining a consistent and high-quality user experience across all platforms. The lack of a standardized approach to evaluating cross-platform usability makes it difficult for developers to identify and address usability issues effectively [8]. This study is driven by the need to bridge this gap by providing a rigorous, quantifiable method for assessing and improving UX in digital banking apps. By focusing on critical aspects such as navigation efficiency, visual appeal, and task completion rates, the research aims to offer financial institutions a deeper understanding of how users interact with their apps across different platforms. This, in turn, will help these institutions design more intuitive, accessible, and satisfying digital experiences, enhancing customer satisfaction and loyalty in an increasingly competitive market.

1.5. Autho's Contribution

This research makes significant contributions to the field of digital usability. It introduces innovative usability metrics tailored for evaluating and enhancing user experience across various digital platforms, such as mobile and web interfaces. This new metrics standardizes usability assessments and provides deep insights into user behaviors, identifying unique challenges and opportunities in digital banking. Through empirical research and detailed comparative analysis, the study validates these novel metrics and offers practical guidelines for designers and developers to optimize app usability [9]. Furthermore, this research establishes benchmarks and best practices that can shape industry standards and suggests future research directions to refine cross-platform usability evaluation in the digital banking sector.

## 2. Literature Review

Native apps are created separately for each target platform using vendor supplied Software Development Kits (SDK). The user has a restricted selection of supported programming languages, which varies depending on the target platform. Android, for example, supports Java, Kotlin, and C++, and iOS supports ObjectiveC and Swift. The benefit of having complete control over the platform APIs serves as a benchmark against the development of apps employing various cross platform methodologies. In general, cross-platform programming use a single code base that can be performed across multiple systems. Platforms in this context often relate to various operating systems offered by software or hardware providers, such as Android or iOS. Furthermore, device fragmentation may lead various versions of the same underlying operating system to be treated as separate platforms. For example, hardware makers frequently modify Android to specific devices, and significant modifications to user interfaces (e.g., Android material design) and technical APIs can occur as platforms grow over time [10].

In the development of digital banking apps, cross-platform development approaches play a pivotal role in ensuring consistent user experiences across various devices. Progressive Web Apps (PWAs) provide a seamless and responsive user interface by leveraging technologies like Service Workers and Web App Manifests, which support offline capabilities and cross-browser compatibility. However, PWAs often encounter limitations in accessing native device functionalities. Hybrid apps, using frameworks such as Apache Cordova and Ionic, allow developers to reuse web code and access native APIs within a native container, promoting efficient development [9] and cross-platform consistency. Despite their advantages, hybrid apps can suffer from performance issues and reliance on WebView. Runtime-based and interpreted apps, exemplified by React Native and Flutter, execute code at runtime to offer native-like User Interface (UI) experiences and rapid development. These apps provide access to native APIs but can face challenges like performance concerns and larger app sizes. Similarly, Xamarin falls into this category, delivering near-native performance while supporting code reuse [11]. Model-Driven Software Development (MDSD)

emphasizes visual modeling and code generation, using tools and modeling languages to boost productivity and maintainability, although it requires a significant learning curve and a comprehensive tool ecosystem. Compilation-based approaches, such as those employed by Kotlin Multiplatform and Xamarin, translate code into native binaries, optimizing performance by allowing platform-specific code execution while facilitating code sharing. However, they necessitate familiarity with multiple programming languages and platform-specific adaptations. Each of these approaches offers distinct advantages and faces unique challenges, making the choice of methodology critical for developers seeking to create efficient, high-quality digital banking apps that cater to the diverse needs of their users across different platforms [12].

Statements were derived via user verbalization, post-transitioning, post-test surveys, and observation notes. Each found usability issue was given a number that corresponds to the number of participants and the assigned test service. Usability issues were documented in a report that also included contextual information [10].

A multi-platform application is one that operates on two or more platforms, allowing seamless exchange of updates between them. Multi-platform development emphasizes optimization by using a common codebase across different platform versions.

An increasing number of individuals are actively involved in utilizing banking applications, particularly mobile banking services. These apps provide users with swift and precise access to essential information, ensuring ease of interaction and thereby enhancing user satisfaction. This heightened engagement contributes to improved service delivery in the realm of mobile banking. Similarly, the adoption of health applications on mobile devices empowers patients to actively participate in managing their health, fostering collaborative relationships with healthcare professionals. The use of mobile health apps positively impacts communication dynamics between patients and service providers, fostering a reciprocal relationship-centered approach to healthcare services. In the business sector, companies are advocating the launch of mobile applications to effectively communicate with their customer base [13].

The usability of a mobile application is contingent upon the user's capacity to effectively engage with it. It encompasses factors like user-friendliness and appropriateness for a particular user group executing designated tasks within a specific environment. Various metrics gauge usability, including task completion, time efficiency, error rates, and subjective satisfaction factors such as enjoyment, ease of use, and safety. In domains like aquaculture, where safeguarding water quality is crucial, monitoring apps like water parameter monitoring systems are gaining prominence to prevent water contamination [14].

Mobile Banking Applications (MBAPs) have emerged as a popular trend in mobile trading platforms, enabling users to conduct financial transactions conveniently at their own convenience. However, the primary concern for mobile banking apps revolves around usability. There is a lack of research examining usability issues based on factors such as user age, gender, trading partners, or level of experience [15].

After years of mobile experience, research findings indicate that there are minimal usability issues across different age categories. The proliferation and accessibility of mobile applications are rapidly expanding. With the increased processing power available on mobile devices, developers are broadening the range of services by integrating smartphones into various practices. However, existing usability models fail to adequately capture the intricacies of interacting with banking applications on mobile platforms. While usability models for mobile banking applications are still in their nascent stages globally, continued exploration may lead to their eventual adoption. Furthermore, diverse categories of mobile apps such as medical, entertainment, and educational apps have distinct functional and non-functional requirements, necessitating customizable models for varied mobile applications [16].

Regarding the usability of banking apps, it primarily pertains to effectiveness, efficiency, and learnability, ease of use, performance, and user satisfaction. Online banking offers numerous benefits, particularly through the ease and convenience provided by mobile or smartphone applications. However, introduction of such apps to the banking sector presents challenges such as security risks, latency issues, functionality concerns, performance limitations, transfer delays, resource-intensive applications, and potential disclosure of personal data [17].

When mobile banking apps prioritize efficiency, effectiveness, learnability, trustworthiness, security, error prevention, and user satisfaction, they significantly enhance the convenience of online banking. Conducting financial transactions and managing finances becomes effortlessly convenient through mobile banking apps, allowing users to handle tasks from anywhere. However, many mobile banking apps currently lack user-friendliness, leading to dissatisfaction among users, particularly concerning financial

matters. This issue is particularly prevalent in underdeveloped regions like Asian countries, where online banking is still a relatively new concept [18].The demand for companies and developers to offer mobile applications compatible with diverse platforms has spurred the increased popularity of cross-platform mobile app development [19].

In 1992, Grady proposed the FURPS model, which stands for functionality, usability, reliability, performance, and supportability. This model categorized characteristics into functional and non-functional requirements, with usability falling under the latter. Usability encompasses factors like aesthetics, consistency, human factors, online help, context-sensitive help, wizards, user documentation, and training materials. However, the FURPS model lacked specific metrics for measuring usability factors [20].

## 3. Research Methodology

### 3.1. Purpose of the Study

In today's digital era, where banking services are increasingly accessed across multiple platforms, ensuring a seamless UX has become paramount for financial institutions. However, quantifying the effectiveness of UX design across diverse platforms remains a challenge [21]. This research aims to address this gap by proposing a novel approach to quantifying cross-platform usability in digital banking applications. By leveraging advanced quantitative analysis techniques, the study seeks to develop a comprehensive framework that assesses key UX elements such as navigation efficiency, visual appeal, and task completion rates across various platforms, including web browsers, mobile devices, and desktop applications. Through a meticulous examination and comparison of user interactions and feedback, the research endeavors to provide actionable insights for optimizing UX design strategies tailored to each platform. Ultimately, this research aims to unlock the user experience in digital banking apps by offering a robust methodology for evaluating and enhancing cross-platform usability, thus empowering financial institutions to better meet the evolving needs and expectations of their diverse user base [22].

### 3.2. Data Collection

#### *3.2.1. Usability Criteria and Metrics*

In 1991, Shackel put forward a framework for evaluating usability, highlighting four key aspects: effectiveness, learnability, flexibility, and attitude. These criteria serve as a guideline for measuring how user-friendly a system or product is. Let's break down what each of these criteria means in simpler terms [23]. By evaluating a system based on these usability criteria and associated metrics, researchers and designers can gain valuable insights into how to improve user experience and satisfaction [24].

In evaluating digital banking applications, several key criteria are essential to ensure a high-quality user experience. Effectiveness is a critical measure, indicating that users should be able to complete their tasks swiftly and accurately, surpassing predefined performance standards. This criterion focuses on the system's ability to enable users to achieve their goals efficiently and without errors. Learnability is another crucial aspect, emphasizing that users should be able to understand and utilize the system effectively after a brief period of learning or training. This ensures that even new users can quickly become proficient in using the application. Flexibility refers to the system's ability to adapt to a wide range of tasks and operating environments beyond its initial specifications. This adaptability is vital for catering to diverse user needs and varying contexts of use. Lastly, the criterion of attitude focuses on user comfort and satisfaction, ensuring that users experience minimal fatigue, discomfort, frustration, or effort when interacting with the system. Together, these criteria of effectiveness, learnability, flexibility, and attitude form a comprehensive framework for assessing and optimizing the usability of digital banking systems [25].

Preece et al. emphasized the importance of safety as a key aspect of usability. They noted that interactive systems aren't just limited to desktop computers but can also be found in various contexts like medical settings and airplanes. This highlights the need for users to be able to use these systems safely without risking harm to themselves, others, or unintentional damage to resources within the system [26].

**Table 1.** Literature Review Table.

| Source | Usability Attribute(s) |
|---|---|
| Shackel [18] | Effectiveness, learnability, flexibility and user attitude. |
| Grady [17] | Human factors, aesthetics, online and context sensitive help, wizards and agents, consistency, user documentation, |

| | |
|---|---|
| | Training materials. |
| Preece, et al. [19] | Learnability, efficiency, throughput, flexibility and attitude. |
| Lecerof and Paternò [22] | Efficiency, learnability, safety, flexibility, Users subjective preference or degree of satisfaction. |
| Donyaee and Seffah [23] | Effectiveness, efficiency, satisfaction, productivity, safety, internationality and accessibility. |
| ISO 9126-1 [24] | Understandability, Learnability, Operability, Attractiveness Usability compliance. |
| Oulanov and Pajarillo [26] | Affect, efficiency, control, helpfulness and adaptability. |

Nielsen [27] both employed similar criteria to evaluate usability, including how easy it is to learn, how efficiently it can be used, how well it's remembered, the occurrence of errors, and user satisfaction. They diverged from other models, such as Shackel's, by prioritizing memorability over learnability. They defined memorability as the system's ability to help users remember how to use its functions and features even after a period of not using it [28].

The ISO 9241-11 (1998) [29] standard outlined three key aspects for measuring usability: effectiveness, efficiency, and satisfaction. These factors help assess whether a product is suitable for users to accomplish their intended goals. According to the standard, effectiveness refers to how accurately and thoroughly users achieve their goals, efficiency relates to the resources expended in relation to the accuracy and thoroughness of tasks, and satisfaction pertains to the comfort and acceptability of the user experience.

### 3.3. Contexts of Use

When determining how usable a product or service is, it's not just about looking at its features alone. We also need to consider other factors that can influence usability, such as the situation in which it's used and the tasks and environments of the specific user. Different devices have different interfaces designed for various contexts. For example, a user might achieve their goal through different interfaces on different devices, but still in the same overall context of use [28] identified different contexts for using multiple interfaces: stationary (like desktop computers), seated (like laptops), standing (like handheld devices), and moving (like smaller handheld devices). When assessing cross-platform usability, it's crucial to consider various characteristics for each interaction session. An interaction session refers to engaging with a service on a single platform as part of using the service across multiple platforms to accomplish a single goal. We've adapted the context of use to fit the measurement of usability across platforms, organizing it into three main factors: user and task, environmental, and situational factor. Different sessions require consideration of different characteristics within these factors [30].

When assessing the usability and effectiveness of digital banking applications across various platforms, several factors come into play, each contributing to the overall user experience. User-related factors encompass psychological elements such as motivation, cognitive style, and attitude. These intrinsic aspects influence how users interact with the application. Additionally, users' knowledge and experience significantly affect their interaction with digital banking services. This includes both general competencies, like speed of learning, computer literacy, and reading proficiency, and specific experiences, such as familiarity with particular platforms, devices, tasks, typing skills, service usage, and domain knowledge. Physical factors also play a crucial role. The complexity of tasks impacts usability, considering aspects like task structure, clarity, sequencing, length, and the use of language free from technical jargon. Moreover, the level of training users has received in cross-platform [16] services, as well as their reliance on external tools like paper and pen, are important considerations.

Frequency and time factors highlight how often tasks are performed either across multiple platforms or within a single platform, and the overall time spent on tasks, including device switching and sub-task durations. On the technical side, the speed and performance of interactive systems, synchronization capabilities, and network conditions are critical. The hardware, such as device capabilities, memory, and input/output devices, along with the operating system's compatibility and performance, also impact the user experience. Physical environmental factors include external conditions like noise levels, privacy, safety, temperature, and lighting, which can influence how users engage with the application. Organizational and social factors encompass the broader context in which users operate. Organizational

culture, reflecting company policies and practices, and the level of social assistance, including support received and the frequency of interruptions, both local and remote, can affect usability. Lastly, situational factors consider the context in which the user interacts with the application, whether they are sitting, moving, driving, or standing, each scenario presenting unique challenges and considerations for user interaction with digital banking service [31] [35].

3.4. Scope and Limitations

The scope encompasses the development and validation of new metrics and frameworks designed to measure and enhance the usability of digital banking applications across multiple platforms, including iOS, Android, and web-based interfaces. The study focuses on providing a comprehensive evaluation of user experience (UX) by analyzing aspects such as efficiency, effectiveness, satisfaction, and learnability. It seeks to bridge gaps in existing usability assessments that often overlook cross-platform consistency and user behavior differences [21] [36].

However, the research has its limitations. Firstly, while the proposed framework is broadly applicable, it may require adjustments for specific contexts or specialized banking applications that cater to niche markets or feature unique functionalities. Secondly, the empirical validation of the framework, although rigorous, is based on a limited set of case studies or user data samples, which might not fully capture the diversity of user interactions across all possible scenarios. Thirdly, the research is primarily focused on usability metrics and may not delve deeply into other critical UX factors such as accessibility, security, and emotional engagement, which are also vital for comprehensive digital banking experiences. Lastly, the rapidly evolving nature of digital platforms and technologies might necessitate periodic updates to the proposed metrics and framework to maintain their relevance and applicability. Despite these limitations, the study provides a robust foundation for future research and practical applications in the realm of cross-platform digital banking usability [32] [37].

## 4. Model Development

The unique characteristics of each factor within the contexts of use require careful consideration regarding their influence on cross-platform usability measurements. Table III provides revised and reexamined characteristics tailored for such measurements, emphasizing the importance of addressing variability across platforms. Cross-platform usability refers to how well different services can be used across various platforms by specific users to accomplish specific goals in different situations, while maintaining acceptable levels of efficiency, effectiveness, learnability, memorability, productivity, accessibility, understandability, satisfaction, universality, helpfulness, safety, and visibility [21]. This definition helped us create a model for measuring cross-platform usability. We improved existing usability measurement models by considering factors like different contexts of use, usability attributes, measurable criteria, and metrics. Similar to other software engineering models, our model is hierarchical, starting from broad factors like learnability, down to specific criteria like task completion, and finally to measurable metrics like the percentage of users who can complete a task across platforms after a certain period of use. Our model, known as CPUM, focuses on horizontal usability aspects and serves as a guide for UX evaluators testing cross-platform usability with users. This section outlines the factors affecting cross-platform usability measurement, as well as the usability factors, criteria, and metrics in CPUM's model [22].

4.1. Cross Platforms Usability Factors, Criteria for Measurement, and Metrics

After reviewing usability attributes in existing literature, we carefully curated 12 usability factors to integrate into CPUM (Cross-Platform Usability Measurement). Our selection process prioritized usability attributes that could be redefined and reconsidered for cross-platform usability. The accompanying figure depicts the adopted and redefined usability factors for cross-platform services. Subsequently, we provide detailed explanations of these factors, including their measurable criteria and metrics. The factors were selected based on their relevance to crafting a measurement model for cross-platform uniformity in software. Each factor can be assessed using appropriate metrics aligned with the specific goals of the evaluation.

4.2. Integration of Usability Factors into CPUM

In this section, we delve into the practical implementation of our proposed solution for measuring Cross-Platform Usability (CPUM). After carefully reviewing existing literature and usability attributes, we curated 12 usability factors specifically tailored for evaluating cross-platform services. These factors were

selected based on their relevance to crafting a measurement model that ensures uniformity in software usability across different platforms [23].

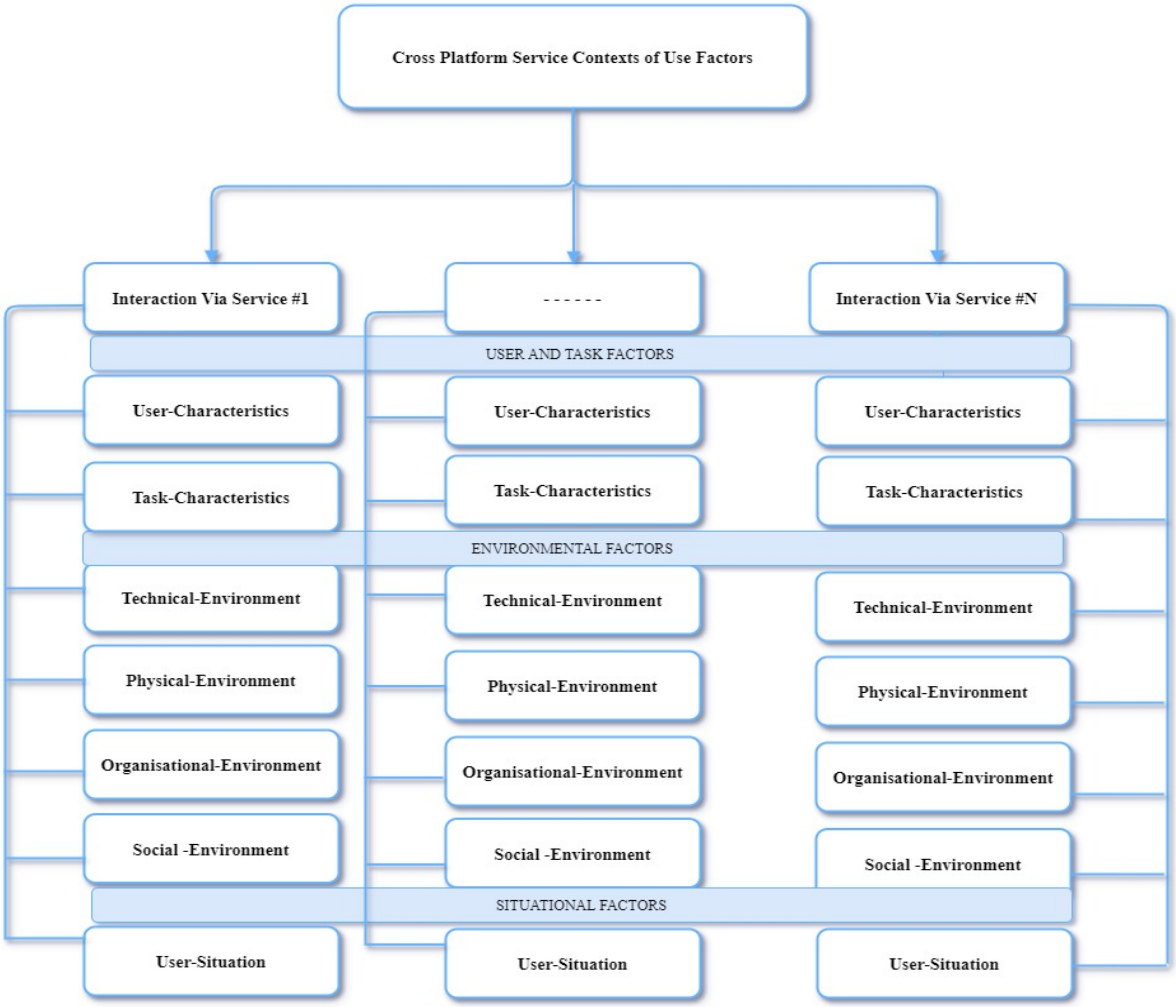


**Figure 1.** Cross Platform Service Contexts of Use Factors [21].

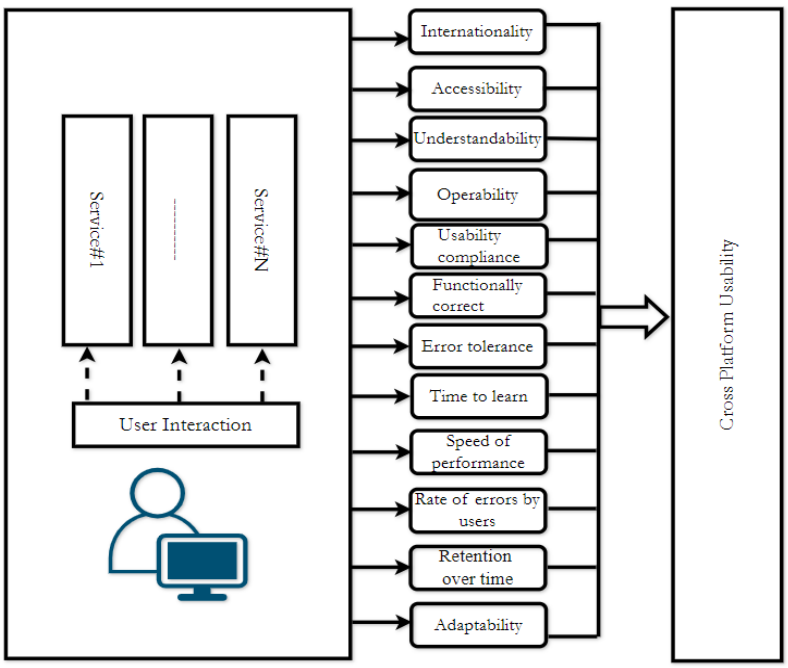

**Figure 2.** Cross Platform Usability Factors [24]

**5. Experimentation**

5.1. Internationality (Equation for Internationality)

$$T_{internationality} = \sum_{i}^{n} \blacksquare = 1(Tsp_i - Ten_i \quad - Tex_i - Tsw_i - Tsy_i)$$

- $Tsp_i$ : Time spent processing each language supported
- $Ten_i$ : Time spent on errors due to non-support of a language
- $Tex_i$ : Time spent on language switch or translation
- $Tsw_i$ : Time spent on switching between language setting
- $Tsy_i$ : Time spent on syntax errors or misunderstandings due to language difference [24].

5.2. Accessibility

$$\textbf{\textit{Accessibility Score (AS)}} = \frac{\Sigma_{i=1}^{n} \ Taf_i}{T_{total}} \times 100$$

- As is the Accessibility Score.
- $Taf_i$ represent the time spent on each accessibility feature.
- $T_{total}$ is the total time spent on the task ,including both accessible or inaccessible interaction.
- $n$ is the total number of accessibility features considerd [25].

5.3. Understandability

$$\textbf{Understanding Score (US)} = \Sigma(T_{ui} / T_{total}) \ 100$$

US is the Understanding Score.

$T_{ui}$ represents the time spent on understanding each aspect (e.g., interface elements, instructions).

$T_{total}$ is the total time spent on the task, encompassing both understanding and executing actions [26].

5.4. Operability

$$\textit{Operability Score (OS)} = \Sigma \ (T\_op\_i / T\_total) \ 100$$

**- OS** is the Operability Score.

**- T_op_i** represents the time spent on executing each operation or task efficiently.

**- T_total** is the total time spent on the task, including both operational and non-operational interactions [27].

5.5. Usability Compliance

$$\textbf{\textit{UCS}} = \frac{\Sigma_{i=1}^{n} \ Ne_i}{N_{total}} \times 100$$

- UCS is the Usability compliance Score.
- $Ne_i$ Represent the number of usability criteria met for each task performed horizontally.
- $N_{total}$ is the total number of usability criteria applicable to the horizontal tasks.
- The summation is performed over all relevant usability criteria for horizontal task [28].

*5.6.* Functionally *Correct*

$$\textbf{\textit{FCS}} = \frac{\Sigma_{i=1}^{n} \ Nc_i}{N_{total}} \times 100$$

- FCS is the Functionally Correctness Score.
- $Nc_i$ Represents the numbers of correct outcomes for each task or operations.
- $N_{total}$ is the total number of outcomes expected for all tasks performed.
- The summation is performed over all relevant tasks and operations [29].

5.7. Error Tolerance (Error Tolerance Metric)

**Error Tolerance Score (ETS)**

$$\textbf{\textit{ETS}} = \frac{\Sigma_{i=1}^{n} \ Nth_i}{N_{total}} \times 100$$

- ETS is the error tolerance Score.
- $Nth_i$ Represents the numbers of errors handled gracefully for each task operations.
- $N_{total}$ is the total numbers of errors encountered during all task performed.
- The summation is performed over all relevant tasks and operations [30].

5.8. Time to Learn (Time to Learn Score (TLS))

$$\textbf{\textit{TLS}} = \frac{\Sigma_{i=1}^{n} \ Tl_i}{N_{total}} \times 100$$

- TLS is the Time to Learn Score.
- $Tl_i$ represents the time taken by users to learn each aspect of the platform (e.g., features, interface elements).
- $N_{total}$ is the total number of aspects considered for learning.
- The summation is performed over all relevant aspects contributing to the learning process [31].

*5.9. Speed of* Performance

$$\textbf{Speed of Performance}=\frac{1}{Responsiveness+Processing\ Speed+Load\ Time}$$

In this equation

Responsiveness, Processing Speed, and Load Time are variables representing the respective components of speed of performance. Each component is inversely proportional to the overall speed of performance, meaning that lower values (indicating faster performance) result in a higher overall speed of performance score [17].

5.10. Rate of Errors by Users (Error Rate Score (ERS))

$$\boldsymbol{ERS} = \frac{\Sigma_{i=1}^{n}\ Ne_i}{N_{total}} \times 100$$

- ERS is the Error Rate Score.
- $Ne_i$ Represents the numbers of errors made by users for each task or interaction.
- $N_{total}$ is the total number of interactions of task performed.
- The summation is performed over all relevant tasks or interactions [32].

5.11. Retention over Time (Retention over Time Score (RTS))

$$\textbf{RTS}=\left(\frac{Pt_i}{Pt_0}\right) \times 100$$

- RTS is the Retention over Time Score.
- $Pt_i$ Represents the percentage of retained knowledge at time $T_i$.
- $Pt_0$ Represents the percentage of initial knowledge or proficiency at the starting time $T_0$ [33].

5.12. Adaptability

Adaptability measures the software's ability to accommodate changes in user needs, preferences, or environmental conditions while maintaining consistency and usability across different platforms. Measuring adaptability involves assessing the platform's capability store accommodate user preferences and changing requirements effectively. Here's the equation and description for the Adaptability metric:

Adaptability Metric (Adaptability Score (AS))

$$\boldsymbol{AS} = \frac{\Sigma_{i=1}^{n}\ Na_i}{N_{total}} \times 100$$

- AS is the Adaptability Score.
- $Na_i$ Represents the numbers of customizable features or options available to users.
- $N_{total}$ is the total number of features or options considered for adaptability.
- The summation is performed over all relevant features contributing to adaptability [34].

## 6. Results & Discussion

6.1. Total Participant

A diverse group of 21 participants, comprising 10 females and 11 males, was engaged to evaluate the usability of digital banking applications based on 12 critical factors. These factors likely encompass key dimensions of usability, such as ease of navigation, responsiveness, visual design, functionality, and overall user satisfaction. The inclusion of a balanced gender representation ensures a more comprehensive understanding of user interactions and preferences across different demographic groups. Each participant's experience was meticulously analyzed to assess how well the digital banking apps perform across various platforms, providing valuable insights into both strengths and areas needing improvement. This user-centric approach allowed for a detailed examination of how different usability aspects affect the overall user experience, ensuring that the findings and recommendations of this research are grounded in real-world user behavior and perceptions. By focusing on a broad range of usability factors, the study aims to offer a holistic view of what constitutes an optimal user experience in the context of cross-platform digital banking applications.

6.2. Number of Banking Applications

Total number of 8 Banking Applications were taken. To calculate the scores for each of the 12 factors based on the survey responses, we'll go through the equations provided earlier for each metric and use the data from the survey responses.

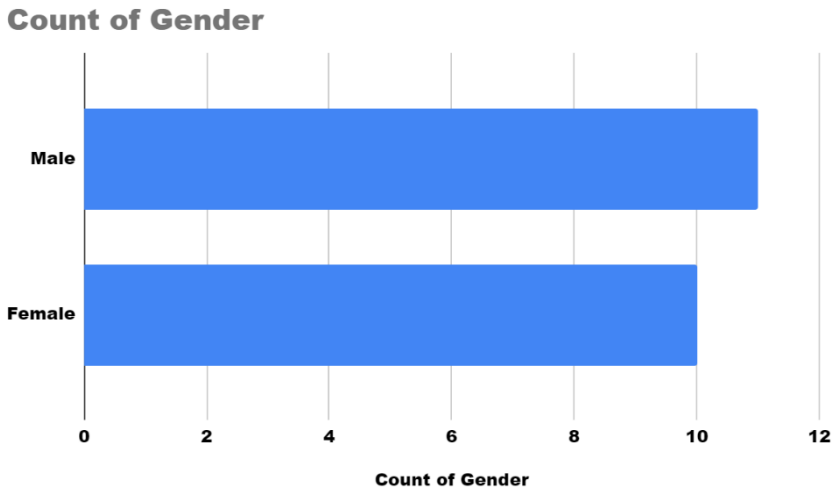


**Chart I**. Count of Gender.

**Table 2.** Usability Scores for Pakistani Banking Applications

| Banking App | Gender | Internationality | Accessibility | Understandability | Operability | Usability Compliance | Functionally Correct | Error Tolerance | Time to Learn | Speed of Performance | Rate of Errors | Retention over Time | Adaptability |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HBL Mobile | Male | 82.4 | 75.6 | 88.3 | 86.7 | 80.2 | 87.9 | 84.5 | 85.6 | 78.1 | 79.8 | 83.2 | 81.4 |
| | Female | 83.2 | 76.8 | 87.9 | 85.3 | 79.5 | 88.1 | 82.7 | 84.9 | 77.5 | 78.2 | 82.6 | 80.1 |
| UBL Digital | Male | 79.8 | 82.1 | 85.6 | 87.2 | 83.5 | 85.6 | 82.9 | 83.4 | 79.5 | 81.2 | 85.1 | 80.9 |
| | Female | 80.5 | 80.3 | 86.3 | 86.5 | 80.9 | 86.3 | 83.1 | 82.8 | 78.7 | 80.1 | 83.7 | 81.3 |
| Meezan Mobile Banking | Male | 85.1 | 78.9 | 89.2 | 84.5 | 81.8 | 88.4 | 81.5 | 87.1 | 77.2 | 78.5 | 81.6 | 83.7 |
| | Female | 86.3 | 79.2 | 88.7 | 83.7 | 80.5 | 88.2 | 80.8 | 88.3 | 76.9 | 77.8 | 80.9 | 84.3 |
| AlBaraka Mobile Banking | Male | 81.5 | 76.5 | 87.8 | 83.9 | 79.3 | 86.7 | 80.9 | 86.3 | 76.8 | 77.9 | 82.3 | 79.8 |
| | Female | 82.3 | 78.1 | 87.3 | 82.7 | 78.6 | 87.1 | 81.2 | 85.7 | 77.1 | 77.5 | 81.8 | 80.4 |
| | Male | 83.2 | 79.3 | 86.7 | 85.9 | 82.1 | 85.8 | 83.1 | 84.5 | 78.9 | 80.2 | 84.7 | 82.1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MCB Mobile | Female | 84.1 | 80.2 | 86.2 | 85.3 | 81.7 | 86.3 | 82.5 | 83.8 | 78.3 | 79.7 | 83.5 | 81.6 |
| Faysal Mobile | Male | 78.9 | 77.6 | 84.5 | 82.3 | 78.5 | 83.6 | 79.8 | 82.1 | 76.5 | 76.9 | 79.4 | 77.5 |
| | Female | 79.2 | 76.8 | 84.2 | 81.8 | 77.9 | 84.1 | 78.5 | 81.6 | 75.9 | 76.3 | 78.8 | 76.9 |
| Bank Alfalah Mobile | Male | 80.7 | 81.2 | 86.3 | 84.2 | 80.6 | 84.9 | 81.2 | 83.9 | 78.3 | 79.6 | 83.1 | 80.2 |
| | Female | 81.2 | 80.8 | 86.1 | 83.8 | 80.3 | 85.2 | 80.7 | 83.3 | 77.9 | 78.9 | 82.7 | 79.6 |
| Standard Chartered Mobile | Male | 84.5 | 80.5 | 88.1 | 86.1 | 82.7 | 87.2 | 83.5 | 86.7 | 79.2 | 80.9 | 85.6 | 82.5 |
| | Female | 85.3 | 81.3 | 87.6 | 85.5 | 82.1 | 87.5 | 83.2 | 85.8 | 78.7 | 80.1 | 84.9 | 81.8 |

Here is a table where we find some value like internationality, Accessibility, Understandability, Operability Compliance, Usability Compliance, functionally Correct, Error Tolerance, Time to Learn, Speed of Performance, Rate of Errors, and Retention over Time and Adaptability.

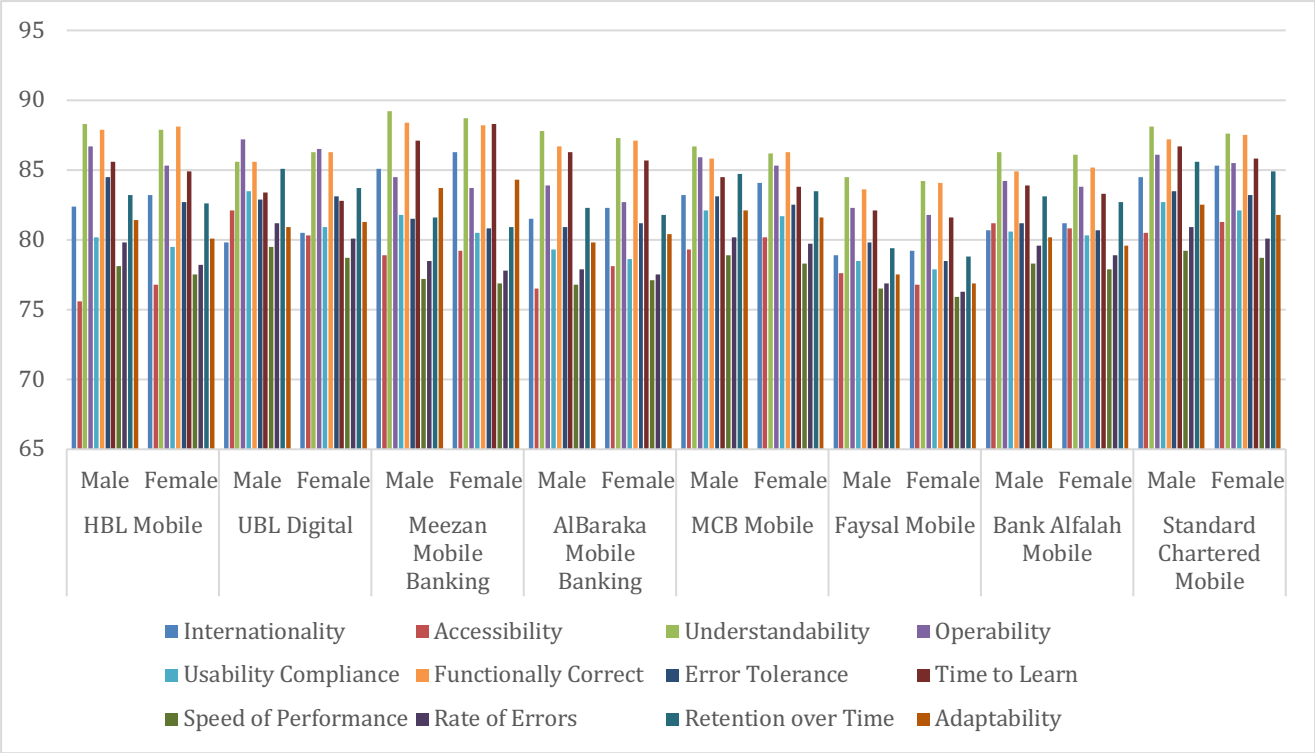


**Chart II.** Comparison of different banks.

## 7. Conclusion

In conclusion, "Unlocking the User Experience: A Novel Approach to Quantifying Cross-Platform Usability in Digital Banking Apps" explores the critical importance of Cross-Platform Usability in the realm of digital banking applications. By ensuring a seamless and consistent user experience across multiple platforms, financial institutions can enhance user satisfaction, foster loyalty, and drive engagement. These factors included how well the apps support different languages, their accessibility for users with disabilities, clarity, understandability of their interface and instructions. Participants also evaluated the smoothness of transactions, adherence to usability standards, and the correctness and reliability of task

execution. They assessed how well the apps handle errors, how quickly users can learn to use them, and their speed and responsiveness. Additionally, they measured the frequency of user errors, user retention of knowledge over time, and the flexibility of the apps to adapt to user needs and different conditions. The overall usability score for each app was calculated by averaging these factors, providing a comprehensive view of their effectiveness and user satisfaction. The paper underscores the significance of understanding the scope of Cross-Platform Usability, including eliminating friction points, prioritizing intuitive navigation, tailoring to platform characteristics, and optimizing for usability. These key principles form the foundation for achieving a cohesive user experience that transcends device boundaries.

**8. Future Work**

In future research endeavors focused on the usability of Pakistani banking applications, several promising avenues could significantly enrich the current findings. Qualitative studies, including user interviews and focus groups, would offer deeper insights into user perceptions and experiences that quantitative metrics may not fully capture. Longitudinal studies could track usability metrics and user satisfaction over time, providing insights into app performance trends and user engagement dynamics. Benchmarking against global usability standards and conducting heuristic evaluations would pinpoint specific usability issues and inform prioritized improvements. Moreover, expanding usability testing across diverse user groups and integrating behavioral analytics could offer comprehensive understandings of user behaviors and needs. Developing tailored usability guidelines, studying the impact of regulatory changes, and refining designs iteratively based on user feedback would ensure continuous enhancement of banking app usability in Pakistan, aligning with evolving user expectations and technological advancements.

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