A Comprehensive Model for Web-based Applications Usability Testing: A Comparative Analysis

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ABSTRACT
With the rapid evolution of science and technology, web-based applications have become an integral part of everyday life, leading to significant growth in user interface design. Usability has emerged as a critical quality factor for web applications. However, many usability models proposed in the literature remain brief, informal, and lack integration. In addition, existing models often suffer from ambiguity, overlap, and inconsistency, which make them difficult to apply effectively in practice. This paper analyzes existing usability models to examine their similarities, differences, strengths, and weaknesses. Based on this analysis, a new framework called the Comprehensive Usability Model is proposed. This model integrates significant factors from various usability models and addresses the limitations of previous approaches by defining usability in a clear, consistent, and unambiguous manner. It defines usability through nine core factors: Effectiveness, Universality, Productivity, Efficiency, Accessibility, Comprehensibility, Safeness, Flexibility, and Satisfaction. Furthermore, the proposed model provides a hierarchical structured association between factors, attributes, and metrics, ensuring clarity in evaluation and minimizing redundancy. While not yet empirically validated, the model serves as a conceptual guideline for usability experts, developers, and researchers. It offers practical support for evaluating the usability of web applications and provides a solid foundation for future empirical studies in usability engineering.

Keywords
Usability Testing; Web-based applications; Usability Model; Usability Factor.

1. INTRODUCTION
Usability assessment is critical method to the examination and improves the quality of web-based applications [1]. Web-based applications are one or more web page that associate to a familiar theme such as a person, business or organization. The front page is usually calling home page, it has the content on the web site. A home page also recognized as an index that has hyperlinks to retrieve other web pages within the website. There are many approaches used to evaluate it. Usability is one of the important factors that determine the effectiveness of a website [2, 3]. Usability testing of web-based application does not cover only user interface, but includes the contents as the information, and functionalities [4]. The applications that have a high level of user experience and usability can improve user effectiveness and satisfaction as well as increase user participation and usage retention [5]. Besides that, business oriented web site or e-commerce can make organization loss of revenue if the web site has a usability problem [6, 7]. Software quality assurance is becoming increasingly important. Therefore, software usability has an important role in the software development life cycle in order to ensure the development of high-quality and usable software products. In addition, it can avoid serious consequences such as financial loss and loss of reputation. This suggests that software quality has emerged as an important part of the software development process [8].

Currently, many usability standards and models exist in the literature, each of which describes the usability of software by various factors. However, the limitations of current usability standards and models are obvious. First, they are characterized by overlap and inconsistency. Also the absence of a consistent model that standardizes the definition of software usability leads to significant issues in software usability testing. As a result, these standards and models are vague and difficult to understand [9]. The issue of selecting a specific model from among the usability testing models is a very complicated. Therefore, this paper addresses the consideration of identifying a specific set of factors based on a comparison of popular usability models, including: Shackel model (1991) [10], Nielsen model (1994) [11], ISO 9241 P-11 (1998) [12], ISO 9126-1 (2001) [13], Abran et al. (2003) [14], Seffah et al. (2006) [15], Mustafa et al. (2008) [16], Wang and Huang (2009) [17], Dubey et al (2012) [18], Aziz et al (2013) [19], Hasan and Al-Sarayreh (2015) [20], Gupta and Sagar (2017) [21], Mousa, et al. (2021) [22], Ajibola et al. (2022) [23], and Alresheedi et al. (2023) [24].

2. LITERATURE REVIEW
Considering the multiplicity of usability assessment models and the absence of a standardized model and consistent metrics, a review of previous literature is necessary to understand the current directions and challenges in this domain. This section introduces and defines the concept of usability according to different models. In addition, it reviews several usability standards and models as a basis for proposing a suitable model for website usability testing.

2.1 Usability Definition
Usability testing plays a significant role in software development process to improve software's product quality. Website's usability testing is determining the quality of the website. There are many attributes to define the quality of website [25, 26]. To ensure the development of website's quality and usability, the usability concept considered an important factor of the software development process can prevent serious consequences, such as financial loss and reputation loss. Therefore, quality improvement after the development of software was not recommended because it only increases the cost and is almost remaking the product. Thus,

Usability testing has a significant role in the success or failure of a website quality [27].

As mentioned, the usability concept has been defined in different ways in the literature, which makes it a confusing concept. Briefly, the usability term is about usable user interface or in other word to make the system easy to learn and easy to use [28]. The several usability definitions were offered by different standards, and authors such as Shackel (1991) defined as "usability of a system or equipment is the capability in human functional terms to be used easily and effectively by the specified range of users, given specified training and user support, to fulfil the specified range of tasks, within the specified range of environmental scenarios" [10]. Nielsen (1993) defined usability as "usability is a quality attribute that assesses how easy user interfaces are to use" [11]. Based on ISO 9241 part 11 (1998), usability was defined as the "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [12]. This definition is clearer, it explains the usability concept is mean and many researchers use this definition [29]. While, ISO 9126 (2001) was defined usability as "the capability of the software product to be understood, learned, operated, attractive to the user, and compliant to conditions" [13]. Web application usability evaluation is concerned with the design, content, and navigation of a website [30]. The Website usability's definition can divide in two manners that examine the interface or final product according to its factors. On the other hand, it refers to techniques in order to improve ease of use through the design process or the approach used to conduct usability research [31]. Based on the above, by analysing previous definitions of usability. A major challenge with usability definitions is that identifying characteristics, factors, or attributes is difficult. Because they are vague and difficult to understand. Thus, website usability can be defined as an evaluation method that focuses on understanding users' interaction with a website to measure its usability, detect and identify usability constraints that prevent convenient access to content or functionality, and improve the overall user experience. A review of existing usability models is presented and compared in the next section to propose a suitable usability model.

2.2 Web-based Application Usability Testing

The essential objective of website usability testing process is to examine a website based on specific criteria and factors. As a consequence, an integrated system and acceptable by consumers has been produced. The usability of websites is evaluated by a combination of factors or attributes that express the quality of the user's experience while interacting with the website [32]. These factors include Clarity, which reflects the extent to which the user understands the site's structure, content, and visual elements. Simplicity, which ensures that functionality is presented in a straightforward manner without complexity or visual clutter [33]. Learnability is also a key factor, as it refers to how easy it is to learn how to use the site when interacting with it for the first time. In addition, Efficiency is measured by the user's ability to perform tasks quickly and effortlessly. Flexibility is the ability of the system to adapt to the needs of different users, such as providing shortcuts for advanced users or customizing the interface [34]. Also, Memorability which measures how easy it is to remember how to use a site after a period of inactivity, is also important. One factor is Error Tolerance, which refers to a site's ability to handle user errors and provide clear messages to resolve them without loss of data or progress. The User Satisfaction metric is a subjective measure that reflects the user's acceptance of the website and their willingness to use it again [35]. In summary, these and related important metrics form an integrated framework for analysing website usability, and are used as tools in practical tests to measure the quality of interaction and usability.

2.3 Usability Standard and Models

With the advent of many of the usability testing models, this section discusses the apparent discrepancy, variety and parity between the existing usability testing models. The extraction the proper and unambiguous factors of website usability testing is the objective of this paper. Therefore, this paper is limited to discussing usability standards and models including including :Shackel model (1991) [10], Nielsen model (1994) [11], ISO 9241 P-11 (1998) [12], ISO 9126-1 (2001) [13], Abran et al. (2003) [14], Seffah et al. (2006) [15], Mustafa et al. (2008) [16], Wang and Huang (2009) [17], Dubey et al (2012) [18], Aziz et al (2013) [19], Hasan and Al-Sarayreh (2015) [20], Gupta and Sagar (2017) [21], Mousa, et al. (2021) [22], Ajibola et al. (2022) [23], and Alresheedi et al. (2023) [24], which have been most prevalent used in practice.

Shackel model [10] described usability by factors as Effectiveness (error, task time), Learnability, Flexibility, and Subjectively Pleasing. This model did not weight dimension and did not recognize that the importance of each of factor different from project to another. It emphasizes the measurement of a number of factors relating to human performance and behaviour. Nielsen model [11] explained Learnability, Efficiency, Memorability, Errors and Satisfaction as usability factors. Like the Shackel's model, this model did not weight dimension and did not recognize that the importance of each of factor differs from project to other. Unlike the Nielsen's model, the ISO 9241-11 [12] does not consider Learnability, Memorability and Errors, but it was included Effectiveness, Efficiency and Satisfaction. This standard also has some disadvantages are too abstract and did not address the learnability factor. While, ISO9126-1 [13] presented Understandability, Learnability, Operability, Attractiveness and Usability Compliance as usability factors. The disadvantage of ISO 9126 is unclear ambiguous structural of the measures, overlapping concepts, lacking of a qualification requirement standard, lacking of guidance in assessing the results of measurement. Abran et al. [14] extended the ISO 9241-11 standard by adding Learnability and Security to propose the ISO 9241-11 enhanced as a Consolidated Model. However, they realize should be highlighted the existing usability models; specifically, it needs more consensus among researchers for usability factors and it requires a more comprehensive model. In addition to, Seffah et al. [15] provided classification of usability factors by more details compared to previous models; it has Efficiency, Effectiveness, Satisfaction, Learnability, Productivity, Safety, Trustfulness, Accessibility, Usefulness and Universality as usability factors. Mustafa and Al-Zoua'bi model consisted of five categories are content, organization and readability; navigation and links; user interface design; performance and effectiveness; and educational information. Each category deals with one usability factor. It outlined usability factors such as Readability, Navigation, Satisfaction, Effectiveness and Accessibility [16]. A similar study conducted by Wang and Huang to evaluate the usability of the website and outlined usability factors in two categories are website success and user experiences. They define usability factors are Efficiency, Learnability, Error Rates, and Satisfaction [17]. An integrated model by Sanjay et al [18] has Efficiency, Effectiveness, Satisfaction, Comprehensibility, and Safety as usability factors. As well as

Aziz et al, proposed usability attributes as Efficiency, Effectiveness, Satisfaction, Learnability, and Accessibility [19]. Hasan and Al-Sarayreh proposed the usability factors as Effectiveness, Efficiency, Satisfaction, Productivity, Universality, Learnability, Appropriateness Recognisability, Accessibility, Operability, User Interface Aesthetics, and User Error Protection [20]. Gupta et al proposed the Efficiency, Effectiveness, Satisfaction, Security, Memorability, Universality and Productivity as usability factors [21]. Mousa, et al. proposed a new instrument called IMUW-APP designed to measure website usability. The instrument's dimensions such as visibility, learnability, simplicity, flexibility, decision-making support, usefulness, and error handling [22]. While IMUW-APP introduces a structured approach for assessing web usability, further validation is needed to examine its applicability across diverse user groups, web application types, and in comparison with existing standard usability models. Ajibola et al. produced a new usability model Mobile Shoppers Application Development (MOSAD) for M-commerce applications. MOSAD includes important factors like efficiency, effectiveness, satisfaction, learnability, and error handling [23]. Although the MOSAD model is a useful contribution to the field of assessing the usability of mobile commerce applications, the study suffers from several shortcomings. Most notably the lack of empirical evaluation on real users. The evaluation is limited to the opinions of user experience experts without actually testing the model. Lack of direct implementation tools. The study relies entirely on a literature review without field empirical support. Alresheedi et al. aimed to produce an enhanced model for improving the quality of web applications. The proposed model based on the ISO 9126 framework established as a standard for software quality assessment that included six main dimensions as functionality, efficiency, usability, reliability, maintainability, and portability [24]. The limitation of this study is that it does not include a systematic comparison between the proposed model and previous models used in assessing the quality of web applications. This reduces the ability to determine the actual added value of the new model in terms of effectiveness, comprehensiveness, or evaluation accuracy.

According to previous discussion, it can conclude that different usability standards or models have given different factors. In addition, the usability researchers consistent to some factors, while they inconsistent the other factors. As a results, this indicate that varying definitions of usability. Moreover, concerning for usability characteristics such as attribute, aspects, factors, and metrics. Usability factors provided by various usability standards or models summarized in Table 1.

Table 1: Usability factors in existing usability models

Author	Year	Usability Factors	Reference
Shackel	1991	Effectiveness (error, task time), Learnability, Flexibility, and Subjectively Pleasing	[10]
Nielsen	1994	Learnability, Efficiency, Memorability, Errors and Satisfaction	[11]
ISO 9241-11	1998	Effectiveness, Efficiency and Satisfaction	[12]
ISO9126-1	2001	Understandability, Learnability, Operability, and Attractiveness	[13]
Abran et al.	2003	Effectiveness, Efficiency, Satisfaction, Learnability and Security	[14]
Seffah et al.	2006	Efficiency, Effectiveness, Satisfaction, Learnability, Productivity, Safety, Trustfulness, Accessibility, Usefulness and Universality	[15]
Mustafa et al.	2008	Readability, Navigation, Satisfaction, Effectiveness and Accessibility	[16]
Wang and Huang	2009	Efficiency, Learnability, Error Rates, and Satisfaction	[17]
Dubey et al	2012	Efficiency, Effectiveness, Satisfaction, Comprehensibility, and Safety	[18]
Aziz et al	2013	Efficiency, Effectiveness, Satisfaction, Learnability, and Accessibility	[19]
Hasan and Al-Sarayreh	2015	Effectiveness, Efficiency, Satisfaction, Productivity, Universality, Learnability, Appropriateness, Recognisability, Accessibility, Operability, User Interface Aesthetics, and User Error Protection	[20]
Gupta and Sagar	2017	Efficiency, Effectiveness, Satisfaction, Security, Memorability, Universality and Productivity	[21]
Mousa, et al.	2021	Visibility, Learnability, Simplicity, Flexibility, Decision-Making Support, Usefulness, And Error Handling	[22]
Ajibola et al.	2022	Efficiency, Effectiveness, Satisfaction, Learnability, And Error Handling	[23]
Alresheedi et al.	2023	Functionality, Efficiency, Usability, Reliability, Maintainability, And Portability	[24]

3. RESEARCHES' GAP AND RATIONALE FOR A NEW USABILITY MODEL

In [10 - 24], a large number of usability standards and models, which describe usability via different factors in a vague and nonhomogeneous manner. Therefore, it creates confusion issue for its usage and applications. This inconsistent approach among usability models is creating major challenges for evaluation of usability of the application. Consequently, there is a rationale to propose a Convenient Model of usability measurement. The usability models described have some

common limitations. They are all rather vague in their definitions and characteristics of usability metrics needed in order to obtain satisfactory measures of usability factors. Authors have different perceptions about usability factors. However, there are many similar factors between usability models as shown in Table 2.

Table 2: The Usability Models' Similarity

Usability factors	Usability Models														
	Shackel [10]	Nielsen [11]	ISO 9241-11 [12]	ISO9126-1 [13]	Abran et al. [14]	Seffah et al. [15]	Mustafa et al. [16]	Wang and Huang [17]	Dubey et al [18]	Aziz et al [19]	Hasan and Al-Sarayreh [20]	Gupta and Sagar [21]	Mousa, et al.[22]	Ajibola et al. [23]	Alresheedi et al.[24]
Effectiveness	✓	Errors	✓		✓	✓	✓	Error Rates	✓	✓	Effectiveness , User Error Protection	✓	Error Handling	Error Handling, Effectiveness	Functionality
Efficiency	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓		✓	✓
Learnability	✓	Learnability , Memorability		✓	✓	✓		✓		✓	✓	Memorability	✓	✓	
Satisfaction	Subjectively Pleasing	✓	✓	Attractiveness	✓	✓	✓	✓	✓	✓	User Interface Aesthetics, Satisfaction	✓		✓	Usability
Flexibility	✓												✓		Maintainability
Understandability				✓					Comprehensibility				Simplicity		
Operability				✓							✓				
Security					✓	✓			✓			✓			
Productivity						✓					✓	✓			
Trustfulness						✓									Reliability
Accessibility						✓	✓			✓	✓				
Usefulness						✓							Decision-Making Support, Usefulness		
Universality						✓					✓	✓			Portability
Readability							✓								
Navigation							✓								
Appropriateness											✓				
Recognisability											✓		Visibility		

Hence, usability has different definitions that are overlapping significantly. Some authors used various names for the same factor. For example, effectiveness-error for the Shackel's model, error for the Nielsen's model, and effectiveness of the ISO 9241 P-11 model are similar; the factor Subjectively Pleasing for the Shackel's model is comparable to Satisfaction for Nielsen's model, ISO 9241 P-11 model and attractiveness of ISO 9126-1 model as well. Moreover, Effectiveness-task time for the Shackel's model is like to efficiency in the Nielsen's model and the ISO 9241 P-11 model. As well as, Learnability factor in some models is similar to Comprehensibility factor and Memorability factor in other models; Security factor and Safety factor are comparable as well.

The issue focused on in this research is that usability models have many common factors, which lead to complexity in the

process of use and interpretation. In addition, the lack of a standardized model with unambiguous criteria makes testing and comparison very difficult. Also, usability metrics vary from domain to domain. All these constraints increase the need to develop usability models through comparative studies [36]. Moreover, the relative lack about calculation method of individual usability factors, such as the role of Learnability versus Understandability in some usability models. This lack of consistent definitions can make it difficult to select a set of usability factors, but considering addressed it through a better High and low level abstraction of usability factors. It can be rather difficult to understand usability factors. Specifically, it is not always clear how usability factors defined in various usability standards or models are similar, different or related. Therefore, Comprehensive Usability Model supports the exploration of the relations among sets of factors in a consistent and clear way in order to incorporate consistency in usability. In this paper, the proposed model selects the most frequent and similar factors in different models and excludes ambiguous and confusing factors. In addition, provide guidance and descriptions of all factors to be clearer. Furthermore, it provides a low-level abstraction for all factors. Hence, usability model is generic so that developers can measure usability without any confusion.

In this paper, several usability models are reviewed. Table 2 presents the main factors identified within these models. Although each model includes a variety of factors, there are significant similarities among them. Therefore, the proposed Comprehensive Usability Model involves the most frequently recurring factors in usability are effectiveness, flexibility, universality, productivity, efficiency, accessibility, comprehensibility, safety, and satisfaction.

4. The Proposed Comprehensive Usability Model

This section produces the proposed Comprehensive Usability Model with its detailed classification. The proposed model can clearly measure the usability of the software product.

Specifically, this model simplified the usability testing process by defining various metrics that are suitable for each identified factors for software product quality and explain them in a consistent way. The proposed model defines the usability using nine factors that are effectiveness, flexibility, universality, productivity, efficiency, accessibility, comprehensibility, safety, and satisfaction briefly described as follows:

i. **Effectiveness**: it indicates to the website capability that enables users to accomplish a particular task with required results with completeness and certainty e.g. measuring the error rates while attempting to complete the task [14-24].
ii. **Efficiency**: it indicates to the website capability that enables users to produce desired results related to the investment of time and resources e.g. ability of the user to complete their task with speed and accuracy [10-12].
iii. **Satisfaction**: it indicates to user responses, feelings during using the website e.g. measuring the perceived level of freedom from discomfort, likeability [10-21].
iv. **Comprehensibility**: it indicates to the website property that enables the user to remember the elements and the functionality of the system product e.g. measuring the time the users spend to learn particular task [18-23].
v. **Universality**: it indicates to the website accommodation of various users with different cultural backgrounds e.g. use of symbols, numeric formats without hindrances [15,20,21,24].
vi. **productivity**: it indicates to the amount of useful results that achieved from user interaction with the website [15,20,21].
vii. **Accessibility**: It indicates to how easy the user to access websites with some type of disability e.g. the website more accessible to persons with visual disability, auditory, vocal [15,16,20,21]
viii. **Safeness**: it indicates to the website avoids the risk and damages to users or other resources i.e. hardware and software [14,15,18,21].
ix. **Flexibility**: it refers to the capability of websites to adapt to diverse user needs, preferences, and contexts without compromising performance. For instance, a web-based email service such as Gmail allows users to switch modes or change the interface language [22,24].

The proposed model aims to model these factors in a coherent and consistent manner by structuring the proposed factors into related attributes. The model also simplified the evaluation process by defining various metrics that are suitable for each identified attribute. This implies that the Comprehensive Usability Model that it decomposes usability into factors, then into attributes, and finally into specific metrics as illustrated in Table 3.

Table 3: Usability factors measurement for the proposed Comprehensive Usability Model

Usability factors	Attributes	Definition	Metrics
Effectiveness	*Task Appropriateness*	It is the number of tasks that have an appropriateness output	• Percentage of tasks completed successfully. • Number of errors encountered per task. • Average task success rate across users.
	Task Accuracy	It is the number of tasks that are achieved correctly	• Error-free completion rate • Average time spent per correct task • Number of retries before correct completion
	Error Generation	It is the number of errors generated for a particular task performed	• Average number of errors per task • Error frequency per user session • Ratio of erroneous actions to total actions

Universality	*Cultural Internationality*	It is the level of the website ability for using by users who have different culture background	• Number of supported cultural/region-specific formats (e.g., date, currency) • Availability of localized content and symbols • User satisfaction across different cultural groups
	Device Compatibility	The extent to which the website can be effectively accessed across different devices (desktop, tablet, mobile).	• Percentage of features available consistently across devices • Rendering accuracy on different screen sizes • Average response time across devices
	Language Accessibility	The level of support for multiple languages to accommodate diverse user groups.	• Number of supported languages • Accuracy of translation/localization • Consistency of terminology across languages
Productivity	*Economic Productivity*	It is the efficient level of cost for performing a task by the user	• Average cost per completed task • Cost savings compared to alternative methods • Ratio of cost to task success rate
	Productive Proportion	It is average user spent time in order to perform productive actions	• Average time spent on productive actions per session • Ratio of productive time to total session time • Percentage of tasks completed within productive time frame
	Relative Number Of User Actions	It is the level of the user performing by the minimum number of actions needed of specific task	• Average number of actions per task • Ratio of actual actions to optimal actions • Task completion efficiency score
Efficiency	*Resource Utilization*	It is the number of correct results obtained by exploiting a specific amount of resources	• Ratio of correct results to resources consumed • Average resource usage per correct result • Efficiency index (correct outputs per unit resource)
	Execution Time	It is the time spent through executing a task	• Average execution time per task • Task completion time variance • Percentage of tasks completed within expected time
	User Effort	It is a level of the appropriate results generation versus the physical and mental user effort	• Average number of interactions (clicks/keystrokes) per correct result • Average physical actions required (e.g., mouse movements, scrolling) • Ratio of correct results to total effort exerted
Accessibility	*Accessibility For Physical Disability*	It is average number of the functions that can be accessed by users who have physical handicaps	• Keyboard-only access percentage • Availability of alternative input methods • Tasks completed without mouse usage
	Geographical Accessibility	It is the ability of the website or system to be accessed from different regions regardless of location.	• System uptime percentage • Average downtime frequency • Task success rate during peak hours
	Technological Accessibility	It is the level of support for users with limited or outdated devices and internet connections.	• Page loading time on low bandwidth • Compatibility with older browsers/devices • Availability of lightweight/low-data mode
Comprehensibility	*Learnability*	It is the average time of the users spend to learn certain functions in the website	• Average learning time per function • Number of trials before correct use • User success rate after first attempt
	Memorability	It is the average time of the users spend to remember the steps of using certain functions without the need to re-learning	• Average time to recall task steps • Success rate in task recall after a period of non-use • Number of errors during re-use without re-learning
	Clarity	It is the level of the website ability to provide of structural elements that enable users to understand functions clearly	• Number of steps required to complete basic tasks • User rating of interface simplicity • Reduction of unnecessary elements in design
Safeness	*Privacy*	It is the level of protection users' personal information appropriately	• Presence of data encryption mechanisms • Compliance with privacy regulations • User trust rating regarding personal data handling
	Resource Safety	It is the rate of input items which conduct regular validation in order to protect information and data for unauthorized persons	• Percentage of input fields with validation checks • Number of security breaches due to invalid inputs • Frequency of updates to validation rules

	Error Tolerance	It is the number of errors the system can recover or repair	• Percentage of errors automatically recovered • Average recovery time per error • User success rate after error recovery
Satisfaction	*Likeability*	It is the level of the user satisfaction of the website in general	• Average user satisfaction score (survey-based) • Percentage of positive feedback • User retention/revisit rate
	Trustfulness	It is the faithfulness level that the website presents to its users	• User trust score from surveys • Percentage of users willing to share personal data • Consistency of website policies and commitments
	Convenience	It is the level of user positive attitude for using the website and towards its design	• Percentage of users rating the website as easy to use • Average score of interface design satisfaction • Frequency of voluntary continued use
Flexibility	*Customization*	The extent to which users can personalize the system according to their preferences.	• Number of customizable interface elements • Percentage of users applying personalization options • User satisfaction with customization features
	Adaptability	The system's ability to automatically adjust based on user behaviour or context.	• Frequency of successful context-based adjustments • Accuracy of adaptive recommendations • User satisfaction with system adaptability
	Scalability	The ability of the system to support different levels of usage and user demands without loss of performance.	• Maximum number of concurrent users supported without performance drop • Average response time under peak load • System resource utilization efficiency at scale

5. RESULTS AND DISCUSSION

Many of the usability standards or models described at the beginning of this paper address aspects of software quality. Most of them follow a hierarchical approach in analyzing usability factors, which are represented as criteria with related metrics. However, across different standards and models, usability factors, criteria, and metrics are not clearly and consistently defined. Existing usability models are limited, often characterized by overlapping and similarity, which leads to ambiguity and difficulties in software usability evaluation. Consequently, these standards and models are sometimes vague and hard to apply in practice.

To overcome these limitations, this paper proposes the Comprehensive Usability Model, which serves as a guideline framework by systematically associating factors with attributes and metrics in a clear and consistent manner. The model defines usability using nine factors: Effectiveness, Universality, Productivity, Efficiency, Accessibility, Comprehensibility, Safeness, Flexibility, and Satisfaction (Figure 1). A comparative overview with existing models (Table 4) indicates that the proposed model consolidates redundant and overlapping factors, eliminates ambiguous ones, and provides a more comprehensive coverage of usability.

At a low-level abstraction, the proposed comprehensive model also specifies the actual metrics for evaluating the usability of web applications, as illustrated in Table 3, making it more practical and applicable. While the model has not yet been empirically tested, it provides a conceptual guideline that can assist usability experts, developers, and researchers in structuring usability evaluation systematically. Thus, the Comprehensive Usability Model contributes a unified and practical foundation for future usability assessments and potential empirical validation.

6. CONCLUSION

In the literature, various usability standards and models have been introduced; however, they often appear divergent, vaguely defined, or overlapping. Moreover, inconsistencies exist in terminology, where different terms are used to denote the same factor, or the same term is employed to describe different concepts. To address these challenges, this paper presents a comprehensive usability model. The proposed model defines usability through nine core factors: Effectiveness, Flexibility, Universality, Productivity, Efficiency, Accessibility, Comprehensibility, Safeness, and Satisfaction.

This model systematically consolidates redundant and similar factors found in existing usability models, while excluding ambiguous and confusing ones. In addition, it introduces a clear classification of all factors, providing better structure and interpretation. Furthermore, it offers a low-level abstraction for each factor, ensuring precision and consistency in usability evaluation.

Importantly, the proposed model can be directly applied to usability testing of web applications, where measuring usability requires clear and practical criteria. By aligning with this model, developers and researchers are able to assess web applications based on standardized factors, minimize ambiguity, and improve both design quality and user experience. Thus, the model is generic and universally applicable, serving not only as a benchmark for usability evaluation but also as a foundation for future research and practical applications in usability engineering.

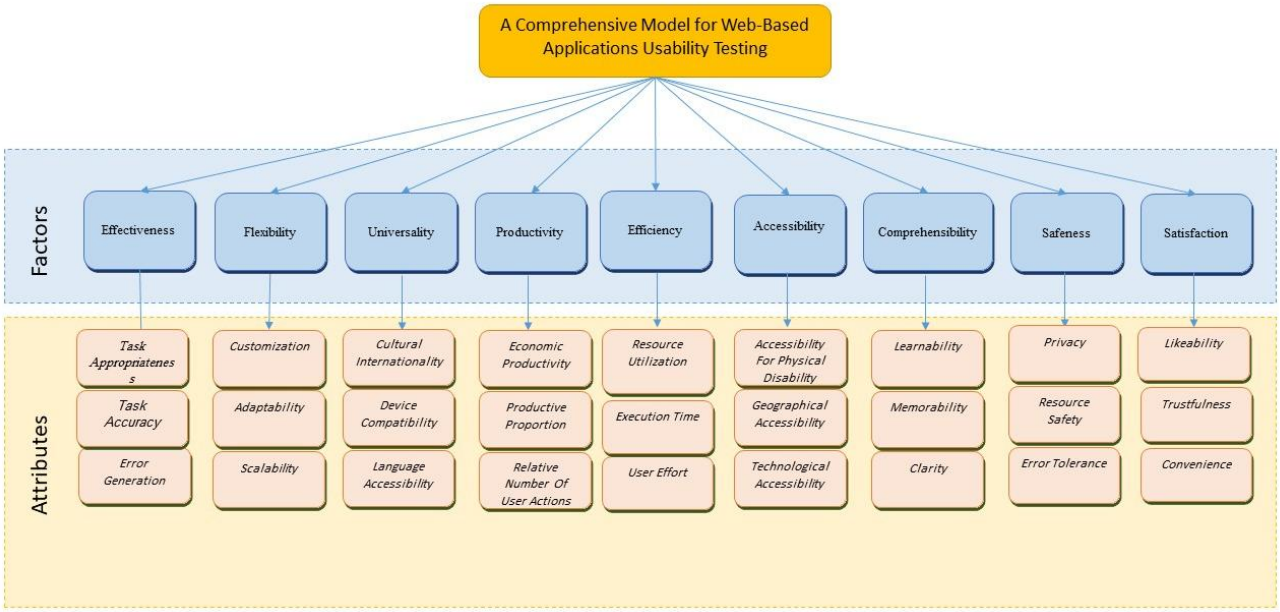

Figure 1. Proposed Convenient Usability Model.

Table 4. Comparison of Proposed Model with Existing Models.

Usability models	Usability Factors								
Convenient Usability Model	Effectiveness	Flexibility	Universality	Productivity	Efficiency	Accessibility	Comprehensibility	Safeness	Satisfaction
Shackel [10]	✓	✓			✓	✓	✓		✓
Nielsen [11]	✓				✓		✓		✓
ISO 9241-11 [12]	✓				✓				✓
ISO9126-1 [13]							✓		✓
Abran et al. [14]	✓				✓			✓	✓
Seffah et al. [15]	✓		✓	✓	✓	✓	✓	✓	✓
Mustafa et al. [16]	✓					✓	✓		✓
Wang and Huang [17]	✓				✓		✓		✓
Dubey et al. [18]	✓				✓		✓	✓	✓
Aziz et al. [19]	✓				✓	✓	✓		✓
Hasan and Al-Sarayreh [20]	✓		✓	✓	✓	✓	✓	✓	✓
Gupta and Sagar [21]	✓		✓	✓	✓		✓	✓	✓
Mousa, et al.[22]	✓	✓					✓		
Ajibola et al. [23]	✓				✓		✓		✓
Alresheedi et al.[24]	✓	✓	✓		✓		✓	✓	✓

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