Федеральное государственное автономное образовательное учреждение высшего образования «Уральский федеральный университет имени первого Президента России Б.Н. Ельцина»
Институт радиоэлектроники и информационных технологий-РТФ
Базовая кафедра «Аналитика больших данных и методы видеоанализа»

На правах рукописи

Агбозо Эбенезер

Развитие веб-инструментария управления сетевыми организационными системами с учетом его адаптации к изменяющемуся пользовательскому опыту

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Медведев Александр Николаевич

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AGBOZO EBENEZER

Development of Web-based Tools for Managing Network Organizational Systems, Taking into Account its Adaptation to Changing User Experience

SPECIALTY 2.3.4 MANAGEMENT IN ORGANIZATIONAL SYSTEMS

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Research Supervisor:
PhD, Associate Professor
Medvedev Alexander Nikolaevich

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INTRODUCTION

Relevance of the research topic. Web tools (information systems) play a critical role in the operational and strategic management of networked organizational systems in the modern digital economy. They are used for internal and external management of business processes and employees (users). The web management tool's user interface serves as an interface between users and business resources, enabling user tasks to be completed within business processes and providing visualization tools to support decision making. Considering the importance of web tools in the operation of network organizational systems, improving their user interface (UI - user interface, GOST R ISO 9241-2016) affects the efficiency of each user and the management system as a whole. Research confirms that the quality of the user interface has a significant impact on users' ability to use web tools effectively and directly affects their productivity.

In web-based organizational systems, users of web tools may work in different geographies, have different skill levels, and have different responsibilities that may change over time. Therefore, one of the key approaches to the development of web tools involves segmenting users into separate groups according to job responsibilities and tasks in order to effectively adapt web tools to improve the management of the network organizational system. User segmentation allows companies to design user interfaces and workflows that are intuitive and convenient for the relevant group of users. However, this is not an exhaustive list of characteristics by which user segmentation is possible; in particular, important factors include user experience (UX - user experience - user perception GOST R ISO 9241-210—2016). Taking into account user experience, which significantly affects the perception of the user interface and user productivity, is an unsolved urgent problem in the field of improving web tools.

With the constant use of web tools, the user experience changes quite quickly, which leads to changes in the assessment of the quality of the user interface. Therefore, maintaining the quality level of the user interface based on its constant monitoring and evaluation in order to take into account changes in user experience is also an urgent task that requires a solution to improve overall productivity in a network organizational system.

Thus, the relevance of the topic of the dissertation research is due to the need to develop web-based tools for managing network organizational systems, taking into account its adaptation to the changing user experience.

The degree of development of the research topic. General issues of managing network organizational systems are considered in the works of Faulkner D., Slonmanskaya, Dubko N.A., Smordinskaya N.V., Davydovich A.R., Aleinova A.A., Telnov Yu.F., Kazakova V.A., Danilova A. V., Denisov A. A., Zheltenkova A. V. Syuzeva O. V.

The results of research into individual management issues in organizational systems are presented in a wide range of publications in a number of areas. In particular, O. Shtorba studied the digital transformation of online retail trade. Issues of human resource management in network companies were considered by L.G. Matveeva, O.A. Chernova and Hussein A.A. In the field of enterprise architecture and value proposition restructuring, contributions were made by E. M. Fayshtein and V. V. Kuvshinova. Factors influencing sustainable innovation in enterprises were studied in the works of Thongsri N. and Chang A.K.

To individually assess the user experience, Speicher M., Malaka R., Maas S., Boll-Westermann S., and Gaedke M. used the usability indicator (usability, GOST R ISO 9241-2016) with confirmatory factor analysis. Bagnón-Bagnon-Gomis A., Tomas-Miguel J. V. and Exposito-Langa M. conducted a heuristic evaluation of the system using the Usability Scale (SUS). Fatta H.A. and Mukti B. evaluated user interfaces using the ease of use (USE) model, and Supriady applied user interface principles and Schneiderman's golden rule.

The use of customized interfaces for web tools seems to be the most preferable from the point of view of ensuring user efficiency, but at present such an approach is poorly implemented, primarily due to its high cost.

Therefore, as part of assessing the quality of the user interface in order to adapt it to the changing user experience, it is advisable to use group approaches, which are represented by two main directions. The former uses selected usability criteria, while the latter focuses on analyzing user behavior.

The non-parametric Kruskal-Wallis test was used for the group evaluation of user experience by Kous, Pushnik M., Herichko M. and Polancic G. To evaluate user interface accessibility, Casare A.R., Basso T.., Silva K.G. and Moraes R. proposed an interface reliability model (QM). Perminov N. and Bakaev M. evaluated the user interface based on ontologies, and Sui M., Shushan M., Mkauer M.V., Kessentini M. and Ghedira K. - based on evolutionary algorithms. Zhang Y, Tennekes M, de Jong T, Curie L, Cook B and Chen M developed a quality assurance (QA) modeling

method based on multi-objective optimization. M. Bakaev, S. Hale, V. Khvorostov, and M. Gaedke looked at machine learning user interface evaluation based on a number of visual complexity metrics. Analysis of image-based user interfaces using functional neural networks was carried out by M. Bakaev, S. Hale, L. Chirkov and M. Gaedke. Automated user interface evaluation based on feature extraction using deep learning is presented in M. Sui, Z. Haddad, R. Trabelsi, and K. Srinivasan.

Charfi S. and Ezzedine H. analyzed user behavior as a key element of user experience. Butkovskaya G.V. explored the alignment between product life cycle and user experience. Sikorski M. highlighted usability as a means of improving user experience, showing its decisive role in the design and development of information products. Akishin V.A. explored customer experience management and its relationship with user experience, emphasizing the importance of user-centric approaches. Pavelošek I., Polzel T., Cao Y., Carmona V.I.S., Liu X., Hu K., Iskender N., Beyer A. and Möller S. presented an overview of user segmentation methods and its application in online platforms, emphasizing the importance of tailoring products to specific user groups. Raizudin, S., Kumar, K. and Aras, R.A. showed the value of user segmentation in supporting management decision making.

These studies use group ratings on one or more individual measures. The task of integral group evaluation of user experience was not set. In addition, a change in user experience represents a change in the user's perception of the system, which leads to a change in the user's assessment of the quality of the user interface, while the user interface itself, as part of the web toolkit, remains unchanged. The task of integrating the results of user experience analysis into assessing the quality of the user interface was also not set.

Purpose and objectives of the work. Development of web tools for managing network organizational systems, taking into account its adaptation to the changing user experience. To achieve the research goal, the following **tasks** are undertaken:

1. To develop a methodological approach to the development of web tools for managing network organizational systems, taking into account adaptation to the changing user experience based on assessing the quality of the user interface.

2. To develop an integral model for assessing the quality of the user interface, including three classes of parameters: usability, performance and

accessibility, taking into account the distribution of users by experience with the web system.

3. To develop a methodology for adapting web tools for managing network organizational systems based on user clustering using machine learning and interpreted artificial intelligence, taking into account an expanded set of usability components (learnability, usefulness, aesthetics and sentiment analysis) and changing user experience based on the functionality of the web system.

4. Develop a software implementation of the proposed model and algorithms for the development of web tools for managing network organizational systems, taking into account adaptation to the changing user experience and test it in practice.

Scientific novelty include:

1. A methodological approach to the development of web-based tools for managing network organizational systems is proposed, including a feedback control mechanism based on the results of assessing the quality of the user interface, distinguished by its adaptation to changing user experience and allowing to determine the directions of development of this web-based tool. (Corresponds to paragraph 9 of the passport of specialty 2.3.4: Management in organizational systems).

2. An integrated model for assessing the quality of the user interface based on a set of parameters has been developed, distinguished in that a full set of parameters is used (ease of use, performance, availability), and ease of use is assessed taking into account the distribution of users by the level of user experience, allowing to make informed decisions on the development of web-based tools for managing network organizational systems (Corresponds to paragraph 5 of the passport of specialty 2.3.4: Management in organizational systems).

3. A method for group assessment of user experience based on expert assessments is proposed, characterized by user clustering using machine learning and interpretable artificial intelligence, as well as taking into account an expanded set of usability components (learnability, usefulness, aesthetics and sentiment analysis), which allows for more precise assessments of the quality of the user interface of web-based tools for managing network

organizational systems, increasing the operational efficiency of users, improving the adaptation of web tools to user experience, ensuring more informed decisions on system updates and function improvements to improve the efficiency of managing a network organizational system (Corresponds to paragraph 5 of the passport of specialty 2.3.4: Management in organizational systems).

Theoretical and practical significance of the work: The theoretical significance of the study lies in the development of approaches to assessing the quality of the user interface of web tools used in the management of network organizational systems.

The practical significance of the work lies in the development of tools for assessing the quality of the user web interface based on expert, user and automated approaches; a method and algorithm for interpreting the results of user clustering to determine criteria for improving the quality of the web interface for various user groups; software for use in the quality control system of the user interface of web tools of organizational systems. The results are used in the educational process of UrFU in the course "Innovation in business and information technology (Introduction certificate dated June 2024), as well as in the Alterna Furniture Company LLC (Implementation certificate dated 14/05/2024).

Methodology and research methods. When conducting research, methods of system analysis, system modeling, multi-criteria decision making, interpretable machine learning, the provisions of the theory of sociotechnical systems and control theory are used.

Provisions to be defended include**:**

1. A methodological approach to the development of web-based tools for managing network organizational systems is proposed, including a feedback control mechanism based on the results of assessing the quality of the user interface, distinguished by its adaptation to changing user experience and allowing to determine the directions of development of this web-based tool.
2. An integrated model for assessing the quality of the user interface based on a set of parameters has been developed, distinguished in that a full set of parameters is used (ease of use, performance, availability), and ease of use is assessed taking into account the distribution of users by the level of user

experience, allowing to make informed decisions on the development of web-based tools for managing network organizational systems.

3. A method for group assessment of user experience based on expert assessments is proposed, characterized by user clustering using machine learning and interpretable artificial intelligence, as well as taking into account an expanded set of usability components (learnability, usefulness, aesthetics and sentiment analysis), which allows for more precise assessments of the quality of the user interface of web-based tools for managing network organizational systems, increasing the operational efficiency of users, improving the adaptation of web tools to user experience, ensuring more informed decisions on system updates and function improvements to improve the efficiency of managing a network organizational system.

Personal contribution of the author. The author formulated the problem statement, analyzed the state of the subject area, formulated the goals and objectives of the study, collected and processed the necessary data, developed hybrid mathematical models, performed the necessary calculations, developed a software implementation of the proposed methods and algorithms and performed its experimental testing on real data.

The degree of reliability of the results of the work. The reliability of the results is ensured by the correct application of research methods, the use of real data sets to develop the model and algorithms, and the results of testing the created software product.

Approbation of the results. The main results are presented at the international scientific conferences: Second International Conference on Recent Trends in Computing (ICRTC 2023) – (Sanjeevani, India, 2023); International Conference on Electronic Business Technologies (EBT) – (Belgrade, Serbia, 2023); 2023 IEEE Ural-Siberian Conference on Biomedical Engineering, Electronics and Information Technology – USBEREIT (Ekaterinburg, Russia, , 2023); European, Mediterranean and Middle East Conference on Information Systems (EMCIS 2023) (Dubai, United Arab Emirates, 2023); Future Technologies (Future Technologies Conference, Vancouver, Canada, 2021); International Conference on Data Analytics for Business and Industry: Way Towards a Sustainable Economy (ICDABI 2020) (Sakhir, Bahrain, 2020); The 12th International Conference on E-Governance Theory and Practice (ICEGOV 2019) (Melbourne, Australia, 2019); Business Engineering of Complex Systems: Models, Technologies, Innovations (Donetsk,

2019); Spring Science Days of GSEM (Ekaterinburg, Russia, 2018); International Scientific Conference "Digital Transformation of Society, Economy, Management and Education" (Ekaterinburg, Russia, 2018); The 11th International Conference on E-Governance Theory and Practice (ICEGOV 2018) (Galway, Ireland, 2018); International Conference on Information Technologies – IVUS 2018 (Kaunas, Lithuania, 2018); 17th European Conference on Digital Government ECDG. – 2017 (Lisbon, Portugal, 2017).

The main provisions and conclusions of the dissertation are presented in 15 scientific articles, including 2 articles in scientific journals included in the Higher Attestation Commission list, 7 articles indexed in Scopus and/or Web of Science, 6 articles in other journals and 1 book chapter. A certificate of state registration of 1 (one) computer program was received from the Federal Service for Intellectual Property.

Implementation of work results. The results of theoretical and practical research are implemented in the form of a software package for managing web-based platform of modern organizational systems. The main results of the dissertation are introduced into the educational syllabus of Ural Federal University within the discipline: “Innovations in Business and IT" under the master’s program IT Innovations in Business.

Publications. On the topic of the dissertation, 16 scientific papers have been published, 11 of which are publications indexed in the international Scopus database, 1 certificate of registration of computer programs.

Structure of the dissertation. The dissertation work consists of introduction, 3 chapters, conclusion and appendices. The volume of work is 149 pages. The work contains 45 figures, 41 formulas, 10 tables. The total number of literary sources cited by the author is 275.

CHAPTER 1. METHODICAL APPROACH TO THE DEVELOPMENT OF WEB TOOLS FOR MANAGEMENT OF NETWORK ORGANIZATIONAL SYSTEMS

This chapter presents an analytical review of networked organizational system and the role of their information systems in streamlining business processes and examines existing methods for assessing user interface quality. This dissertation examines two key tasks in improving networked organizational systems through the improvement of their web-based information systems which is a core component of the organizational system. The dissertation accomplishes this by developing web user interface quality assessment and developer assessment as feedback control mechanisms to improve web tools within networked organizations considering changing user requirements. Within the framework of these tasks, the technical condition of the networked organizational system and all constituents is determined, the current technical condition of the system is characterized, and possible impediments of system efficiency and productivity are determined.

This chapter is devoted to the analysis of the current state of the art, methods, shortcomings and research gaps associated with user interface evaluation of web-based technologies. The chapter reviews scientific studies and conducts computational literature analysis on the state-of-the-art which forms the basis for offering competent methods and algorithms that can be used for the effective implementation of these approaches. The assessment of the advantages and disadvantages of these methods and tools obtained as a result of the analysis was used in the process of developing an optimal approach.

1.1. The Role of Web Technologies in Solving Tasks in the Management of Network Organizational Systems

Information systems are as computer-based systems that process financial information and support the task of decision making in the context of coordination and control of organizational activities [1]. They can also be defined as electronic information management elements that impact business processes and their practical implications for knowledge generation [2]. From an organizational system's perspective, information systems are an important value-creation instrument. All information systems are built for the purpose of managing different aspects of an

organization's business processes. To understand the role of information systems in any modern organization, there are two main perspectives to view:

(a) Level of Information System Deployment: For every modern organizational system such as virtual (network), it is important to understand the depth/level of integration of the information system within the organizational system's business processes; and

(b) Information Visualization: The development of information systems must consider the cognitive load of end users based on theories and guidelines that support quality information presentation in information systems.

All class of information systems and technologies are developed to solve different management tasks [3]. These information systems are integrated at different levels of the complex organizational system (Table 1-1).

Table 1-1 Levels of Classification of Information Systems

№	I.S. Classification	Levels	Sources
1	Organizational level	1. Operational 2. Knowledge 3. Management 4. Strategic	[4]
	Decision Types	1. Structured 2. Semi-structured 3. Unstructured	
2	Business Function	1. Transaction Processing Systems (TPS) 2. Management Information Systems (MIS) 3. Decision Support Systems (DSS) 4. ESS (Executive Support Systems)	[5]
2	Business Orientation	1. ERP (streamlines business operations across various departments) 2. CRM (front-office business functions)	[6]
3	Technology Infrastructure	1. Desktop-based (traditional) 2. Web-based	[7]
4	Software Distribution	1. Packaged Software (pre-built) 2. Custom (Bespoke)	[8]
5	Deployment	1. On-Premises 2. Off-Premises 3. Hybrid	[9]

5	Processing Infrastructure Classification	1. Real-time Processing 2. Batch Processing	[10]
6	Network Authorization	1. Intranet (Secure private network limited to employees only) 2. Extranet (Controlled Private Network with external partners/suppliers/vendor access)	[11]

It must be noted also that, the progress of information systems according to research can be identified as: (1st era) Mainframe computers; (2nd era) Personal computers; (3rd era) Client/Server networks; (4th era) Enterprise computing; and (5th era) Cloud computing [12]. As such, cloud-based information systems have been widely adopted by many distributed/virtual organizations because of the cross-platform capabilities of web programming technology, cheaper cost of hosting, ease of deploying and maintenance in comparison to traditional desktop software installed, and ubiquity of the internet. With respect to ERP and CRM systems, studies have indicated that the integration of both systems has a moderating effect on organizational performance [13]). Researchers also proposed Anthony's Triangle which presents the three (3) core levels of management of organizational systems and classifies them according to the traditional classification of information systems (Figure 1-1).

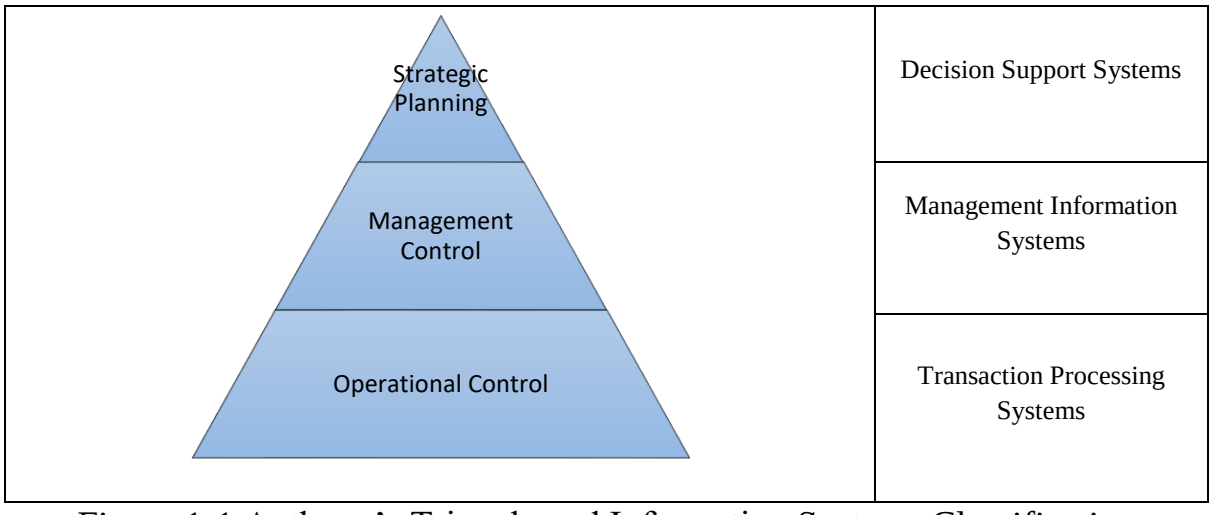

Figure 1-1 Anthony's Triangle and Information Systems Classification

Also, it is important to point out that user interfaces of any modern information systems are developed to serve as a medium for users to perform technical tasks within the organizational system. In the process of development of user interfaces for information systems, it must be noted that the visual characteristics of the

interface need to be considered because user cognition is linked with system aesthetics which influences user experience and user productivity.

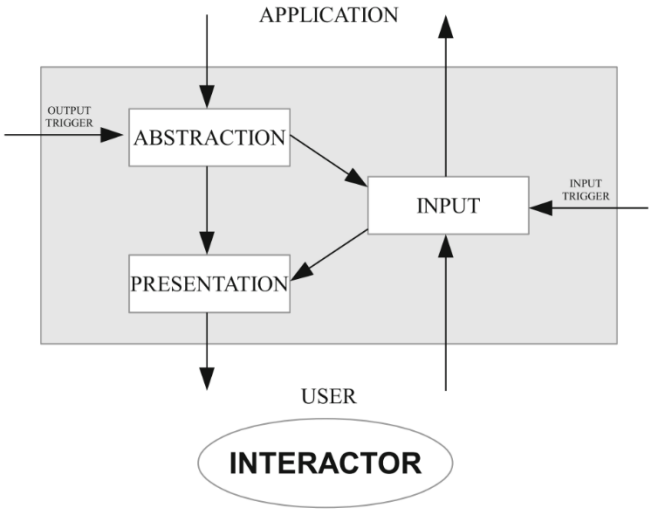

Figure 1-2 Paternò's Interactor Architecture [14]

As highlighted in Figure 1-2, information systems are made up of (1) an abstraction layer, that embed the description of data to be visualize; (2) input elements that processes user(s) input which is redirected to the core application or have an effect on the third component; and (3) the representation element, which defines the aesthetics of the interaction object [15]. From the model architecture one may infer that each component of an information system are crucial and the user interface (the representation element) plays an essential role in unveiling the abstractions of the algorithm in order for users to perform desired tasks within the scope of the system. Thus, from Paternò's Interactors Architecture**,** one can therefore define a Web-Based Information System, its constituents (Web-Based UI (UI); Users (U); UI Developers (Dev)) are formalized using first-order logic as follows:

$$\forall x \in UI\ (x) \rightarrow \{Dev | Dev \rightarrow UI\ (x)\}$$
$$\forall x \in UI\ (x) \rightarrow U\ (x) \qquad (1\text{-}1)$$
$$\exists\ UI\ (U) \rightarrow Category_N(U), \text{где } \{N \in \mathbb{Z} | (N > 0)\}$$

As represented in formula 1-1, x refers to any web-based information system and all web-based user interfaces are designed and built by UI developer(s) and these web-based user interfaces have users. Web-based information systems enable users to perform tasks through their web-based user interfaces.

It must be noted that UIs are constituted of elements (i.e. UI Elements) which serve as the building blocks and universal primitives for composing interaction patterns [16]. UI elements are designed to facilitate user interaction, enhance the overall user experience as they collectively contribute to how users interact with and perceive the interface [17]. UI Elements, within the constraints of the device used, serve as an abstraction layer for technical tasks, and provide feedback to users on the state of a given system [18]. Based on the taxonomy of UI Elements [19], they can be represented given a set W for any Web Application with the fundamental UI elements such as container (C), control (K), text (X), images (M), and dialog box (D):

$$\mathbf{W = \{C, K, X, M, D\}}$$

Where: $\mathbf{\{C, K, X, D \subset \mathit{W}\}}$

with the internal subset relations: $\mathit{I} \subset \mathit{K}$, $\mathit{T} \subset \mathit{I}$, $\mathit{L} \subset \mathit{K}$

Decomposing the subsets within the main set :

$$\begin{gathered}\mathbf{C} = \{\text{Window, Panel, Tab Panel}\} \\ \mathbf{K} = \{\text{Button, Input}\} \\ \mathbf{X} = \{\text{Label, Structured Text}\} \\ \mathbf{M} = \{\text{Simple Image, Map Image}\} \\ \mathbf{D} = \{\text{Information Dialog Box, Input Dialog Box}\} \\ \mathbf{I} = \{\text{Text Input, Checkbox, Radio button, List}\} \\ \mathbf{T} = \{\text{Text Field, Text Area, Password}\} \\ \mathbf{L} = \{\text{List Box, Dropdown List, Combo Box}\}\end{gathered} \tag{1-2}$$

The visual clarity, navigability, color, aesthetics and composition of the UI elements contribute to robustness, consistency, and completeness of web applications which influences users' ability to efficiently undertake tasks [19]. Research has also highlighted the relevance of UI element grouping UI elements using HTML tags like "div" enhances code readability, maintainability, and performance, while users perceive these groups visually, aiding navigation; this process is essential in UI visual intelligence and significant in UI-related software engineering tasks like testing, automation, and interaction [20]. Thus, the use of UI elements by front-end

developers requires a deep understanding of user requirements (which are subject to evolution and influences user experience), an understanding of the technology environment (which is also subject to rapid evolution) [19]. As such, for a seamless user experience, it is important for the choice and composition of UI element as well as layout adjustment during design and development to be considered iteratively (post-release) in accordance with varying user accessibility deficiencies, user skill levels, and total user experience.

In the design of UI, it must be understood that user characteristics such as skill level, role, system usage duration, and personal preferences influence UI design and determine how effectively and efficiently users can interact with an application. These user characteristics are informed by users' cognitive and mental capabilities. Beginners or less tech-savvy users typically require more straightforward, guided interfaces with clear instructions and minimal complexity to avoid confusion and reduce the learning curve. In contrast, advanced users may prefer more customizable and feature-rich interfaces that allow for greater control and efficiency. Preferences, including color schemes, layout styles, and interaction patterns, also vary widely among users, impacting their satisfaction and engagement with the UI. Adapting UIs to user requirements address these diverse needs by dynamically adjusting the interface based on user characteristics and behaviors.

The rapid adoption of web-based technologies is driven by the need for user-friendly, touch-based interfaces, open standards like TCP/IP, ease of setup, redundancy-free nature, e-commerce investments, multimedia support, and the rise of ubiquitous computing through smart devices. [21; 22]. Web-based technologies are the preferred user interface for emerging technologies due to their cross-platform compatibility, large developer community, redundancy, added security, responsive interfaces, ubiquity, ease of deployment, and low maintenance requirements.[23; 24]. To meet the evolving needs of consumers, legal regulations, and governmental requirements, businesses continually reinvent themselves by adopting and frequently improving technology in alignment with Moore's Law[25; 26].

One of such business models is that of networked (chain) organizational systems. Examples of such networked organizational systems include: Service-oriented firms; firms that deal in Fast-moving consumer goods (FMCG) or consumer-packaged goods (CPG) – Proctor and Gamble (PG); Global Trade Chains (major global retailers) such as IKEA, Carrefour, Sephora, Metro Cash & Carry, Auchan, Douglas, Leroy Merlin, and OBI [27]. These organizational systems

contribute to global and local economies through foreign direct investment, collaboration with local institutions (knowledge transfer), corporate social responsibilities, local industry growth, as well as contribution to lowering unemployment through job creation [27]. In the modern Russian business ecosystem, network companies operating across diverse sectors of the economy stand out as highly dynamic entities, boasting significant human resources and demonstrating strong adaptability to evolving business landscapes [28].

Due to their structure, networked organizational systems (also known as chain companies) play a key role in the development of innovation, integration of production and education, as well as in increasing the competitiveness of organizations through the effective use of information and communication technologies. They are characterized by automation, research and development (R&D), as well as innovative management as a means of gaining competitive advantage [27]. The effect of networked organizational systems is also evident from a financial technological (FinTech) perspective with the diffusion of innovations and financial models through partnerships such as "buy now, pay later" (BNPL) with platforms such as Apple Pay Later, Klarna and Afterpay; as well as loyalty programs (through gamification), and cashback models; personalized shopping experiences; digital wallets and cryptocurrency payments (smart contracts) [29; 30].

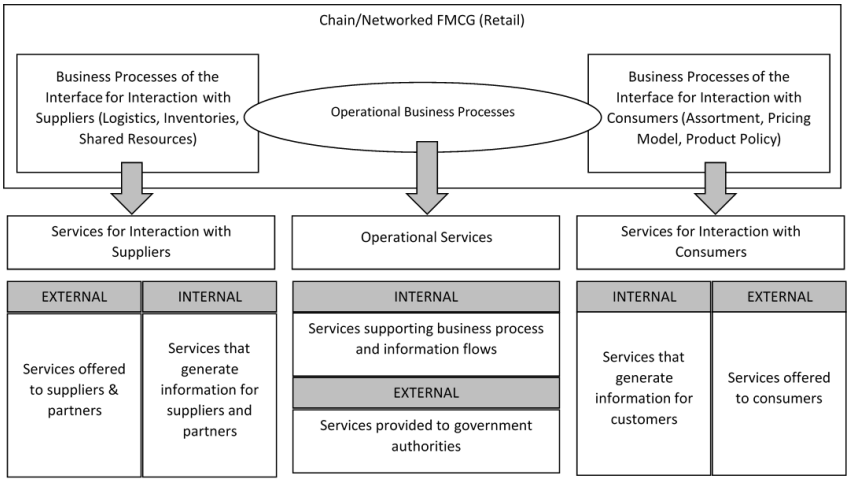

Figure 1-3 Classification of Business Services of Networked Organizational Systems (adopted from Voronova et al. [31])

According to studies, top-level business processes of networked organizational systems can be identified as three (3) functions: (a) basic/fundamental, (b) managing, and (c) supporting; which are aimed at value creation with respect to all business activities [32]. For any given networked (chain)

organizational system, according to an architectural model constructed by Voronova et al. (for the context of FMCG-oriented firms), there exist business services offered can be placed in three (3) classes: Supplier-oriented services, Operational Services, and Consumer-focused services; where all can furthermore be conducted at both internal or external levels (Figure 1-3) [31]. This can be formally represented as follows so as to captures the hierarchical structure of business services: Let S be the set of all business services for a networked (chain) organizational system. Let $S_{Supplier}, S_{Operational}, S_{Consumer}$ be subsets of S representing Supplier-oriented services, Operational Services, and Consumer-focused services, respectively. Each subset can be further divided based on their internal (int) and external (ext) components:

$$\begin{aligned} S_{Consumer} &= S_{Consumer(int)} \bigcup S_{Consumer(ext)} \\ S_{Supplier} &= S_{Supplier\ (int)} \bigcup S_{Supplier\ (ext)} \\ S_{Operational} &= S_{Operational(int)} \bigcup S_{Operational(ext)} \end{aligned} \tag{1-3}$$

Another study developed a conceptual model that structure of networked organizational systems from a data distribution perspective which serves as an architectural foundation for building any information system within the organization (Figure 1-4). These schema are indicative of the crucial role that information systems play in connecting all aspects of business processes in networked organizational systems for internal and external perspectives of business.

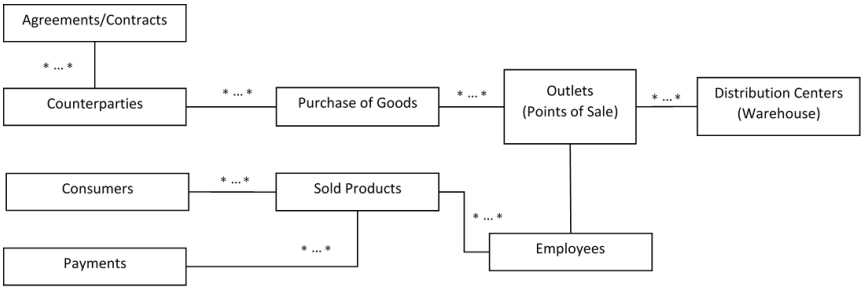

Figure 1-4 Conceptual Model (Data Structure) of a Networked Organizational System (The Case of FMCG Retail Network Companies) [33]

Networked companies as organizational systems depend on information systems to manage business activities and optimize business processes. With respect to information systems, presently, web-based technologies are adopted by most organizations because of the cross-platform capabilities of web programming technology, cheaper cost of hosting, ease of deploying and maintenance in comparison to traditional desktop software installed, and ubiquity of the internet.

Thus, network (chained) companies play a key role in the development of innovation, integration of production and education, as well as in increasing the competitiveness of organizations through the effective use of information and communication technologies [34].

Within the organization, the web-based information systems can be either purchased, built in-house, or hybrid (where modules are purchased and others are customized), depending on the firm's business requirements, budget and the level of expertise of the IT department. After implementing the web-information system, the IT department manages the entire life cycle of the information system. These web-based information systems, are used by employees of all technical skill levels and according to studies, software's characteristics (user interface, algorithmic structure, and system architecture) influence the efficiency of employees which in turn can affect the overall productivity of the firm. It must be noted that system users (employees) have different technical competencies which are subject to improvement over time. In addition, within the workforce of virtual organizational systems, there is a cycle of onboarding of staff which means new users have to adjust to the system. Developers' focus on backend improvements often overlooks the quality of the user interface, impacting user experience. Research should therefore develop a web instrument to cyclically improve both user interface quality and developer efficiency, addressing gaps in previous studies by aggregating relevant indicators into a comprehensive evaluation method and using UI quality as a feedback mechanism.

Organizations can be categorized as social systems which are created to make decisions and these complex decision making activities are capable of overwhelming the capacity of any business executives [35]. Today, organizational systems are adopting web-based information systems for managing their business processes. Thus, the use of web-based information systems provide interoperability between employees (users) to have access to necessary data and communicate effectively. Within the virtual organizational systems, presently, business intelligence (BI) and data are relevant components of information systems and serve as a mechanism to understand the state of the business and make necessary improvement [36]. As much as BI is important, a very necessary component of BI is the user interface component. In business analytics, storytelling is a popular paradigm where data analytics is used to present complex data in a comprehensive and compelling narrative to business executives support decision-making.

Backed by the theory of “bounded rationality”, researchers have postulated that it assumes that individuals have limited capacity to process information [37]. This is a cognitive component of user interfaces with respect to the users of the information systems in organization systems. Research highlights that majority of organizational decision makers (despite being experts in their domains) have non-technical backgrounds [35]. Also, organizational systems employ workers with varying skillsets and accessibility issues (for example visual impairments), as such, the use of visual representations, more precisely quality visual representations eases the complexity of use of information systems. Visualizations play the role of supporting analysis and knowledge transfer between analysts and decision makers [35]. Visualization improves perception, provides insight as well as control, and also harness the flood of valuable data for organizational systems to gain a competitive advantage for making business decisions (Al-Kassab et al., 2014).

Research has recommended visualization guidelines for modern information systems which should consider the cognitive aspects (the reduction of cognitive load), aesthetic relevance, and interactive visualizations as necessary components when developing the user interface of the information systems [38].

Control Tasks within Networked Organizational Systems

Digital transformation in enterprises is a widely adopted phenomena due to the benefits of technology adoption. One of such paradigms in the networked organizational system perspective is Retailer 4.0, where the transformation of the retail industry (including network/chain companies) adopt Industry 4.0 technologies, such as cyber-physical systems, cloud computing, Internet of Things (IOT), and big data analytics [39]. A primary task of managing chain organizational systems is their performance efficiency (which according to ISO 9241-11:1998 is the indicator characterizing the relationship between achieved results and resources used) because one unit of the firm is composed of a large amount of activities and resources which is connected to the profitability of the organizational system [40]. As such, monitoring allows decision-makers to determine how effective current strategies are and make the necessary changes.

Networked organizations/companies are modern organizational systems whose business processes depend on SAAS (software as a service) platforms. They purchase or build their web platforms based on their budget, long-term goals, and

the competencies of their IT department. After implementing an information system, the IT department manages the entire life cycle of the information system. System users, employees, have different technical competencies and improve their experience with the product over time. The user interface is the means to access the business logic. A quality user interface correlates with user experience, which influences user productivity and indirectly contributes to the effectiveness of the organizational system. Server metrics receive the most attention because companies believe that it is the core of an information system, but the user interface is not widely considered when measuring system quality. A networked (chain) company/organizational system can be formally represented in set theory as C= {E, S}. Thus, the developed system can be described as a tuple.

$$C = \langle \{U\}; \{S\}; R \rangle \quad (1\text{-}4)$$

Where:

$\{U\}$ – The set of company employees that are users.

$\{S\}$ – A collection of all IT tools and infrastructure, including web tools;

R – Matrix of connections between connections.

In the current work, there is a set $\{U\}$ of characteristics of the integral indicator of user experience UX, which consists of individual results UX_i, a set of $\{S\}$ characteristics of the integral indicator of user interface quality Q. Then the state of the system can be described as:

$$C = \langle \{U\}; \{S\}; Q; UX; R \rangle \quad (1\text{-}5)$$

According to the work of Гарматина and Готская (2018)[1], Huang et al. (2018)[2], Miya and Govender (2022)[3], Ma et al. (2023)[4], Goosen (2023)[5], Нурмухамедов

[1] Гарматина И. А., Готская И. Б. ВЛИЯНИЕ АНИМАЦИИ ИНТЕРФЕЙСОВ НА UX ВЕБ-САЙТОВ //Альманах научных работ молодых ученых университета ИТМО. – 2018. – С. 104-107.
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[3] Miya T. K., Govender I. UX/UI design of online learning platforms and their impact on learning: A review //International Journal of Research in Business and Social Science (2147-4478). – 2022. – Т. 11. – №. 10. – С. 316-327.
[4] Ma K. et al. Research on Influencing Factors of Elderly User Experience of Smart Home Social Software Based on Grounded Theory //International Conference on Human-Computer Interaction. – Cham: Springer Nature Switzerland, 2023. – С. 17-30.
[5] Goosen W. Curated eLearning in South Africa: A user burgeoning perspective //American Journal of Online and Distance Learning. – 2023. – Т. 5. – №. 1. – С. 1-24.

(2024)[6], user interface quality Q is a function of many variables, including user experience UX. All other things being equal, it can be described as such:

$$Q = f(UX) \tag{1-6}$$

At the same time, the UX value is a variable value over time, that is:

$$UX = f(t) \tag{1-7}$$

Thus, the quality of the user interface Q also becomes a function of time:

$$Q = f(UX(t)) \tag{1-8}$$

In instances where the user interface remains unchanged. Thus, the state of the system is:

$$C = \langle \{U\}; \{S\}; Q\big(UX(t)\big); UX(t); R \rangle \tag{1-9}$$

One of the parameters for managing organizational systems is the quality of the information tools used, including web tools. Therefore, the quality of user interface Q also becomes one of the control parameters. Traditionally, the Q value is an integral characteristic that combines the criteria of performance (P), availability (A) and usability (USE):

$$Q = f(P, A, USE) \tag{1-10}$$

However, according to the previous formula, the value of Q changes over time due to its dependence on the user experience $UX(t)$, then:

$$Q = f(P, A, USE, UX(t)) \tag{1-11}$$

Assessing the quality of the user interface Q depending on the user experience $UX(t)$, which changes over time due to changes in $UX(t)$, is the author's methodological approach. User experience $UX(t)$ is also an integral parameter that combines individual assessments UX_i of each user. In any organizational system, there is a wide distribution of employees by UX value, so clustering of users by UX level with subsequent weighted assessment of the integral UX value is proposed.

[6] Нурмухамедов А. Я. ВЛИЯНИЕ ДИЗАЙНА ПОЛЬЗОВАТЕЛЬСКОГО ИНТЕРФЕЙСА НА ЮЗАБИЛИТИ МОБИЛЬНЫХ ПРИЛОЖЕНИЙ //Вестник науки. – 2024. – Т. 3. – №. 5 (74). – С. 1146-1149.

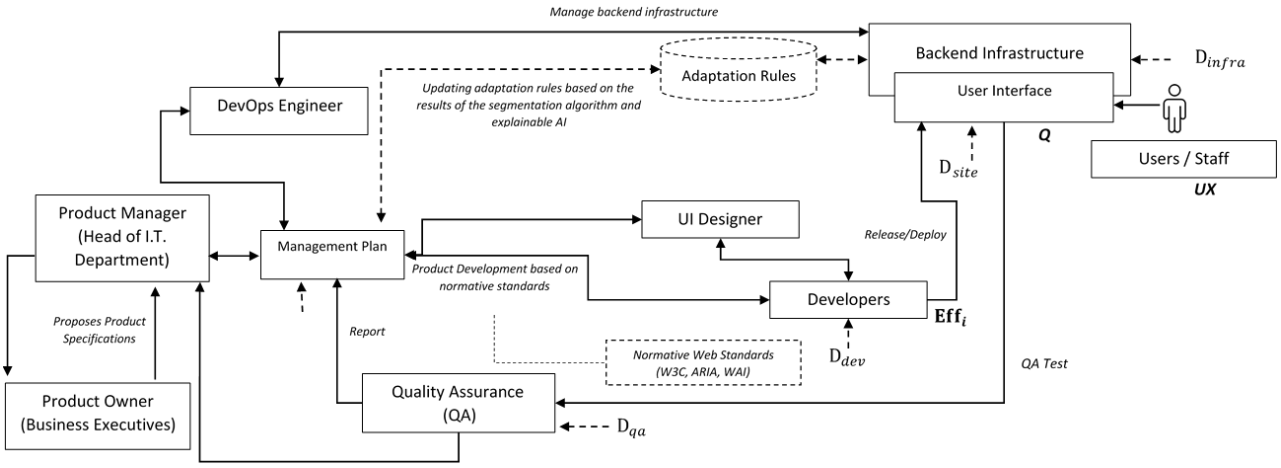


Figure 1-5 Structural Model for Decision Support through the Management of Networked Organizational Systems Taking into account Adaptation to Changing User Needs

Figure 1-5 represents the interaction of agents (users – developers, managers, and employees) with the information system within the networked organization system taking into account changing end user need. Let $D = \{D_{dev}, D_{pm}, D_{infra}, D_{site}, D_{qa}\}$ — set of disturbances or noise. Previous research backs the premise that design inconsistencies (poor aesthetics), complexity in user interface, system inefficiency influence the user experience which affects user efficiency and productivity [41]. Thus, the Pearson correlation between the quality of the user interface and the user experience which influences the user's performance in completing tasks can be represented as $r(Q, UX)$. Therefore, the goal is to $max\ (Q)$**,** under the condition where $D \leq 0$.

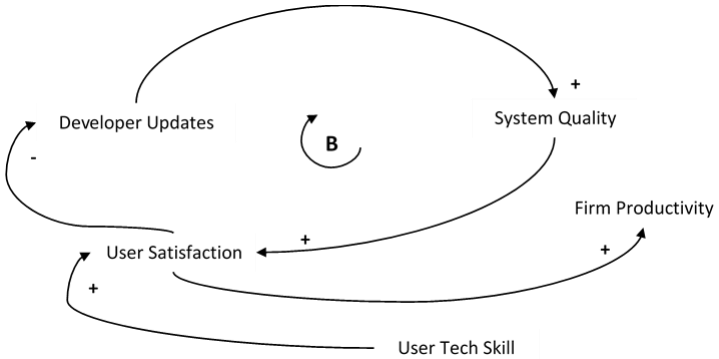


Figure 1-6 Conceptual Causal Loop Model of Networked Organizational System's (Relationship between Information Systems and Firm Productivity)

In the context of networked (chain) companies, this system dynamics model (Figure 1-6) highlights the interplay between employee user satisfaction and firm

productivity within a web information system platform. User Satisfaction according to ISO 9241-11:1998 is defined as when the user has no discomfort when using the product and has a positive attitude towards it. The model suggests that frequent updates to the system can improve system quality, which in turn leads to higher user satisfaction among employees. However, there's a potential downside: very frequent updates can also lead to user frustration, represented by the negative feedback loop on User Satisfaction. The model emphasizes the importance of achieving a balance. By considering both the positive impact of system quality and the potential drawbacks of overly frequent updates, chain retail companies can leverage their web information system platforms to enhance employee user satisfaction, ultimately leading to increased firm productivity. As such, when employees observe and recognize that management prioritizes service quality, these perceptions often shape their personal values regarding service excellence and subsequently impact their performance in delivering services [42].

The ubiquity of internet and its integration into business activity means that for networked organization systems, the achievement of a return on investment (ROI) is an important component of their information systems [43]. Thus, their research indicated that poor design, aesthetics and development influence the quality of web-based platforms which influences ROI. The web-based systems are not for one-time interactions as such they are developed to build a long-term relationship with users [44].

Modern Web Tools and Approaches to its Development

A recurring theme within the digital age is the surge in web-based enterprise management tools, designed to streamline operations, improve decision-making, and enhance overall business performance. Web-based enterprise management tools have revolutionized how businesses operate. By understanding existing approaches, their strengths and weaknesses, businesses can select and leverage the most suitable tools to enhance their productivity, competitiveness, and overall success [45].

According to experts, the level of flexibility and turnaround time of response/feedback in network organizations with respect to changing consumer requirements which sets the tone for constant development and evolution in the information system and the strategies of the system [46]. This characteristic of network organizational systems allows them to thrive in a rapidly changing

ecosystem (i.e. self-develop on the basis of continuous updates as a result of an innovation-oriented nature) [47]. Digital technologies used in the process of network interaction between enterprises. According to Slomanskaya and Dubko [48], there are four (4) levels of use of digital technologies in business:

a. Basic technologies used to improve business processes (Internet connectivity, website, as well as email);

b. Advanced technologies used to improve business processes (cloud computing solutions, social networks, e-commerce, Internet of things (IoT), big data and artificial intelligence);

c. Integrated deployment of digital technologies to transform business processes (such as web-based platforms and automation of business process such as using chatbots, workflow management tools, document robotization, cron jobs, etc.);

d. Digital technologies and management capabilities that contribute to business transformation (digital assets that spark new business models).

For the development of any form of digital technology in business, it must be noted that experts have developed, and proposed paradigms, frameworks and solutions to cater for evolving industry standards, changing IT landscape, user requirements, rapid research and development, governmental and legal regulations; such as:

a. Modular Design: Many tools adopt a modular architecture, allowing businesses to select specific functionalities (e.g., CRM, ERP, project management) based on their needs. This approach offers flexibility but can lead to integration challenges between modules from different vendors.

b. Cloud-based Solutions: Cloud deployment offers scalability, accessibility, and reduced IT infrastructure burden for businesses. Developers primarily adopt cloud models such as Platform as a service (PaaS), Infrastructure as a Service (IaaS), and Software as a service (SaaS) [49]. Cloud-based solutions also influence development and improvement of data security and reliable network communication.

c. Mobile-first Design: The increasing use of mobile devices has driven a focus on mobile-friendly interfaces which improves user experience and accessibility for employees on the go [50].

d. Privacy-by Design: A proactive approach that integrates privacy considerations into the design and development of systems, aiming to enhance user privacy, build trust, and ensure compliance with privacy regulations [51]. It involves incorporating privacy features early in the design process, utilizing values-oriented design approaches, and addressing the challenges posed by evolving technologies and regulatory landscapes.

e. Persuasive Systems Design: The goal of this approach is to build interactive computing systems designed to change the attitudes or behaviors of people [52]. To begin with, persuasion must be a product of HCI, as opposed to computer-mediated communication [53]. Also, it is important for persuasive effects to be intentional and planned, in contrast to being technology byproducts. Another important point is that, a persuasive intent should be endogenous to the product; in this way, the motivational appeal originates from the product itself. PSD's components encompass - Primary Task Support, System Credibility Support, Dialogue Support, and Social Support [53].

f. Data-driven Insights: Integration with business intelligence tools allows for data analysis and reporting, providing valuable insights for informed decision-making [54]. Experts continue to ensure data quality and user-friendliness of reporting tools for easing decision-making.

g. Artificial intelligence, Machine Learning, and Reinforcement Learning: Within the development of advanced enterprise web-based tools are incorporating AI automate tasks, improve forecasting, detect anomalies, and provide personalized recommendations [55]. In addition, developers and managers take into consideration the ethical perspective of AI ensuring interpretable results from AI models.

1.2. Approaches to Estimation of User Interface Quality

A relevant component of any information system [56], particularly web-based information systems is its graphical user interface (UI). There has been a huge growth in user interface design and its capabilities it affords to information systems [57]. According to ISO 9241-110:2006 UI can be defined as all components of an interactive system (software or hardware) that provide information and control tools to the user to perform specific tasks. Studies have defined UI as:

I. A medium a system provided for users such that they are able to interact with the system and vice versa, either they need to operate it, insert data, or utilize the contents that the system has [58].

II. The point of human-computer interaction (or a link between humans) and communication in a device (artefacts) and the overall he overall ease of use, aesthetics and overall design of a given information system [59; 60].

III. An aggregate of techniques with respect to information by which users interact with particular systems such as machines, devices, and programs [61].

Some components or forms of UI include, natural language interfaces, question-and-answer interfaces, form-fill interfaces, menu interfaces, command-language-interfaces (CLI), and graphical user interfaces (GUIs) [56]. According to studies, UI elements makes up 80-90% of information systems [56]. User interfaces form a level of abstraction that models tasks and serves as a medium between individuals and systems. In most contexts, UIs are a combination of multiple input modalities including speech, touch, body gestures and mouse movement in coordination with diverse outputs available within a given information system or multimedia system. Thus, it must be noted that UI communication is bidirectional where users perform actions and obtain results [62].

Historically, UIs have transitioned from: (1) CLI; (2) GUI; (3) natural user interfaces (NUI); and have been predicted to evolve into (4) organic user interfaces (OUI) [63]. As technological innovation has had its fair share of rapid improvement, HCI studies have proposed, conceptualized and deployed various UI concepts. These include:

a. Ontology-enhanced: a UI whose interaction possibilities, visualization capabilities, or development process are enabled or improved (at least) by the use of one or more ontologies [64].

b. Natural: These make it possible for interaction with the real world [65]. When the user can achieve his/her aim in an easy, intuitive and fast understandable way [66]. Examples include tangible interfaces, speech recognition, touchscreens, visual feedback made possible by tactile feedback technique and holographic displays [67].

c. Adaptable: These are systems in which the user can explicitly customize the presentation layout or settings of the system. An advantage of this category of UI

is that, users are in control of the personalized appearance of the UI and demerits include the need for learning as well as invasiveness/distractions. As such users with disabilities and lower IT literacy would benefit most from personalized user interfaces, as they often have severe problems with standard configuration [68].

d. Tangible: everyday objects or environments that augment the physical world by being coupled to digital information [69]. Studies have highlighted the transition of tangible UI into two (2) directions, namely Mixed Reality domain (XR: Extended Reality) and Material domain (HMI: Human Material Interaction) [70].

e. Multilingual: enable the localization of user interfaces for globalized applications [71].

f. Locomotion: a locomotion user interface (LUI) delivers an immersive experience to users whereby whole body motion is simulated by using motion devices in augmented and virtual reality [72].

With respect to user interface design, ISO standards have been established and studies have advised UI designers to follow through. ISO 14915-1-10 - Ergonomics of increased waves of interfaces. Part 1. Design principles and structure; ISO 14915-2-2013* - Ergonomics of multimedia user interfaces. Part 2. Navigation and control of multimedia tools; ISO 55241.1-2012 - Ergonomics of human-system interaction. Part 100: Introduction to standards related to software ergonomics; ISO 9241-161-2016 - Ergonomics of human-system interaction. Part 161. Elements of the graphical user interface; ISO/IEC 12119-2000 - Information technology. Software packages. Quality requirements and testing; ISO/IEC 9126-93 - Information technology. Evaluation of software products. Guidelines and Quality characteristics for their use. These ergonomic principles are used to improve the efficiency of UI between the user and complex technical objects.

According to research, human-centered UI design seeks to bridge the following gaps during the interaction between humans and digital interfaces: "Gulf of Execution" (the challenge when people are incapable of performing an action) and "Gulf of Evaluation" (the instance where individuals are incapable of assessing the result of an action) [73]. Human-centered user interface design could result in increasing the perceived utility (the degree to which an individual considers that using a given system creates the tendency of increasing performance in their activities) [74]. It must be noted that within any given organizational system’s information system, UIs are designed to perform technical tasks conducted by users

for delivery of business activities. According to ISO 9241-11:1998, tasks are defined as activities necessary to achieve goals. These technical tasks include: (a) Presenting (Abstracting) functionalities for users of cyber-physical systems and user data or action validation; (b) Tracking health data and notifying users in the instance of the surmounting of set parameters; (c) In virtual environments to orient the laser pointer on a button and click for the selection, as well as to teleport to other places within the scene; (d) Visualization purposes [75]; (e) Reduce mobile device positional uncertainty over time as well as monitor power utilization [76].

In as much as web-based information systems are built to perform desired tasks, some web-based information systems are unable to undertake these technical tasks. Reasons why web-based information systems may be unable to perform the desired technical tasks for which they were built include:

I. Insufficient resources: The system may not have enough computational power, memory, or storage space to perform the required tasks efficiently.

II. Browser compatibility issues: Different browsers may interpret the same code differently, leading to compatibility issues and difficulties in achieving the desired performance.

III. Poorly written code: The code that runs the system may contain bugs, be poorly optimized, or be written in a way that is not scalable, leading to performance issues.

IV. Network connectivity: If the system relies on a network connection, a slow or unreliable connection can impact the system's ability to perform its tasks.

V. Integration issues: If the system integrates with other systems, compatibility issues or poorly designed integrations can impact the system's ability to perform its tasks.

VI. Security vulnerabilities: Web-based systems are vulnerable to security threats such as hacking, malware, and data breaches, which can impact the system's ability to perform its tasks.

VII. User errors: Users may make mistakes, such as entering incorrect data or using the system in a way that was not intended, which can impact the system's ability to perform its tasks.

VIII. Outdated technology: As technology advances, web-based systems may become outdated and unable to perform the tasks for which they were built, due to the lack of compatibility with new technologies or standards.

A summary of UI challenges are indicated as follows:

I. Research reported that for end-to-end (E2E) encrypted communication tools, a main UI challenge is the ability to provide assurance that users are actually communicating with the intended party [77]; pointing to the fact that UI is relevant in presenting trustworthiness as well as easing communication on platforms.

II. Usability: Ensuring that the GUI is user-friendly and intuitive can be challenging, as different users may have different preferences and requirements. Adapted definition from ISO 9241-11:1998, usability is defined as the property of a system, product, or service that enables the intended user to use the product under specified conditions of use to achieve specified goals with desired effectiveness, efficiency, and satisfaction.

III. Accessibility: Making sure the GUI is accessible to users with disabilities, such as those who are blind or have limited mobility, can be a significant challenge.

IV. Cross-browser compatibility: Ensuring that the GUI works seamlessly across different web browsers and devices can be a complex task.

V. Performance: GUIs can be resource-intensive, and ensuring good performance, especially for complex applications, can be challenging.

VI. Design consistency: Maintaining design consistency across different pages and components of the application can be difficult, especially as the web information system evolves over time.

VII. Interactivity: Implementing interactive elements, such as hover effects, animations, and drag-and-drop functionality, can be challenging, especially in older browsers.

VIII. Security: Ensuring that the GUI is secure against attacks, such as cross-site scripting (XSS) and cross-site request forgery (CSRF), can be challenging, as attackers can exploit vulnerabilities in the GUI to gain unauthorized access to sensitive data.

These challenges have been widely discussed in the literature, with studies indicating the need for a more systematic approach to GUI design and development in web applications (e.g. [78]).

User Interface (UI) evaluation is a critical step in software development, ensuring that the system effectively meets user needs. By gathering feedback from users, UI evaluation helps developers and system administrators identify areas for improvement, enhancing communication and overall user experience [79]. Early UI evaluation provides designers with valuable feedback on their design concepts, allowing for timely adjustments and improvements before investing significant resources in the development process [80].

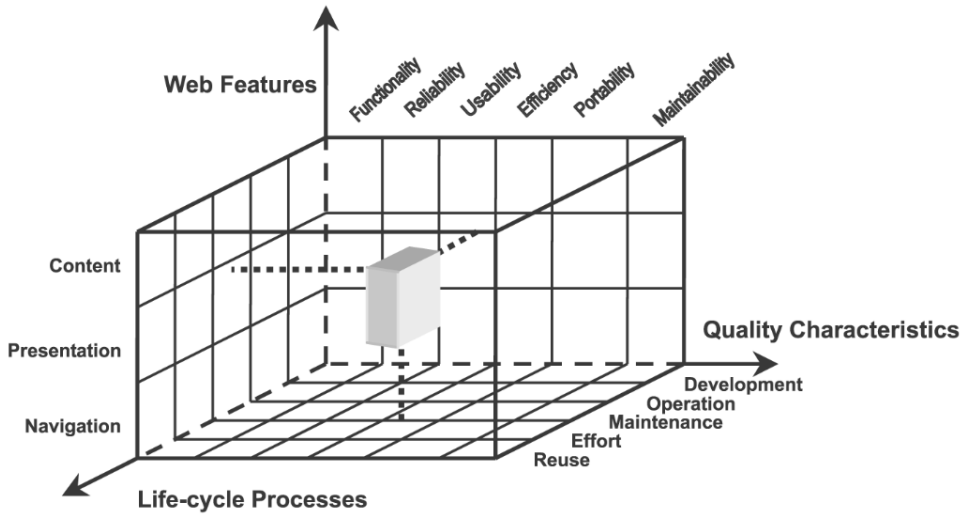


Figure 1-7 Web Quality Model (WQM) Cube [81]

The short lifecycles of web-based application development results in a lack of quality and research identified that the adoption of metrics is a good quality control mechanism [81]. As presented in Figure 1-7, Calero et al. proposed the WQM as a blueprint and framework for organization of testing across three (3) dimensions: Life-Cycle Processes, Web Features, and Quality Characteristics [81]. The cube forms a basis for this study with respect to development of web-based UI quality assessment of information systems in networked organizations as a control mechanism considering changing user requirements. Research has pointed out that most web quality metrics are built on an ad-hoc basis as such do not consider the software lifecycle in the evaluation model. In the case of this study, the changing user requirements is considered as a crucial factor when developing the proposed model (web-based UI evaluation). The goal of web-based UI evaluation considering changing user requirements is to:

- estimate a web-based information system's productivity and performance;
- establish the components leading to issues or errors;
- improve and optimize the system's interactivity, efficiency and productivity;
- understand user behavior and user experience so as to leverage them for designing interactive systems [82];

Wilson identified five (5) categories of UI evaluation techniques: Heuristic Evaluation, The Individual Expert Review, Perspective-Based UI Inspection, Cognitive Walkthrough, Pluralistic Usability Walkthrough, and Formal Usability Inspections [83]. A recent study categorized UI evaluation methods into three primary groups: Cognitive Walkthrough, Heuristic Evaluation, and Perspective-based inspection [84]. Cognitive Walkthrough, Heuristic Evaluation, and Action Analysis were also identified as categories of UI evaluation methods [85].

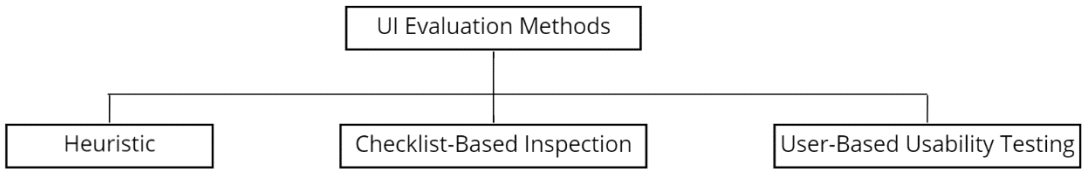


Figure 1-8 UI Evaluation Methods

Figure 1-8 illustrates the three (3) categories of UI evaluation into. The thesis adopts the classifications presented by Marcin Sikorsi and Jean Scholtz [86; 87]. To improve the efficiency of any given information system so as to align with an organizational system's goals, experts have encouraged the adoption of key performance indicators and metrics. Research supports this by stating that, control is attained by four control mechanisms which include: (a) planning, (b) measurement, (c) feedback and (d) evaluation-reward [88]. Figure 1-10 presents the framework proposed in that study. The framework outlines a central control system consisting of organizational structure, culture, and external environment, aiming to influence employee behavior. While the core control system directly influences behavior, the context provides indirect mechanisms. This model focuses on human agents, with the operational subsystem encompassing individual, group, and organizational levels. Processes involve planning, setting standards, monitoring adherence, providing feedback, and adjusting standards. The control context elements can either facilitate or hinder the effectiveness of the core control system, impacting communication and acceptance of standards [89]. Organizational culture

influences whether control mechanisms manifest as formal or informal behavior control, with context configurations potentially strengthening trust and enhancing employee performance. One category of UI evaluation is the expert-based approach where a group of experts play the role of existing or would-be users and strive to identify possible paucities within the interface design [80]. They enable a quick and easy evaluation process [90].

Heuristic evaluation is an informal methodology (as described by Jakob Nielsen) where a number of evaluators (experts in most cases) assess whether each element of a GUI complies with established usability principles (heuristics) [85; 91]. It is defined as a subjective approach aimed to assess the degree of compliance of specific user interfaces and rather than simply unveiling existing usability problems, it creates room for discovering newer opportunities for improving user experience [86]. Its applications include evaluating government e-portals; higher education websites; mobile augmented reality [92]. It is a quick and easy approach for user interface design evaluation and is less expensive to undertake in comparison to laboratory tests[84]. In spite of its merits, heuristic evaluation also has its shortcomings such as: inconsistencies within evaluators' analysis; in some instances, the actual user needs are not identified due to the lack of experts with requisite domain knowledge of the information system. Another heuristic evaluation challenge is inability to identify core issues due to the fact that it is capable of identifying solely usability issues [83].

The **Checklist-Based Inspection** method detects ambiguities in user interfaces by providing essential information to stakeholders [93]. It is undertaken by a qualified specialist or tester who works on a particular developer team [86]. An example of a checklist-based inspection method is MoLVERIC which was developed to inspect MoLIC (Modeling Language for Interaction as Conversation) – a language for representing interaction models for building artifacts including mockups – diagrams that use cards with verification items with the principles of gamification [94].

Perspective-Based Inspection method is a heuristic evaluation approach where a list of usability concerns are split by evaluators into various perspectives yet the goal is to focus on one perspective of the heuristics through the inspection session. Studies have applied it in reviewing agile requirements (primarily security-related components) of web applications [95]. The researchers highlighted this method as a formal technical procedure.

Cognitive Walkthrough (CW) method is used to assess usability and user experience (UX) of systems and is referred to as a discount evaluation method which is comprised of four (4) questions answered by novices. Here, an evaluator assigns a scenario-based task and questions to users [96]. It is used in identifying the parts of an application that requires improvement. This technique has been implemented in the evaluation of UI for numerous years and in usability enhancement. Researchers extended the CW method (the Enhanced Cognitive Walkthrough) for identifying errors (with respect to system use) and usability problems. It is easily implementable and not time-constraining. CW method has been identified as a supplementary tool in usability engineering [97].

Action Analysis is a usability evaluation approach used to split the procedure of a task setup into uninterrupted activities to discover solutions to identified usability problems [97]. **Action analysis** decomposes the operation process of users into continuous basic actions to discover issues of interaction with respect to UI design [98]. Action analysis has been applied in Quality Assurance Processes for Machine Learning (QA4ML) processes, as well as to accurately predicting the required time for an expert user to complete tasks [99].

Method	Description	Scope	Data Source	Evaluation Indicators
Interface Trustworthiness Quality Model (QM) [100]	The study was aimed at proposing an evaluation model that seeks to complement the overall trustworthiness of information systems by evaluating the user interface. The interface trustworthiness quality model is comprised of 21 Metrics and score ranges from 0 to 1.	Website *(E-Commerce)*	User Evaluation *(7-Point Likert Scale Survey*) Automatic Tools (*to measure subjective attributes*)	• Usability • Accessibility • User Experience • Responsive Rate, • Performance Page Up, • Affordable Rate • Broken Links
Heuristic [101]	The study proposed the utilization of a heuristic approach and usability measurement for UI and UX evaluation of Learning Management Systems (LMS). UI quality is essential for the effective system efficiency. The Heuristic evaluation • Visibility of system status • Match between system and the real world • User control and freedom	Website *(Learning Management System)*	User Evaluation	[Usability] • Learnability • Efficiency • Memorability • Error • Satisfaction

Method	Description	Scope	Data Source	Evaluation Indicators
	• Consistency and standards • Error prevention • Recognition rather than recall • Flexibility and efficiency of use • Aesthetic and minimalist design • Help users recognize, diagnose, and recover from errors Help and documentation			
System Usability Scale (SUS) [102]	As a means of improving UI design (user-friendliness) and functionality, the system usability scale (SUS) is adopted to evaluate UI quality.	Website *(IOT Monitoring Platform)*	User Evaluation *(5-Point Likert Scale; 10 questions)*	• System Usability Scale (SUS)
User Survey [103]	The study applied UI Principles and Shneiderman's Golden Rule to evaluate an e-commerce website (Shopee).	Mobile Application *(E-Commerce)*	User Evaluation	• Minimalize horizontal scrolling • Design consistency • Providing a history list • User-customization

Method	Description	Scope	Data Source	Evaluation Indicators
				• Design for smaller devices • Providing back button • Explanatory elements
Heuristics [104]	Researchers proposed an extended usability evaluation criteria associated metrics for web environments to minimize the influence of subjectivity in previous evaluation techniques. The method is less sensitive to a change of evaluator and expert evaluators are not a prerequisite thus creating room for robustness.	Website	User Evaluation *(Scale of 0–10 per question)*	[Usability Evaluation Criteria] • Main page - 50% weighting • Main links - 30% weighting • Interior pages - 20% weighting
Quality Assurance (QA) Simulation Methodology [99]	Researchers proposed a simulation-based approach which is for evaluating UI design parameters and optimizing interfaces.	Intelligent User Interfaces for Quality Assurance Processes	Simulation-based approach	• Quality Assurance Processes for Machine Learning (QA4ML) data ○ Layout

Method	Description	Scope	Data Source	Evaluation Indicators
	The approach enables UI specialists to optimize UI via simulation of potential design parameters. Simulations though non-comprehensive are capable of addressing a number of small but costly design issues.	for Machine Learning (QA4ML) processes		○ User Actions (Global and Local Commands) ○ Time Cost
Group-based Usability Evaluation [105]	Studies evaluated the usage of a website with respect to the different categories of users, based on the usability guidelines defined in ISO 9241-11 (ISO/IEC, 1998). From their studies there were no significant difference between the various groups with respect to satisfaction level. Recommendations were made based on the observed weaknesses.	Websites	User-Based Evaluation • *Empirical Data – Task Based Methodology (Formal Usability Testing - 10 Tasks)* • *Qualitative Data (System Usability Scale (SUS))* *(Grouped Approach based on Demographics)*	Statistical Analysis • Statistical Significance Test (Non-parametric Kruskal-Wallis H test) Usability Evaluation • Effectiveness • Efficiency • System Usability Score
Metric-based Usability Evaluation (INUIT)	Due to the fact that previous methodologies such as AttrakDiff and UEQ which focused more on user	Websites	User Evaluation (Questionnaire)	Usability factors (based on ISO 9241-11) • Informativeness

Method	Description	Scope	Data Source	Evaluation Indicators
[106]	experience, lacked usability evaluation, and lacked the appropriate level of abstraction.		*Confirmatory factor analysis* *Goodness of Fit Test*	• Understandability • Confusion • Distraction • Readability • Information Density • Accessibility
UI evaluation with USE model [107]	Researchers applied the USE (Usefulness, Satisfaction, and Ease of Use) Questionnaire to evaluate food delivery services.	Websites	Usefulness, Satisfaction, and Ease of Use (USE) User Evaluation (Questionnaire) *Likert Scale*	Likert Summated Rating (LSR) • Usefulness • Ease of use • Ease of learning • Satisfaction
Multi-objective optimization (Automated) [108]	According to the researchers there are few studies on evaluation of mobile user interfaces. Existing techniques are error-prone and time-consuming. As such their study proposed the integration of user's feedback and profile in evaluating MUIs. They proposed a fully automated framework where	Mobile UI (MUI)	Multi-objective evolutionary algorithms	Aesthetic Features and User Feedback • Density • Composition • Sorting • Integrality • Regularity • Complexity • Symmetry • Repartition

Method	Description	Scope	Data Source	Evaluation Indicators
	mobile UI evaluation is viewed as a search-based multi-objective optimization problem. Here, their research is aimed at maximizing the number of violations detected while minimizing the complexity detected as well as enhancing the overall quality of UI via guidance and coherence.			
Image-Based UI Analysis with Feature-based Neural Networks [109]	As UI testing and evaluation techniques are beginning to depend on Computer Vision algorithms, despite deep learning being computationally expensive. Researchers built a predictive model built based on Rico dataset to predict subjective user impressions. The dataset was trained on labelled (subjective UI impressions) by users and a model was built as a benchmark for UI evaluation.	Websites	Automated Approach – Deep Learning *(7-Point Likert Scale)*	Subjective impression scales: • Complexity • Aesthetics • Orderliness Regression Analysis (Error Metrics) • ANOVA • MSE

Method	Description	Scope	Data Source	Evaluation Indicators
Deep features extraction for UI Evaluation (Automated) [110]	To reduce the difficulty in manual evaluations, researchers proposed an approach based on graphical MUI analysis using screenshot (i.e. no source codes and user involvement). They adopted the GoogleNet architecture and applied the K-Nearest Neighbor algorithm to classify MUIs as good or bad. To obtain a balanced dataset Borderline-SMOTE method (BSM) was utilized.	Mobile UI (MUI)	Automated Approach – Deep Learning (Screenshots)	Deep features extraction
Domain Ontology [111]	To evaluate the quality of web UI, researchers proposed a novel framework and developed a web platform which incorporates domain ontology. The initial stage involved UI conceptualization and its related concepts (based on existing research and standards), followed by	Website	Domain Ontology	• Attributes: ○ Accessibility ○ Clarity ○ Consistency ○ Desirability ○ Familiarity ○ Reliability ○ Responsiveness ○ Usefulness ○ Usability

Method	Description	Scope	Data Source	Evaluation Indicators
	designing an ontology used to calculate the metrics.			○ Searchability ○ Simplicity ○ Visual Hierarchy • Metrics: ○ Performance ○ Security ○ SEO ○ Sociality ○ Convenience
Metric-based assessment of web user interface (WUI) quality attributes [112]	Researchers developed a visual analyzer and a novel predictive model for web user interface visual complexity.	Website	Screenshots Subjective Evaluation *(7-Point Likert Scale)* Analysis of Correlations	• 7 Visual Analyzer (VA) Metrics • 10 Aalto Interface Metrics (AIM) Metrics (Perceptual Fluency) • MATLAB (entropy)

Table 1-2 Summary of UI Evaluation Algorithms and Methodologies

Table 1-2 highlights the state of the art with respect to UI evaluation of web-based information systems. Evaluation of UI has transitioned from user survey and heuristic approaches to the integration data-driven techniques. Thus, creating the opportunity for more quality and efficient evaluation techniques. Despite the techniques presented in Table 1-2 having distinct approaches to user interface evaluation, it is observable that usability is a common metric adopted in the process. While algorithms and methods for UI evaluation offer valuable insights, they have limitations. Studies highlight the following drawbacks:

- A number of criteria have a susceptibility to the lack of objectivity when measuring usability [104].
- Web quality metrics often lack a systematic approach tied to the software development lifecycle, leading to potential inconsistencies and omissions [113].
- Relying solely on user testing can miss usability issues that users with limited human-computer interaction (HCI) expertise might not recognize [114].
- The cognitive walkthrough method primarily focuses on identifying usability issues related to task completion and understanding. It may not fully capture aspects like task efficiency, aesthetic appeal, or overall user satisfaction [115].
- Simulation methods, while valuable for certain aspects of UI evaluation, cannot fully replace the insights gained from direct user testing and observation [99].
- Existing research often relies on subjective evaluations of aesthetic defects, which depend on feedback from end-users. This manual approach can be time-consuming and prone to errors [108].
- Expert-based evaluations can be limited in their ability to identify usability issues influenced by multiple contextual factors that occur in real-world user interactions with information systems [90].
    - Weight-based metrics have pre-defined or static coefficients and do not make room for possibly variation in weights over time.
- User interface testing is an essential phase within the software engineering process for resolving existing problems. Automated UI testing helps developers to conveniently test different versions of their web-based

technologies in during multiple stages of the software development lifecycle, as well as on multiple devices for a long period of time. It has been pointed out to be a time-conserving activity especially when working on large development projects [116].

- Automated Visual Testing is a quality assurance approach designed to automatically verify the visual display of an interface [117]. It follows the procedure of establishment of the state of the web UI, capturing the layout (usually via CSS element verification and/or screenshots), evaluating the layout with algorithms, and reporting. Researchers developed VTEST (an industrial automated visual testing framework) which has been applied in evaluating the Taobao e-commerce app in China and recommended it for industry practices [118]. Another study applied automated visual testing in the evaluation of UI of IoT systems in healthcare (precisely mobile healthcare or m-health) [119].

- Goal-Based Evaluation utilizes user representations to assess the extent to which users are able to achieve targets during the UI testing phase. User Representations are artificial extensions of a user's physical body, which enables the user to execute actions in virtual environments (web-based UI in this case), which otherwise would be unreachable [120]. Thus, they map input space and out space depending on the physical device. Examples user representations considered in the analysis of UI include: mouse pointer, scrollbars, buttons and HTML input. For example, the state of the user is encoded in the current position (where *x* and *y* are co-ordinate positions) of the pointer as a vector (*z*):

$$z = [x , y]^T \qquad (1\text{-}12)$$

- Where *x* and *y* are state variables representative of the screen coordinates. According to the researchers, a critical understanding of their proposed u0/ser representation framework may enable researchers and practitioners to evaluate in-depth how a User Representation's visualization and control-mapping function can be adapted to effectively support a specific task, as well as can be leveraged to promote behavioral changes [120].

- It must be noted that, aside widely known automated evaluation techniques, Deep Reinforcement Learning (Q-learning-based algorithms), due to the intensity involved in preparing data for supervised learning, has also been

recently proposed for exploratory UI testing, which was reported to have performed better than inexperienced human users and almost as good as experienced human users [121].

Research has recommend the combination of both heuristic evaluations and usability tests in order to perform a comprehensive evaluation [85]. For example, heuristic approaches can make up for overlooked errors during user-based evaluations [114]. UI evaluations are relevant because they are focused mainly on the component of the information system that enables users to communicate instructions to the machine [80]. Web-based UI's are usually non-static, thus, prone to changes (constant) which is as a result of functionality upgrades, improved usability, evolving user requirements and also evolving contexts within the business world. As such UI quality assessment is highly relevant for the following reasons:

a. User Experience: A web-based systems that is easy to use, visually appealing, and provides relevant and accurate information is likely to have a higher user engagement and satisfaction. In addition, research has identified that, good user interface design makes a difference between a product accepted or rejected in the marketplace [122].

b. Credibility: Inaccurate or misleading information, and lags in interaction on a web-based information system can damage the reputation of the system and the organization behind it [123]. Assessing the quality of information and content on a web-based systems can help establish its credibility and build trust with the users.

c. Accessibility: A web-based systems that is not accessible can limit the ability of some users to access its content [124]. By assessing the quality of accessibility, a web-based systems can be made more inclusive and accessible to all users.

d. Search Query Optimization: Working with information systems in organizational business process requires search as part of user activity. As such, running queries must be made feasible and quick through optimizing the code to reduce the search result return time [125].

e. Legal Compliance: Web-based systems must comply with various legal requirements, such as privacy and data protection laws [126]. Assessing the quality of a web-based systems can help identify any legal compliance issues

and ensure that the web-based systems meets the necessary standards (i.e. feedback and compliance mechanism for networked organizational systems).

According to research, businesses that conducted evaluation of web-based applications experienced satisfaction with performance and success of their digital projects [43].

1.3. Approaches to Estimation of User Experience

Research has established a correlation between the quality of user interface and user experience. Quality UI enables users to find relevant information as well as sums up design decisions that result in effective products [127].

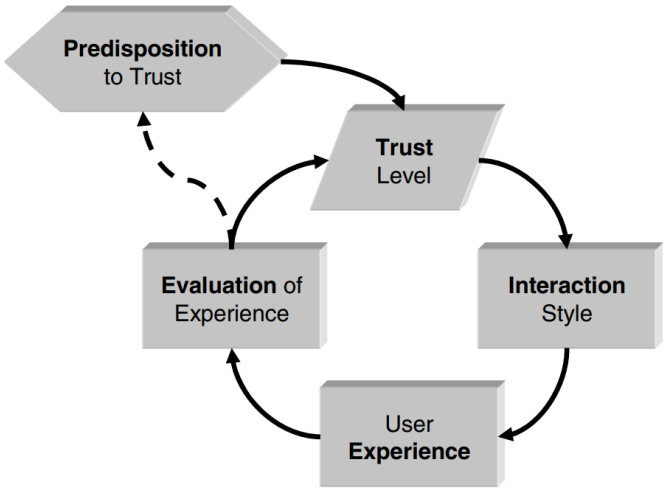


Figure 1-9 Larry Constantine's Feedback model of trust in user-system interaction [128]

According to studies UI must encompass the following properties: Usability, Effectiveness, Responsiveness, Predictability, Transparency, Visually Appealing, Competence, and Benevolence [129]. These properties are salient factors relevant for user interaction and must be considered in UI design. User trust of a given UI emerges from prior experience which then influences the evaluation of the system; creating a cycle (as seen in Figure 1-9). The inclusion of the salient properties enforce trust which can be fostered initially, increased, decreased, lost, and regained [130].

User experience (UX) encompasses the overall impression and satisfaction a user has when interacting with a technology product or service [131]. A poorly designed user interface can hinder user effectiveness and efficiency, undermining

the productivity goals envisioned by system developers [56]. Also, UX is highly dependent on user profiles and engagement management. Research has noted that positive user experience is the result of a combination of the fundamental principles of user interface, with usability including: factors motivating the user; causes inconvenience to the user; reliability design; clarity of content; and analytics [132]. ISO 9241-210:2019 defines UX as the user's feelings, thoughts, and actions resulting from using or anticipating the use of a product or service. [133]. According to the technical document, user perception includes emotions, beliefs, preferences, perceptions, comfort levels, behaviors, and accomplishments experienced before, during, and after using a product or service [133]. User experience is influenced by a user's internal factors (e.g., emotions, beliefs) and external factors (e.g., context, abilities). These factors interact to shape the user's overall experience. In summary, the formula below formally represents the makeup of UX:

$$UX = \{\text{Prior Experience, Skills, Personality, Usage Context}\} \quad (1\text{-}13)$$

User experience has also been identified as a set of impressions, knowledge, skills and experience that a client receives in the process of using or consuming a product by a company [134]. This occurs within the lifecycle of any given product and must be managed. User experience is a core component of the customer experience, and has one of the key influences on the user's customer experience. As such, customer experience management involves all activities associated with the lifecycle management to ensure optimal user experience [135]. Activities that are undertaken with respect to customer experience management include strategic planning, analytics, user feedback assessment; and one of the ways of contributing to customer experience is segmentation of users to curb churn and improve system efficiency [136].

Segmentation as defined by experts is the division of datasets into groups (semantically interpretable); accomplished based on based on information such as geographic location, socio-demographic features (for example salary, age, or gender), psychographic features, and behavioral factors [137]. Segmentation provides a means for communicating users' needs effectively as well as assesses their needs for a given product or service. In the domain of marketing, segmentation has been recognized as a de-facto standard in understanding clients, potential customers with homogeneous characteristics, behavior and needs, so as to target them with improved or even personalized products or services [138].

In the software engineering lifecycle, research has highlighted that during the requirements engineering phase it is important to segment users (potential and target) based on the system's goals; and this will be beneficial for marketing purposes. The role of user segmentation in improving user experience include [139]:

- Personalized Services: By segmenting users based on their characteristics, preferences, and behaviors, companies can tailor their services to meet the specific needs of each user group. This leads to satisfying user experience.
- Targeted Marketing Strategies: Understanding user segments allows businesses to create targeted marketing campaigns that resonate with different user groups. By delivering relevant content and promotions to each segment, companies can improve user engagement and conversion rates.
- Improved Product Recommendations: User segmentation enables companies to provide personalized product recommendations based on the preferences and behaviors of different user groups. This targeted approach enhances the user experience by offering relevant suggestions that align with individual preferences.
- Enhanced Communication: Segmented user groups can benefit from tailored communication strategies that address their specific needs and interests. By customizing communication channels and messages, companies can foster better engagement and interaction with users.
- Efficient User Support: Understanding user segments allows companies to provide more efficient and effective user support services. By tailoring support resources and channels to the preferences of different user groups, companies can enhance the overall user experience and satisfaction.

Table 1-3 highlights a summary of applications of user segmentation with respect to user experience. With respect to the application of segmentation in web-based systems, majority of the applications are within the e-commerce and marketing-oriented; in addition, studies focus on a fixed number pre-defined segments. To contribute to scientific and practical research, an article was published as part of the dissertation results where user segmentation was applied to usability data through a machine learning algorithm - K-Means clustering [140]. Machine learning in user experience research is quite recent and can be attributed to the trustworthy diffusion of ML and AI algorithms in more recent times within many industries.

Table 1-3 Summarized Overview of User Experience Assessment Techniques and Use Cases

Method	**Description**	**Application Context**	**Data Source**	**Measurable Data and Metrics**
Mixture of Factor Analyzers (MFA) & Factor Analysis (FA) [141]	This study was aimed at systematically analyzing the connections between users' hidden (latent) conceptual interests and their observable navigation patterns (online behavior analysis) using a principled probabilistic approach.	Web Platforms	Navigation data of users (server logs)	• browsing history • user sessions
Neural Network-based segmentation based on application usage sequence [142]	Researchers used neural embedding and a sequence-to-sequence (seq2seq) model architecture. According to the study, the following segments were established: Conversationalists; Utilitarian; Social stars; Photographers; Music lovers; News and magazine readers; Video streamers; Gaming buffs; Power users; Beginners.	Smartphone Applications	Smartphone Logs	• menus in applications, • application notifications, • search history
Top-Down and Bottom-Up Approaches to User Segmentation [143]	The study used hierarchical cluster analysis for highlighting respondents groups of with similar answers to questions about their usage of a career website. According to the research, cluster analysis can generate detailed, personas built on data-based, offering valuable insights into user preferences and needs while providing design teams with prompt, meaningful recommendations.	Career research websites	survey data	• salary • demographics • preferences • frequency of use • employment status • parental status

Method	Description	Application Context	Data Source	Measurable Data and Metrics
Activity Monitoring Segmentation Model for Recommendation Systems [137]	The researchers identified that activity-based segmentation as a marketing approach which can provide customer insight to sports apparel manufacturers and sports equipment marketers. In their study, the following segments were defined for a segmentation model for the sports apparel market: Sporty; Elite sports; Everyday wearers; Fashion sports; Budget-conscious consumers. In addition, with respect to segmenting customers based on their habits and running performance, the following clusters were pre-defined: Novice, Recreational, and High-caliber.	Wearable Devices	Fitness Tracking Application	• user activity profile • average training/week • average race distance • speed min/km
Customer Segmentation through Information savviness [144]	This research focused on improving conversations through user experience from customer service conversational agents (chat bots). According to the study, decision makers can potentially enhance the user experience of clients by adeptly tailoring the information level and bot type, such as medical chatbots or sales bots, to suit their needs and preferences. The study used a pre-trained BERT model (DistilBERT) Users were segmented into two classes - high and low information savviness.	Conversational Agents (Chatbot)	User Chat/Dialog Logs	• System helpfulness • Clarity and scope • Solution accuracy

Method	Description	Application Context	Data Source	Measurable Data and Metrics
Task based segmentation [145]	For this research, experts aimed to cluster users based on task completion for the personalization of e-government services (i.e. the incorporation or removal of tasks and services depending on a given user segment). The study's proposition is in contrast to the use of demographic or geographic data which researchers claim user characteristics-based segmentation is time consuming and complicated for a diverse population.	E-Government Services	Surveys, interviews, focus groups and expert reviews.	• Task-based attributes
User-Centered Modelling based on Behavioral Records [146]	The study applied user segmentation and user borrowing behavior modelling by leveraging user borrowing records to improve the library services. The research applied a number of classifier algorithms such as Naïve Bayes, KNN, and Decision Trees for segmenting users.	Digital Library Services	Library Management System Log	• Booking date • Return date • Subject • Book Details (Subject)
User Experience Improvement through Persona Modelling through Segmentation	The study was aimed at creating user personas through the proposition of segmenting users. The segments are utilized by designers and developers in improving gameplay.	Motion Sensing Game	Survey	• Age • Daily Average Game Play Time • Game Objective Cognition

Method	Description	Application Context	Data Source	Measurable Data and Metrics
[147]				• Willingness with regards to Game Type
User Segmentation based on Network Traffic [148]	The study utilized mobile data traffic from internet-enabled applications to understand customer segments with the aim of improving customer satisfaction and minimize churn rates. The study adopted four fixed user segments: (a) users consumed by mobile gaming and social applications; (b) young urban individuals who lack time; (c) senior urban individuals with a lot of time;	Mobile Network Subscription	Mobile Data Traffic	• traffic consumption patterns • VoIP data • P2P communication data • Social networking data • Gaming data • Web browsing • M-Commerce and M-Banking • demographic

Research will continue to adopt ML in web development and user behavior analysis due to the promise of improved adaptive experiences, personalization, and recommendation which in turn contribute to business development [149]. With respect to user clustering, challenges can arise due to various factors, and these include [150]:

- Determining the optimal number of clusters: Selecting the right number of clusters is crucial for effective segmentation, but can be difficult to determine. In addition, defining meaningful user segments requires thorough understanding of user behaviors, needs, and preferences, which can be complex and multifaceted.

- Dealing with data challenges: User data can be incomplete or noisy making it difficult to accurately label users and poses challenges for accurate user segmentation.

- Incorporating Semantics of User Behavior: Traditional segmentation methods may overlook the semantic relationships between users and their behaviors. Thus, ensuring that the segmentation accurately captures the diversity and nuances of the user base poses a difficulty.

- Accounting for dynamic user behavior: User interests and preferences can change over time, making it challenging to maintain accurate segmentation. Longitudinal studies and monitoring algorithm updates are needed to adapt to changing behaviors

- The optimization of segmentation models with respect to user experience and changing user requirements requires validating the effectiveness of segmentation strategies in improving user experiences requires careful planning and iterative refinement.

Today, UX designers are confronted with the task of comprehending the importance of machine learning in crafting enhanced user experiences, envisioning novel products and services, and effectively collaborating with data scientists. In their study it was outlined that sources of data include: surveys, log data, video capture and user sessions which can be used together with algorithms such as: K-Nearest Neighbors, Logistic Regression, Support Vector Machine, Bayesian Network, Random Forest, and Neural Networks. Research revealed that there is a lack of awareness and lack of research about machine learning algorithms in UX design [151].

Conclusion and Methodological Approach to the Development of Web-based Tools for Managing Network Organizational Systems, taking into account Adaptation to Changing User Needs

In the realm of network organizational systems, developing effective web-based management tools requires a methodological approach that prioritizes adaptability to evolving user requirements. The development of web-based tools follows the software engineering models (such as Waterfall, Rapid Application Prototype, Spiral, Rational Unified Process, V-shaped or Agile methodologies [152]) and begins with a comprehensive needs assessment to understand the specific challenges and demands faced by chain businesses in their daily operations. By gathering insights from key stakeholders and end-users, such as managers, employees, and customers, the development team can identify critical functionalities and features that will enhance productivity and streamline operations [153].

Network organizational systems face unique challenges in managing geographically dispersed operations (remote) and a diverse workforce (skill levels). Web-based tools can be powerful assets, improving communication, streamlining processes, and providing real-time data for better decision-making. However, user needs within the organizational system are capable of evolving as a result of their exposure to new technologies, requiring flexible and adaptable web tools [154]. Thus, it is pertinent that networked organizational systems develop web-based management tools for emphasizing user-centricity and adaptability.

Figure 1-10 illustrates a proposed methodological approach (agile-based) to the development of web-based tools for managing networked organizational systems considering changing user needs. The system is characterized by user-centered design, integration of analytical models, feedback mechanisms for improved user interface quality, continuous improvement and continuous development (CI/CD), and seamless integration with legacy systems [155]. The benefits of the presented methodological approach include: (a) Improved User Adoption and Engagement: User-centric design and continuous feedback loops ensure the web tool meets user needs, leading to higher adoption and engagement. (b) Enhanced Adaptability to Change: Modular architecture, a content management backend, and agile development practices allow the web tool to adapt to evolving business requirements and user needs. (c) Reduced Development Costs: Prioritizing functionalities based on user feedback can streamline development and reduce unnecessary features. (d)

Increased Employee Productivity: Streamlined workflows, automated tasks, and access to real-time information empower employees to be more productive. (e) Improved Decision Making: Data-driven insights from the web tool can aid better decision making across all levels of the chain company.

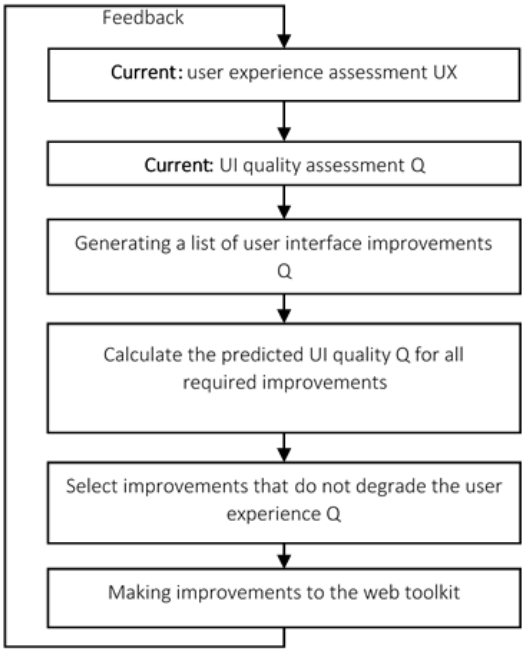


Figure 1-10 Methodological Approach to the Development of Web-based Tools for Managing Networked Organizational Systems considering Changing User Needs

Furthermore, a user-centered design approach is essential, focusing on intuitive interfaces and seamless user experiences that empower employees at all levels to leverage the tools effectively. Incorporating feedback mechanisms and analytics enables ongoing improvement and optimization, fostering a cycle of continuous enhancement driven by real-time user insights. Thus, a methodological approach to developing web-based tools for chain companies must prioritize user needs and adaptability. By leveraging iterative development, user-centered design principles, and ongoing feedback loops, these tools can evolve alongside the dynamic demands of chain businesses, ultimately enhancing operational efficiency and driving business growth.

Figure 1-11 highlights CRISP-DM model which was developed by a consortium of leading data mining users and suppliers: DaimlerChrysler AG, SPSS Systems Engineering Inc., NCR, and the Dutch insurance company OHRA [156]. CRISP-DM (Cross-Industry Standard Process for Data Mining) provides a structured framework for data-driven projects.

Figure 1-11 CRISP-DM (Cross-Industry Standard Process for Data Mining) [156]

The CRISP-DM model begins with Business Understanding, where project objectives are defined and translated into a data mining problem definition. This phase is closely linked to Data Understanding, which involves initial data collection, exploration, and identification of data quality issues. The subsequent Data Preparation phase involves cleaning, selecting, and transforming data for modeling. In the Modeling phase, various techniques are applied and calibrated to build models that meet project objectives. The Evaluation phase ensures model quality and alignment with business goals, identifying any overlooked issues. Finally, the Deployment phase focuses on presenting findings in a usable format, whether through reports or operational implementations, ensuring that the project's insights can be effectively applied in practice. Through this iterative and structured approach, CRISP-DM guides organizations in leveraging data for informed decision making and problem solving [157]. In managing information systems, data-driven decision making enables real-time monitoring and performance evaluation across multiple locations or branches. Key performance indicators (KPIs) and metrics are tracked and analyzed to identify trends, anomalies, and opportunities for improvement of business processes. This information empowers decision makers to optimize resource allocation, streamline operations, and enhance customer experiences. Data-driven approaches facilitate proactive risk management and compliance within chain companies [158]. By analyzing historical data and trends from the information system as well as user interaction data, organizations can anticipate challenges, mitigate risks, and ensure regulatory compliance across different locations.

In summary, data-driven decision making transforms information systems management in chain/network companies by enabling evidence-based insights, informed strategic planning, and adaptive responses to dynamic business environments. Embracing this approach empowers organizations to leverage their data assets effectively and achieve sustainable growth and competitiveness in today's interconnected business landscape.

1.4. Results and Summary

The results presented in Chapter 1 discusses network/chain organizational systems, the role technology plays within their business model, and primarily web-based platforms as a central component of the organizational system. In addition, the prevalence of web-based technologies in creating graphical user interfaces (GUI) for a wide variety of information systems, such as e-commerce, e-learning, healthcare, and gaming systems. Web-based technologies are highly sought after as UI for emerging technologies because of their cross-platform compatibility, large community of developers, security, accessibility, and ease of maintenance. The chapter also details the challenges that web-based information systems may face, including insufficient resources, browser compatibility issues, poorly written code, network connectivity, integration issues, security vulnerabilities, user errors, and outdated technology. The challenges faced by UI include usability, accessibility, cross-browser compatibility, performance, design consistency, interactivity, and security. UX focuses on the user's overall satisfaction and feelings when interacting with a technology product, considering factors like user profiles and preferences. UI design aims to facilitate efficient task completion and satisfaction within the context of the product's technical capabilities. The chapter also highlights an important structure of network organizational systems which constitutes of decentralized systems and employees who access these systems to perform various technical tasks via the graphical user interface. Finally, the need for managing information systems of networked organizational systems taking into consideration the changing user requirements is presented.

CHAPTER 2. MODEL FOR ASSESSING THE QUALITY OF THE USER INTERFACE CONSIDERING THE DISTRIBUTION OF USERS BY EXPERIENCE IN WORKING WITH THE WEB SYSTEM

2.1. Set of metrics for assessing the quality of the user interface, considering the distribution of users by experience with the web system

The quality of a user interface is crucial for software applications as it directly affects user experience and overall business processes in networked organizational systems. A mathematical model can provide a structured and objective approach to evaluating user experience, thereby improving system quality and employee productivity. This model can quantify interface quality, aiding in comparison, benchmarking, and continuous improvement, and helping to identify and prioritize areas for development. Consider the scenario with N users and a user interface quality metric (W_t) derived from a linear combination of independent variables representing a set of UI quality properties measured over time $W_t = \sum_{\{t \in \mathbb{Z} \mid t \leq 1\}}^{n} a_1 {X_1}^t + a_2 {X_2}^t + \cdots + a_n {X_n}^t$. Furthermore, the distribution of user interface quality metric (W_t) is incorporated to create a more user-centric model. To consider the distribution of users by experience with the system, a variable X_{Ui} for each user's usability metric is measured, for a user (i). It is possible to categorize users into discrete levels as set by the product manager (for example:$L = \{novice, intermediate, expert\}$), X_{Ui} can be assigned different values based on the user's experience level (L). In addition, a distribution function can be used to calculate the probability of a user having a certain value of L and X_{Ui}, belong to a particular segment of users (derived from a segmentation algorithm). On a basic level, users can be grouped also according their level (L). These forms of segmentation (basic or complex algorithmic) can be used to understand the distribution of user experiences (represented by UI quality) with the system and how the system can be improved at different segmentation levels (iteratively for:$t + 1$).

To solve the research task at hand, this section describes the procedures, architectures, methodology and algorithms employed in obtaining a hybrid user interface (UI) model for evaluating UI quality. Before investigating the proposed model, the next sub-sections take a look at an essential component to consider when designing user interfaces.

Metric 1 – Accessibility (A)

Web accessibility is defined as the ability for content to be adaptable to the needs and preferences of individual users; and also the as the ability of users to universally access web-based services and obtain necessary information [159]. User interface (UI) design is a crucial aspect of web development, ensuring that web resources are accessible to a wide range of users [160]. It ensures that websites are usable by people with a wide range of disabilities, including visual, auditory, physical, speech, and neurological impairments [161]. It promotes social inclusion by ensuring that websites are usable by people with disabilities and other diverse groups, fostering equal access to information and opportunities [162]. Web accessibility relies not only on content accessibility but also on the accessibility of browsers and other user tools. [163]. In addition, slow internet, outdated technology, and low-resolution devices can hinder web accessibility [111]. Accessibility solutions are diverse and depend on user and environmental factors. Despite advancements in HCI, challenges remain in developing suitable user models, classifying appropriate solutions for various contexts, and creating innovative evaluation methodologies [164]. These challenges motivated the study.

Evaluation of web accessibility is essential and crucial regardless of the platform being used to access the web [165]. Web Accessibility Evaluation could take the following forms: (1) Automated Testing: which involves either online or local testing via applications. It is a time-saving methodology. (2) Manual Inspection: undertaken by expert human evaluators where checks are conducted to meet accessibility guidelines. (3) User Testing: by use of surveys, recorded system interactions, or interviews, users provide feedback to evaluators. This approach is complex to undertake. A study utilized WAVE and SiteImprove tools and proposed the coverage error ratio (CER) and web accessibility accuracy (WAA) metrics; where they utilized web accessibility checkers, collected errors, derived the union of web accessibility errors, and computed the CER [166]. CER is a ratio of "the number of errors detected by a given tool" to "the number of errors detected by all tools". Research assessed SAAS E-Commerce platform’s accessibility through expert evaluation techniques such as Fuzzy TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) [167].

With respect to web accessibility evaluation metrics, studies have proposed a number of metrics including the Failure-rate (FR); Unified web evaluation methodology (UWEM); A3; Web Accessibility Barrier (WAB) score; Page measure (PM); Reliability Aware Web Accessibility Experience Metric (RA-WAEM); Web Accessibility Barrier Severity (WABS); Overall accessibility metric (OAM); Page

measure (PM); SAMBA; Web accessibility quantitative metric (WAQM); Web interaction environments (WIE) as presented in Table 2-1 [168–179]. Each accessibility metric caters for various aspects and can be classified by their focus in terms of WCAG standards, the level of automation captured by the method, as well as the technology in focus.

Research has recommended the integration of artificial intelligence in web accessibility evaluation. Past research has posited that web accessibility is not only an intrinsic characteristic of any given digital resource but as well determined via other complex contextual factors (including political and social). As reported by a prior study, the lack of appropriate standardized testing approaches is one of the reasons why web accessibility is difficult to attain [180]. This research aims to address the lack of standardized testing methods for user accessibility by incorporating social context and improving web-based technology interfaces.

Metric 2 – Performance (P)

Web application systems are susceptible to lags in response time of the server and server overload is capable of causing system crash; thus affecting the efficiency of networked organizational systems [181]. Web UIs are designed for specific tasks, like online shopping or proctoring services. The speed at which these UIs load and display content significantly impacts the overall user experience. [182]. Web performance also involves using a reasonable amount of resources to achieve efficient results [183]. From the end-user's perspective, web performance is measured by the time between URL click and completion of entire page loaded; formalized as:

$$\min \rho \qquad \rho = \alpha_T - \beta_T \qquad (2\text{-}1)$$

Where ρ is the load time (in seconds), β is the time at which the user opened the link, and α is the time at which the page content downloads.

Table 2-1 Web Accessibility Metrics

Metric	Formula	Breakdown	Source
Unified Web Evaluation Methodology	$UWEM = 1 - \prod 1 - \frac{B_i}{P_i} W_i$	B_i - number of failure points (actual) of checkpoint (i) P_i - number of failure points (potential) of checkpoint (i) W_i - Barrier i severity	[172; 173]
A3	$A3 = 1 - \prod_b (1 - F_b)^{\frac{B_{pb}}{N_{pb}} + \frac{B_{pb}}{B_p}}$	B_{pb} - number of failure points (actual) of checkpoint (b) in page (p) N_{pb} - number of failure points (potential) of checkpoint (b) in page (p) b - barrier (violation of checkpoint) F_b - Barrier b severity	[174]
Web Accessibility Barrier Score	$WABscore = \frac{\sum_p \sum_v \left(\frac{n_v}{N_v}\right)(w_v)}{Np}$	p - Number of web pages v - Violations of a web page n_v - Total number of violations N_v - Potential violations w_v - Weight (Coefficient) of violations inversely proportional to WCAG priority level Np - Total pages checked	[168]
Page Measure	$PM = \frac{\sum_c \frac{B_c}{priority_c}}{N_{attributes} + N_{elements}}$	B_c - Number of checkpoint (c) violations $priority_c$ - Priority level for checkpoints 1, 2, or 3. $N_{attributes}$ - number of HTML attributes with respect to a given webpage $N_{elements}$ - number of elements on a web page	[176]

SAMBA	$$AI_r = \prod_d (1 - F \cdot \vec{D}_d)^2$$ $$\underline{AI_w} = \prod_d (1 - F \cdot \min\{1, \overline{H_d}\})^2$$ $$\overline{AI_w} = \prod_d (1 - F \cdot \underline{H_d})^2$$ $$\underline{H_d} = \frac{\underline{f}_{d,mnr}}{w_{mnr}} + \frac{\underline{f}_{d,maj}}{w_{maj}} + \underline{f}_{d,cri}$$ $$\overline{H_d} = \frac{\overline{f}_{d,mnr}}{w_{mnr}} + \frac{\overline{f}_{d,maj}}{w_{maj}} + \overline{f}_{d,cri}$$	AI_r - Raw Accessibility Index AI_w - Weighted Accessibility Index $\left[\underline{AI_w}, \overline{AI_w}\right]$ - AI_w interval F - Ratio of potential barriers to number of HTML lines of code H_d - Violation severity for a disability type (d) f - Relative frequency mnr - Minor violation maj - Major violation cri - Critical violation	[177]
Overall accessibility metric	$$OAM = \sum_c \frac{B_c W_c}{N_{attributes} + N_{elements}}$$	B_c - number of violations of checkpoint c W_c - checkpoint c weight $N_{attributes}$ - number of HTML attributes with respect to a given webpage $N_{elements}$ - number of elements on a web page	
Web accessibility quantitative metric	$$WAQM = \frac{1}{N} \sum_{x \in \{p,o,u,r\}} N_x \sum_{y \in \{e,w\}} \frac{N_{x,y} \sum_{z \in \{1,2,3\}} W_z A(x,y,z)}{N_x}$$	Predefined weights for checkpoints with priorities 1, 2, and 3 respectively: (W1 = 0.8, W2 = 0.16, W3 = 0.04) N - number of checkpoints N_x - total checkpoints for a given principle x where x $\in \{Perceivable, Operable, Understandable, Robu$	[178]

	$A(x,y,z) = \begin{cases} \frac{-100}{b}\frac{B_{x,y,z}}{P_{x,y,z}} + 100, & if\ \frac{B_{x,y,z}}{P_{x,y,z}} < \frac{a-100}{a-100/b} \\ -a\left(\frac{B_{x,y,z}}{P_{x,y,z}}\right) + a, & otherwise \end{cases}$	$N_{x,y}$ - total number of checkpoints from a given principle x and type of test y ($y \in \{manual, automatic\}$) W_z - checkpoint weight (according to priority level z) $B_{x,y,z}$ - accessibility errors with respect to checkpoint of the priority level z $P_{x,y,z}$ - test cases (total) of a given checkpoint according to priority level (z), test type (y), and principle (x).	
Reliability Aware Web Accessibility Experience Metric	$q_i = P_i w = \sum_{j=1}^{m} P_{i,j} w_j$	q_i - Accessibility score i - Website $w = \{w_1, w_2, \dots, w_m\}^T$ - Checkpoint weights (for m checkpoints) P - pass rate matrix ($m \times n$)	[169]
Web interaction environments	$WIE(p) = \frac{\sum v_c}{n}$	p - webpage v_c - assumes the value of 1 if checkpoint (c) passes, else 0 n - total number of checkpoints	[179]
Web Accessibility Barrier Severity	$WABS = \frac{\sqrt{\sum_{d=1}^{k} freq(bi)^2}}{\sqrt{\sum_{d=1}^{k} b(pc)^2}} \times \frac{n(bi)}{N} \times \frac{Pc}{\sqrt{\sum_{d=1}^{k} (b)^2}}$	d - Webpage k - Most recent webpage checked bi - Violation being checked b - Number of violations appearing in webpage d $b(pc)$ - Number of violations Pc - Priority level coefficient violated by the tested barrier	[170]

Thus, the goal of any quality web-based technology UI development would be to minimize ρ, thereby maximizing web performance. Web performance is affected by factors like network speed, server efficiency, and the effectiveness of the domain name system [184].

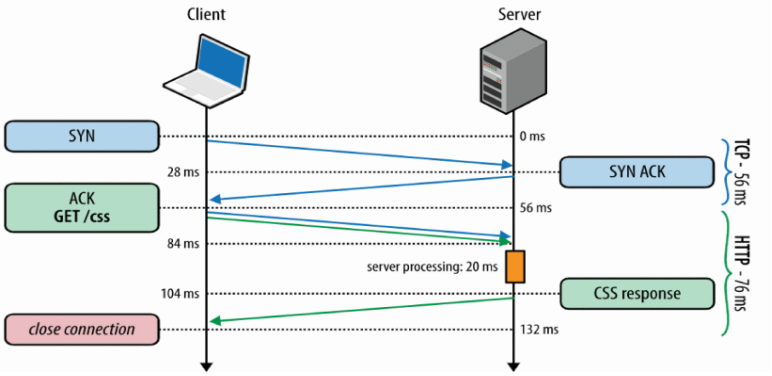


Figure 2-1 Concurrent Connections (Schematic Diagram) [181]

Web performance involves understanding client-server communication, exemplified by the three-way TCP handshake where the client and server exchange SYN, SYN-ACK, and ACK packets to establish a connection before the client sends an HTTP GET request and the server responds with the requested resource data (Figure 2-1). In modern web-based applications, cloud-based technology plays a central role and as such optimal web performance is a highly desirable feature [185]. Research has highlighted a correlation (strong) between slow applications and loss of revenue due to user dissatisfaction [186]. In addition, studies have concluded that performance influences product/service acquisition and customer retention [187]. A quick web UI load speed is synonymous to more visitors willing to return and firms such as Google and Amazon lost 20% in revenue due to half a second increase in page load time, and 1% decrease in sales due to an additional load time of 100 milliseconds respectively [187]. As such, performance is key to traffic which in turn influences business revenue [188].

With respect to Web Performance Optimization (WPO), research has recommended these as means of peak performance: CDN Caching, Caching (through Asset caching, page caching, browser caching) as well as Prefetching (realizable through Markov prediction model, Stochastic Petri nets, Effective Cost Functions, Association rules-based prefetching, prediction by partial match, dependency graph, Clustering techniques, etc.) [185]. In addition, Categorized Performance Rules (a WPO checklist) made up of Web object size optimization, Request Optimization, Asset placement, HTTP Header Optimization, Image

Optimization, External Dependency Optimization, Network Optimization, and Web Application design optimization has been developed [189]. Research discovered how WPO has increased the conversion rate from 6.35% to 14.30% in six-month a period [182]. Research encourages best practices such as search-centered experiences, asynchronous alternatives, monitoring lightweight design, layered architecture, iterative testing, and omni-channel optimization. This is symbolic of the research advancement with regards to optimizing web performance [185].

Web Performance pitfalls research has identified include: (a) Redirects: Excessive redirects can significantly increase page load time, impacting user-centric metrics like Time-To-First-Paint. (b) Browser Bugs: Browser inconsistencies can affect the accuracy of HTTP Archive (HAR) data, particularly for object sizes. (c) Data Limitations: Lack of data sources, such as DNS responses for failed TCP connections or certificate errors, hinders comprehensive analysis [190]. Quantifying web performance is difficult due to the wide variety of web pages, the diverse range of devices and browsers used, the choice of metrics (network-focused, browser-focused, or user-focused), and the lack of standardized measurement methods [190].

A suitable web performance audit tool, Lighthouse 10 is integrated into modern browsers and developer tools [191]. It analyzes a website's code-base (front-end) and performance which provides scores and recommendations for improvement across various DOM elements. The web performance metric assesses the speed and lags in loading web content and can be broken down into the following sub-components: First Contentful Paint (FCP); Speed Index (SI); Large Contentful Paint (LCP); Total Blocking Time (TBT); and Cumulative Layout Shift (CLS).

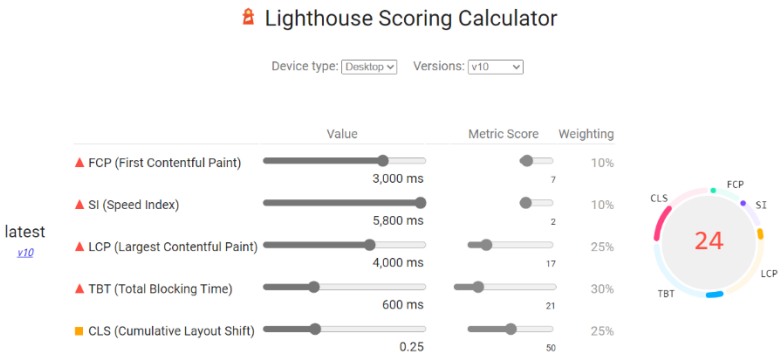


Figure 2-2 Lighthouse Web Performance Scoring Calculator[7]

Figure 2-2 highlights a dashboard for comprehending the web performance scoring calculator and Table 2-2 summarizes the web performance audit metrics, their weight, and quality intervals of the performance metrics (according to Lighthouse version 10) which were adopted in this dissertation research. After collecting performance metrics, Lighthouse transforms each audit value into a metric ranging from 0 to 100. This Lighthouse's scoring distribution follows a log-normal distribution and is obtained from real-world website performance data on HTTP Archive.

Table 2-2 Performance scoring (Lighthouse v.10)

Audit	**Weight**	**Performance Metric Quality Intervals**
FCP	10%	$f(FCP) = \begin{cases} Good, & FCP \leq 1.8 \\ Needs\ Improvement, & 1.8 < FCP \leq 3.0 \\ Poor, & FCP > 3.0 \end{cases}$ (in seconds)
SI	10%	$f(SI) = \begin{cases} Fast, & 0 < SI \leq 3.4 \\ Moderate, & 3.4 < SI \leq 5.8 \\ Slow, & SI > 5.8 \end{cases}$ (in seconds)
LCP	25%	$f(LCP) = \begin{cases} Fast, & 0 < LCP \leq 2.5 \\ Moderate, & 2.5 < LCP \leq 4 \\ Slow, & LCP > 4 \end{cases}$ (in seconds)
TBT	30%	$f(TBT) = \begin{cases} Fast, & 0 < TBT \leq 200 \\ Moderate, & 200 < TBT \leq 600 \\ Slow, & TBT > 600 \end{cases}$ (in milliseconds)
CLS	25%	$f(CLS) = \begin{cases} Good, & 0 < CLS \leq 0.1 \\ Needs\ Improvement, & 0.1 < CLS \leq 0.25 \\ Poor, & CLS > 0.25 \end{cases}$

Metric 3 – Usability (USE)

Usability is defined as the extent to which a product or system can be utilized by specific users in order to achieve desired goals effectively, efficiently and satisfactorily within a given context of specific use [192]. System usability is characterized by: understandability and suitable for user needs; learnability; ease of

[7] Lighthouse Scoring Calculator, URL: https://googlechrome.github.io/lighthouse/scorecalc/ (Date Accessed: 07/11/2023)

operation and control; prevent users from making mistakes; attractive UI that satisfies user interaction; allows it to be used by users with certain characteristics and disabilities [193]. According to ISO standards 9241-400 and 9241-110, usability refers to how effectively, efficiently, and satisfactorily a product or service can be used by specific users to achieve their goals in a particular context.[194]. According to ISO 9241-400 usability engineering is characterized by five (5) key components: effectiveness, safety & security, efficiency & functionality, joy & fun, and ease of learning & memorizing [195]. In addition, usability can be classified into that which is "Observed" and what users can "Perceive" [196].

UI evaluation is crucial for improving software systems. This process involves expert-based or user-based testing methods to assess usability [197]. These usability metrics include satisfaction, effectiveness, and self-description ability. Usability evaluation is essential for functional systems and it aims at ensuring their conformity with expectations, helpfulness, and affect [198]. The goals of usability testing are to improve UX; align design inconsistencies; improve UI navigation; as well as improving information architecture [199]. Usability testing could take the form of Cognitive Walkthrough, Formal Usability Inspection, Heuristic Evaluation, or Pluralistic which could be achieved via Empirical Testing method such as Card Sorting, Eye tracking or Questionnaire [200]. A study proposed Guideliner (a tool built on the Selenium Web Driver) for automatic conformance evaluation of web UI to predefined usability guidelines [201]. It consists of the Client-Side Web Application, Ontology Repository (which is its core element), Ontology Processing Engine, and the UI Evaluation Component. According to studies [202], usability issues arise (are developed over time) as a result of:

- System vs. Real-world Mismatch – non-user oriented;
- No Documentation and Poor visibility – no feedback of the system's status;
- Transient challenges – network load leading to delays and downtime (slow web pages and APIs), system updates, etc.
- Hardware issues and System configuration challenges – such as slow devices;
- Adversarial actions (such as DoS/DDoS (denial of service attacks), SQL Injection, Malware, etc.);
- Complex design patterns and ambiguous language – navigation, layout, colors, fonts, wrong use of pagination, etc.;

- Irrelevant functionality and prolonged steps to accomplish a task;
- Poor adaptability to all users: User capability – age-related, health-related, as well as cognitive functionality limits which influences attention, motor skills, comprehension, and spatial visualization. Recall-time exceeded – longer duration for re-establishing proficiency;
- Poor change management in the development process;

Such challenges affect users in conducting activities for personal purposes, business activities, and limits the ability to communicate within networked organizational systems. In addition, usability challenges lead to user fatigue (cognitive load in performing tasks). Research has highlighted that usability cannot be directly measured [203], as such industry practitioners utilize numerous usability techniques (Table 2-3). From the perspective of this research, Usability is measured via user-based testing.

Table 2-3 Usability Evaluation Methods and Dimensions

Metric	**Overview**	**Source**
QUIS	9-point scale; Subjective satisfaction of users with respect to specific aspects of their interaction with the system. Dimensions: • Screen • Terminology and System Information • Learning • System Capabilities	[204]
SUMI	Questionnaire with psychometric 50-items; Provides a more in-depth understanding of the underlying cognitive mechanism with respect to observed effects and actual information. Requires at least 10 users. Dimensions: • Influence • Efficiency • Helpfulness • Control • Learnability	[205]
UEQ	26 psychometric items (semantic differential scale); A time-based user experience evaluation technique requiring 3 to 5 minutes for respondents. Dimensions:	[206]

	Attractiveness Perspicuity Efficiency Dependability Stimulation Novelty	
CSUQ	19 positively-worded psychometric items; Proposed to handle larger samples of respondents and conducted in a non-laboratory setting. Dimensions: • system usefulness • information quality • interface	[207]
NetQu @l (NetQu al)	15 psychometric items; Measures user e-service quality based on perceptions of users. Dimensions: • Design • Information quality • Ease of use	[208]
UMUX	4 psychometric items (7-point likert scale); Aimed at measuring perceived usability and focuses on purpose, validity, reliability, and structure. Dimensions: • Efficiency • Effectiveness • Satisfaction	[209]
SUS	10 psychometric questions (5 Positive & 5 Negative tone); Its bi-dimensional structure, flexibility, and ability to analyze perceived usability makes it highly recommended by experts. Dimensions: • Learnability • Perceived Usability	[210]

In addition to conducting usability testing, statistical analysis of respondent results is a relevant step to ensure the consistency of the data before analysis. Other in-depth statistical methods used include: Construct validity, coefficient reliability, internal consistency, Cronbach's alpha, Sensitivity analysis (Mann-Whitney test); Normality Test Results (Kolmogorov-Smirnov, Shapiro-Wilk, etc.) [211].

The system usability scale (SUS) is a qualitative tool that ascertains the usability of any innovative system on a scale through ten (10) questions with a likert

scale response ranging from one (1) to five (5) – i.e. strongly agree to strongly disagree respectively [212]. SUS is a popular measure for software systems' perceived usability. It was developed in 1986 by John Brooke as a quick and reliable way to evaluate the usability of interactive systems [213]. SUS is a standardized questionnaire that provides a quick and easy way to obtain feedback from users about the usability of a system. The questionnaire consists of ten (10) questions, and users rate their agreement with each statement on a Likert scale ranging from "strongly agree" to "strongly disagree" (5-point). It is the most used usability metric in most recent times as reported by researchers [214].

Over the years, SUS has been used in a wide range of research studies to evaluate the usability of various systems, including software applications, websites, mobile apps, and medical devices [215]. Research publications have used SUS to compare the usability of different systems, to evaluate the impact of design changes on usability, and to assess the usability of systems across different user groups. For example, one study used SUS to compare the usability of two different electronic medical record systems, while another study used SUS to evaluate the usability of a mobile health application for postoperative care [216]. Within the context of e-learning platforms, a study suggested the utilization of SUS as well as the inclusion of extensive constructs for various contexts in order to provide new insights and develop stronger information systems evaluation standards [217].

Despite its widespread use, the System Usability Scale (SUS) has limitations, such as relying on subjective self-reported data and not providing detailed feedback on specific usability issues or accounting for factors like performance and accessibility [214]. Additionally, SUS overlooks criteria like efficiency, memorability, and ergonomic considerations, and may not be suitable for all user groups or system types [218]. Nonetheless, SUS is valued for evaluating overall user satisfaction and can be implemented quickly, making it a useful part of a comprehensive evaluation framework when combined with other measures [219]. For this proposed framework, user feedback/review is made mandatory. UX industry experts have indicated that mandatory user reviews have the tendency of corrupting feedback data since users may seem forced to undertake it, but citing the example Uber, users get accustomed to the practice and thus, the mandatory approach has ability to provide insight [220]. Sentiment analysis is the extraction of text and the analysis of emotions and opinions in order to estimate its expressive direction [221]. Sentiment analysis approaches could take the form of machine learning, lexicon-based, or hybrid, and research has discussed the pros and cons of these approaches

[222]. Despite the pros of sentiment analysis, the following number of challenges have been highlighted: domain specificity, negation handling incapability, inability to handle multiple opinions in a sentence, inability to detect sarcasm, and subjectivity detection [222].

For this study, the sentiment analysis framework adopted the Tensorflow.js (TFJS) library. It provides an easy-to-use experience without compromising on functionality, and is able to run edge devices, web-based technologies, embedded systems and IoT [223]. It is used in web-based tasks such as face and eye tracking, body segmentation, hand (gesture) tracking, speech recognition, and NLP tasks [224]. Due to Tensorflow.js's being recommended for prototyping Web ML HCI projects, as well as its ability to encode expressions, sentences and small paragraphs, it is identified as a perfect match for sentiment analysis in the context of this study.

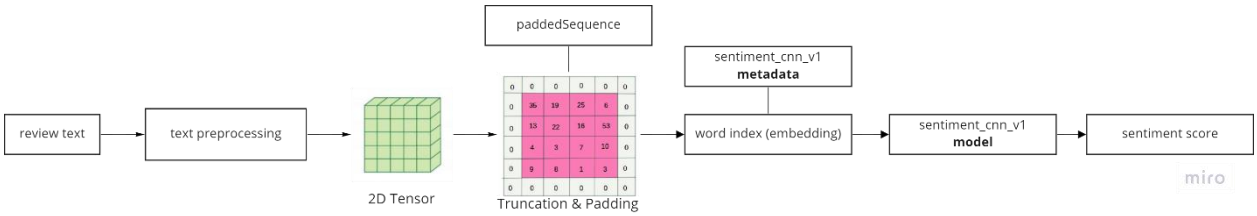


Figure 2-3 Sentiment Analysis (Tensorflow JS)

Figure 2-3 illustrates the inner workings of tensorflow.js for this study with respect to the sentiment analysis component. User review text is processed through a sequence of steps. First, it undergoes text preprocessing, then it's converted into a padded tensor (2-dimensional) for batch processing. Next, the sentiment_cnn_v1 model (with specific parameters) analyzes the text, and finally, a sentiment score between 0 and 1 is calculated. The derived sentiment score contributes to the usability component of the overall UI Evaluation Model.

Table 2-4 Standard Word Embeddings Overview

Model	**Description**	**Source**
TF-IDF (Term Frequency-Inverse Document Frequency)	$w_{x,y} = tf_{x,y} \times \log\left(\frac{N}{df_x}\right)$ $tf_{x,y}$ - frequency of x in y df_x - number of documents containing x	[225]

PPMI (Positive Pointwise Mutual Information)	$PMI(w,c) = \log\frac{p(w,c)}{p(w)p(c)}$ w - word (token) c - category $p(w,c)$ - probability of w and c co-occurring $p(w)$ - probability of w occurring $p(c)$ - probability of c occurring	[226]
LSA (Latent Semantic Analysis)	$A_{[n\times m]} = U_{[n\times r]}\Lambda_{[r\times r]}\left(V_{[m\times r]}\right)^{\mathrm{T}}$ n - words r - context m - documents	[227]
Word2vec *Skip-Gram & CBOW (Continuous bag of words model)*	$P(w_o \mid w_c) = \frac{exp\left({u_o}^{\mathrm{T}} v_c\right)}{\sum_{i\in V} exp({u_o}^{\mathrm{T}} v_c)}$ $v_i \in \mathbb{R}^d$- center word with index (i) for a d-dimensional word representation in dictionary $u_i \in \mathbb{R}^d$- context word with index (i) for a d-dimensional word representation w_c - center word w_o - context word V - vocabulary index (set) T - text sequence length $w^{(t)}$ - word at time step t m - window size $\prod_{t=1}^{T} \prod_{-m\le j\le m, j\neq 0} P\left(w^{(t+j)} \mid w^{(t)}\right)$	[228]
GloVe (Global Vectors for Word Representation)	$J(\theta) = \sum_{w,c\in V} f\left(N(w,c)\cdot\left(u^{\mathrm{T}} v_w + b_c + \overline{b_w} - \log N\,(w,c)\right)\right)^2$ w - word (token) c - context b_c, $\overline{b_w}$ - bias terms (learned) $N(w,c)$ - weighting functions to penalize unforeseen events	[229]

In language modelling it is necessary to encode alphanumeric text as numeric values to be comprehended by mathematical modelling in NLP. One of such methods for learning word representation (contextualized) is known as word embeddings [230]. Table 2-4 highlights an overview of the most widely utilized word embeddings. In addition to these embeddings, there has been massive progress in artificial intelligence with respect to the introduction of the Transformer model. One of such models is the BERT (Bidirectional Encoder Representations from Transformers) model which outdoes all the above mentioned. For the purpose of this study, the BERT model (pre-trained) was adopted due to its advantages such as:

- BERT is pre-trained on a massive dataset of text and code, which allows it to learn general language patterns and relationships between words. This pre-training provides a strong foundation for subsequent fine-tuning on specific tasks (i.e. transfer learning) [231].

- In contrast to traditional word embeddings (as highlighted in Table 2-6), that assign a single vector to each word regardless of the context, BERT generates contextualized word embeddings. Thus, the meaning of a word is derived based on the surrounding words in a sentence [232].

In the first stage (pre-training), the model learns language structure by completing missing words and predicting sentence connections. In the second stage (fine-tuning), it focuses on a specific task, such as writing creative content; thus, this research used the BERT model for word embeddings during sentiment analysis preprocessing.

2.2. Multi-Criteria Mathematical Model of UI Quality Evaluation

The goal of this study is to present a novel approach to evaluate the quality of web-based UI. This study adopts mathematical modelling as an approach which merges the automated and user-based evaluation techniques in order to quantify UI quality of a given web-based information system. Mathematical modeling involves using mathematical concepts to describe and analyze a system, allowing for the quantification and interpretation of relevant data. This approach is valuable for understanding the behavior of systems and studying the impact of different factors [233].

For the study, mathematical modelling is adopted in the formulation of an evaluation metric for web UI quality (WUIQ) by adopting MCDM – AHP (Analytical Hierarchical Process), Statistical Analysis for testing qualitative data robustness, and K-Means Cluster Analysis for segmenting usability of users. Multi-criteria decision making (MCDM) is a branch of decision sciences and operations research (OR) which serves as a medium for identifying, selecting and dealing with decision-based problems under a number of different (in some cases conflicting) criteria [234]. MCDM finds its relevance due to the uncertainty and complexity of decision making in everyday life [235]. MCDM has been applied in various scenarios such as in making decisions on whether to outsource information security management or not, supplier selection, ERP implementation criteria; a more

optimized organization of the architectural design process using decision support systems.

MCDM has been applied in the evaluation of websites of Iranian universities (VIKOR method) - based on six (6) dimensions – "usability", "content", "functionality", "efficiency", "student services", and "reliability" – to expose design weaknesses thus improving UI and UX [236]. Research adopted AHP and TOPSIS methods) to derive the factors that contribute to improving e-commerce customer experience in [237]. Another study adopted the Logarithmic Fuzzy Preference Programming (LFPP) method to rank Indonesian university websites based on accessibility and usability criteria - backlink, stickiness, and web page loading time [238]. Thus proving MCDM's efficacy in UI research.

Despite MCDM's shortcomings including subjectivity, and potential inaccuracy in results (due to brevity) MCDM algorithms are highly recommended [239]. The dissertation uses AHP's pairwise comparison method due to MCDM's ability to evaluate all given options under variable degrees with ease of use and its capacity to incorporate multiple outputs and inputs [240]. In addition, research has not adopted AHP as a method for coefficient calculation in the context of UI quality.

Proposed by Professor Thomas Saaty, Analytic Hierarchy Process (AHP) has been defined as a procedure that prioritizes factors/options within multi-criteria decision making problems. AHP is multi-criteria decision-making (MCDM) technique that leverages on hierarchical relationships in order to represent a problem [241]. It is mostly applied in solving MCDM problems in business, supply chain and logistics, but applicable in other fields where pairwise comparison of alternatives is feasible. Researchers have applied AHP as a meta-heuristics strategy to select the best suppliers [241]. With respect to UI research, MCDM, particularly AHP (and Fuzzy AHP in other scenarios) has been applied in the evaluation of remote video conferencing software based on security, usability, functionality, technical performance, and pricing; usability of information services based on the following criteria attractiveness, learnability, navigability, understandability, and searchability; prioritizing usability heuristics according to the following top 10 criteria - "user control and freedom, visibility of system status, consistency and standards, error prevention, compatibility between the system and the real world, recognition rather than recall, help and documentation, flexibility and efficiency of use, aesthetic and minimalist design, helping users identify, diagnose and recover from errors" [242].

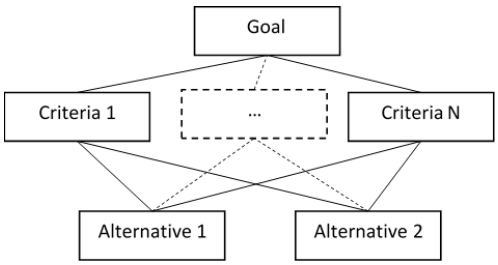


Figure 2-4 Basic Structure of AHP

Figure 2-4 illustrates a standard overview of AHP where a Goal consists of a set of criteria with alternatives at the bottom level. Statement of the problem in the process of applying MAI: let there be many alternatives (solution options) $\{A_1, \dots, A_n\}$. Each of the alternatives is evaluated by a list of criteria $\{K_1, \dots, K_n\}$. In the case of this study, alternatives are ignored, but the AHP method is used as a novel approach to formulate coefficients within a linear system of equations for obtaining the weights of the metrics for assessing UI quality. For the coefficient formulation the goal is the UI quality metric and the criteria are associated with the independent variables (derived from user-based testing and manual testing of UI) for calculating the overall metric. In this study the main goal of Analytical Hierarchical Process (AHP) is evident in its attribution of weights for each of the three (3) main web-based UI quality (Q) indicators – Performance (P), Accessibility (A), and Usability (USE). This study utilizes AHP to rank *P*, *A*, and *U*SE based on expert survey data.

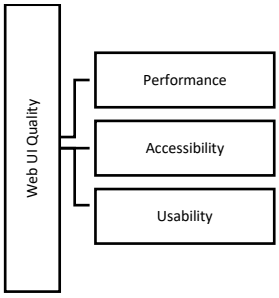


Figure 2-5 Model Components

After identifying the decision problem, and determining the goal, in this study, the AHP methodology is as follows:

a. The framework comprises the overall goal (WUIQ) and intermediate metrics (Performance, Accessibility, Usability).

b. A pairwise comparison matrix (n x n) was created using Saaty's 1-5 scale. The matrix was defined by comparing the relative importance of each metric.

c. The significance of the pairwise comparisons was determined by creating a relative ranks matrix.

d. The consistency index (CI) and consistency ratio (CR) were calculated to assess the reliability of the comparisons.

e. Weights that did not meet the CI and CR criteria were excluded.

f. The geometric mean of the remaining weights was calculated to obtain the final weights.

For this research, an expert is a stakeholder of a web platform with knowledge in web design, development, UI/UX design, and UI/UX quality assurance.

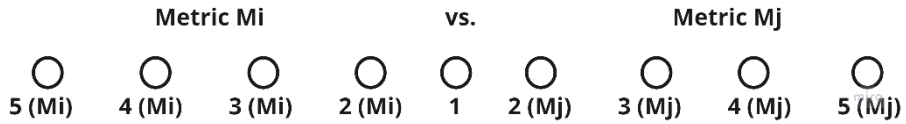


Figure 2-6 Sample of Pairwise Metric Comparison in Expert Survey

As shown in Figure 2-6, the expert makes pairwise comparisons to assess the relative importance of alternatives at the same hierarchical level, transforming these judgments into numerical values using ratio scales. These values are then placed in a matrix to establish decision weights, with the Saaty Eigenvector method used to estimate priorities within the judgment matrix.

Table 2-5 Pairwise Comparison Values

Standard Values	**Inverse Values**	**Definition**
1	1	Equal Importance
3	1/3	Low Importance
5	1/5	Strong Importance
2,4	½, ¼	Intermediate Values

The mathematical formalization of the AHP method used in this study is represented below for $n = 3$ (i.e. the total number of alternatives which represent the metrics to be compared by experts):

$$M = \begin{bmatrix} m_{P,P} & m_{P,A} & m_{P,USE} \\ m_{A,P} & m_{A,A} & m_{A,USE} \\ m_{USE,P} & m_{USE,A} & m_{USE,USE} \end{bmatrix} \quad (2\text{-}2)$$

Where:

M – Pairwise comparison matrix

P – Performance metric

A – Accessibility metric

USE – Usability metric

$$m_{ij} > 0, m_{ij} = (m_{ji})^{-1}, m_{ii} = 1, \text{and } i, j = \text{P, A, USE} \quad (2\text{-}3)$$

The algorithm is followed by the normalization of pairwise comparison matrix based on the sum of the columns:

$$M = \begin{bmatrix} \frac{m_{P,P}}{\sum m_{iP}} & \frac{m_{P,A}}{\sum m_{iA}} & \frac{m_{P,USE}}{\sum m_{iUSE}} \\ \frac{m_{A,P}}{\sum m_{iP}} & \frac{m_{A,A}}{\sum m_{iA}} & \frac{m_{A,USE}}{\sum m_{iUSE}} \\ \frac{m_{A,P}}{\sum m_{iP}} & \frac{m_{USE,A}}{\sum m_{iA}} & \frac{m_{USE,USE}}{\sum m_{iUSE}} \end{bmatrix} \quad (2\text{-}4)$$

This is followed by summing normalized elements divided by the total number of alternatives ($n = 3$) to obtain the local weight of the alternatives “

$$\omega = \begin{bmatrix} \omega_P \\ \omega_A \\ \omega_{USE} \end{bmatrix} = \begin{bmatrix} \frac{m_{P,P}}{\sum m_{iP}/n} + \frac{m_{P,A}}{\sum m_{iA}/n} + \frac{m_{P,USE}}{\sum m_{iUSE}/n} \\ \frac{m_{A,P}}{\sum m_{iP}/n} + \frac{m_{A,A}}{\sum m_{iA}/n} + \frac{m_{A,USE}}{\sum m_{iUSE}/n} \\ \frac{m_{A,P}}{\sum m_{iP}/n} + \frac{m_{USE,A}}{\sum m_{iA}/n} + \frac{m_{USE,USE}}{\sum m_{iUSE}/n} \end{bmatrix} \quad (2\text{-}5)$$

Where ω is the set of global weights for $n = 3$ factors/alternatives $\omega = \{\omega_P, \omega_A, \omega_{USE}\}$;

The consistency vector is calculated ($M \times \omega$ matrix) to control the weight values' (ω) consistency and obtain the eigenvector's best approximation.

$$M \times \omega = \begin{bmatrix} m_{P,P} & m_{P,A} & m_{P,USE} \\ m_{A,P} & m_{A,A} & m_{A,USE} \\ m_{USE,P} & m_{USE,A} & m_{USE,USE} \end{bmatrix} \times \begin{bmatrix} \omega_P \\ \omega_A \\ \omega_{USE} \end{bmatrix} = \begin{bmatrix} x_P \\ x_A \\ x_{USE} \end{bmatrix} \quad (2\text{-}6)$$

$$\lambda_{max} = \sum_{\mathrm{i=\{P,A,USE\}}}^{n} \frac{x_i}{\omega_i} \quad (2\text{-}7)$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (2\text{-}8)$$

$$CR = \frac{CI}{RI} \quad (2\text{-}9)$$

Where:

λ_{max}– Estimation of maximum eigenvalue of the M.

C – Consistency index

CR – Consistency ratio

RI – Random index

RI is proportional to the (n × n) matrix's size. The CR must not exceed 0.1 (10%) because a CR > 0.1 is indicative of inconsistent findings, thus the procedure must be repeated, and data those comparisons are eliminated.

Table 2-6 Average Random Consistency Index

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 2-6 highlights the average random consistency index where, ***n*** is the matrix order number, and ***RI*** is the random consistency index.

$$CR = \begin{cases} < 0.1, & acceptable \\ \geq 0.1, & unacceptable \end{cases} \quad (2\text{-}10)$$

The formal mathematical representation of the proposed evaluation metric for managing networked organizational systems by improving UI quality of the web information system is given as follows:

$$WUIQ_t = \sum_{i=1}^{\infty} (P_i \omega_P) + (A_i \omega_A) + (U_i \omega_U) \quad (2\text{-}11)$$

$$U_i = \left(\prod_{j=1}^{n} ŭ_j \right)_i^{\frac{1}{n}} \quad (2\text{-}12)$$

$$WUIQ_t = \sum_{i=1}^{\infty} (P_i \omega_P) + (A_i \omega_A) + \left(\left(\prod_{j=1}^{n} ŭ_j \right)_i^{\frac{1}{n}} \omega_U \right) \quad (2\text{-}13)$$

Where:

$\boldsymbol{WUIQ}$ = Web interface quality metric

t - Time (in months/years)

ω_A - Web interface accessibility coefficient

A_i - Web interface accessibility score

ω_P - Web Interface Performance coefficient

P_i - Web Interface Performance Evaluation

ω_U - Web Interface Usability coefficient

U_i - Web Interface Usability Assessment score

n – Number of users

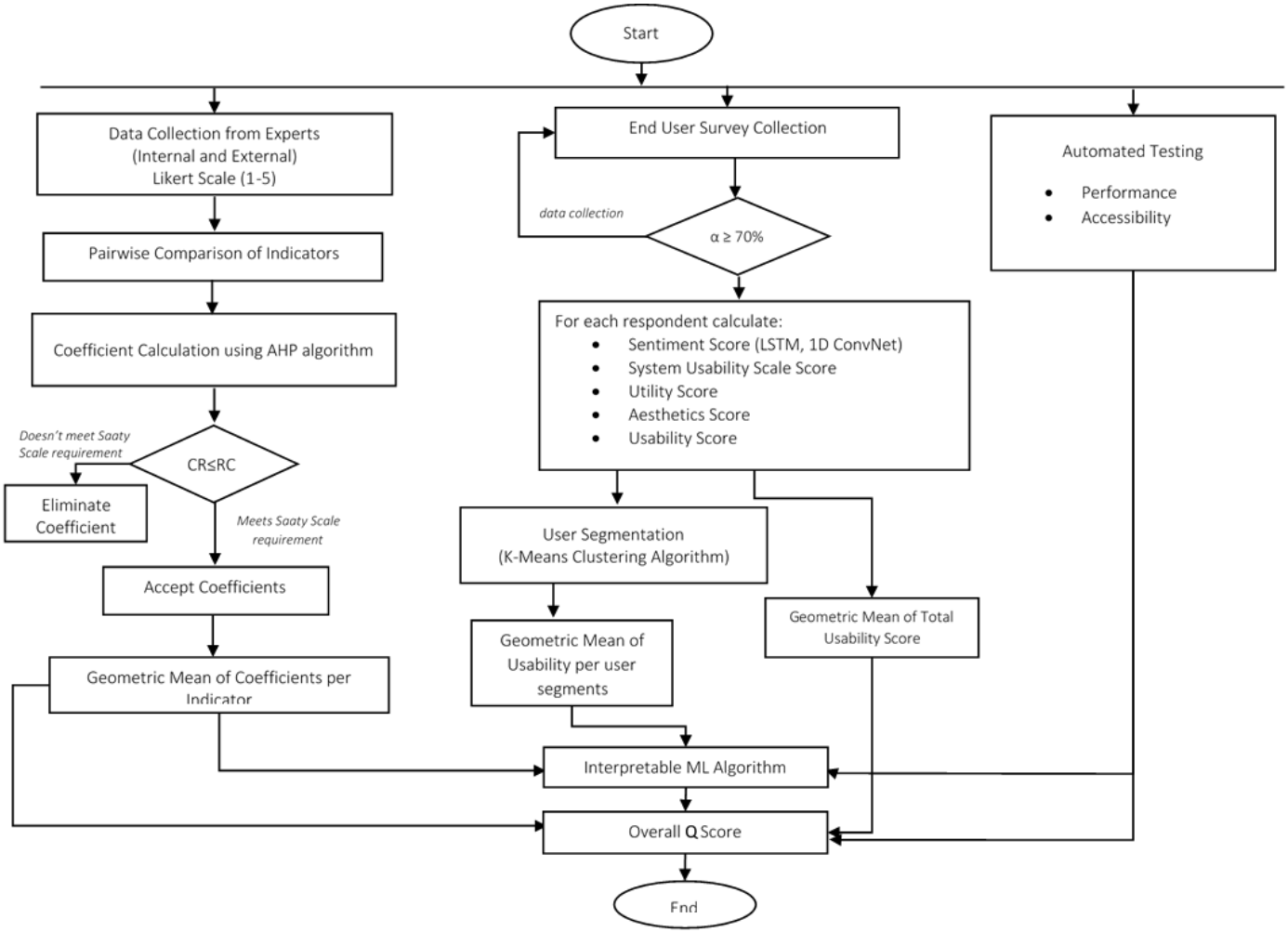


Figure 2-7 Overall Schematic View of Web-Based UI Quality Evaluation Model

2.3. Technique for assessing user experience and user clustering algorithm based on machine learning and interpretable artificial intelligence

Networked organizational systems, with their decentralized structures and project-based teams, require adaptable web tools that cater to diverse user needs. By analyzing user interactions with the web tool through the proposed model, algorithms can be employed by analysts within the networked organizational system to group users based on several factors such as their experience level with the web-based information system. This allows analysts and decision-makers to understand the specific needs and challenges faced by different user segments. The methods and algorithms proposed in this research for adapting web tools for managing network organizational systems based on user clustering and experience with the web system using machine learning and interpreted artificial intelligence involve leveraging user data to enhance system functionality. By analyzing user interactions and preferences, quantitative, qualitative and statistical analysis in collaboration with machine learning algorithms can be applied to segment users based on their behavior and tailor the web tools to meet their changing needs. The algorithms and methods proposed aim to improve user experience, system efficiency, and indirectly influence user efficiency within networked organizational systems. This involves propositions such as:

- Data Collection: Gather user data from interactions with the web system, including preferences, usage patterns, and feedback.
- Feature Extraction: Identify relevant features from the collected data that can be used to characterize user behavior and preferences.
- Clustering: Adoption of ML algorithms including K-means clustering to create a set of users with similar characteristics.
- User Profiling and Adaptation Rules: Develop user profiles based on the clustered data to represent different user segments with distinct preferences and behaviors. This is followed by improvement of the web tools based on the identified user clusters to provide tailored experiences and functionalities for each user group.
- Feedback Control: Continuously update and refine the system based on user feedback and interactions to improve the clustering accuracy and tool adaptation.

By implementing the proposed methods and algorithms, networked organizational systems can enhance web tool effectiveness by adapting to diverse user needs, leading to a more personalized and efficient user experience. Further insight into user responses involves segmenting users with similar experience quality preferences, typically based on demographic information, which often lacks a comprehensive account of overall user performance.

The dissertation adopts an unsupervised ML algorithm, precisely K-Means clustering which was introduced in the1960s [243]. The ML algorithm groups entries based on their shared attributes into a desired number of clusters. This unsupervised algorithm is preferred for clustering studies and customer segmentation due to its adaptability to data, high-dimensional feature handling, guaranteed convergence, scalability, efficiency, and effective minimization of within-cluster variability while maximizing between-cluster variability [243]. The k-means method aims to minimize the total intra-class variance. This is accomplished via metrics such as Euclidean distance or Manhattan distance metric.

$$V = \sum_{i=0}^{k} \sum_{X_j \in C_i} \left(X_j - \mu_i\right)^2 \qquad (2\text{-}14)$$

Where X_j - characteristic vectors; k - number of clusters; C_i - clusters; μ_i - cluster centers. As reported by research, the algorithm description does not guarantee finding the best solution. As such, to reduce the dependence on poor choice of centers, the algorithm is often iteratively run with different initial centers, and then the solution with the smallest variance V is selected. The algorithm consists of four (4) steps: (1) Initialization; (2) Classification; (3) Centroid Recalculation; (4) Convergence Condition [244].

A given dataset represented as $X = \{x_1, x_2, \dots, x_n\}$, in a d-dimensional (Euclidean) space $\mathbb{R}^d$. c - cluster centers are represented as a set $A = \{a_1, a_2, \dots, a_c\}$ with binary data $z = [z_{ik}]_{nxc}$, where $z_{ik} \in \{0,1)$ is data x_i which is a member of cluster ($k = \{1, \dots, c\}$) [244]. As such, the cost function of the algorithm is:$J(z, A) = \sum_{i=1}^{n} \sum_{k=1}^{c} z_{ik} \|x_i - a_k\|^2$. The algorithm (Figure 2-12) is iterated in order to minimize the objective function $J(z, A)$ by updating the cluster centers and its member data points respectively, as:

$$a_k = \frac{\sum_{i=1}^{n} z_{ik} x_{ij}}{\sum_{i=1}^{n} z_{ik}} \tag{2-15}$$

$$z_{ik} = \begin{cases} 1, & if \|x_i - a_k\|^2 = \min\limits_{1 \le k \le c} \|x_i - a_k\|^2 \\ 0, & otherwise. \end{cases} \tag{2-16}$$

To determine the optimal number of clusters (K) as one of the initial parameters before running the algorithm, research has identified six (6) approaches: rule of thumb; elbow method; information criterion approach; information-theoretic approach; silhouette method; and cross-validation. K-Means clustering has been applied in UI-related studies to group similar user interaction data (log analysis) based on similarities; these logs contained detailed information at the page elements level as well as events associated with user interaction with the web-based system [245]. In their study, cluster quality was derived via entropy, where a resultant value from **0 – 1** is representative of the measure of the purity of a cluster; the smaller the entropy, the purer. Thus, the advantage of using k-means clustering within their study was the fact that there is a reduction of instances that should be analyzed with respect to usability evaluation supported by log analysis (i.e. identification of UI issues to be improved). Thus the evaluator will need to focus the usability analysis on a few instances of the same cluster (i.e. effort minimization and less human intervention) to understand if a given user's behavior is indicative of a usability problem.

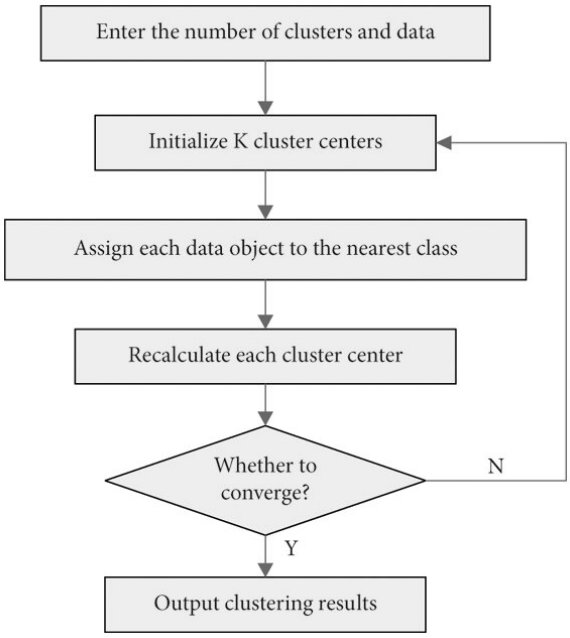


Figure 2-8 Flowchart Schema of K-Means Algorithm

When user acquires expertise in the system they expect user interfaces which satisfy their unique needs, as such, researchers believe that UI should adapt to different users based on user context history [246]. Their study proposed a conceptual prototype framework that creates adaptive UI. User interaction data and user feedback were utilized as training data, with K-means clustering, for building an inference engine for user-type selection (i.e. three (3) user experience (UX) levels - novice, intermediate and expert). The UX level is fed into the UI rendering engine which renders a new UI based on each experience level.

K-means clustering has also been applied in previous studies for the automatic creation of unique thresholds to distinguish between index pages and article pages on websites (individual), which furthermore paved the way to classify webpages for altering content display on an accessible web browser (IWeb Explorer) that the researchers developed for users with disabilities [247]. The application of k-means clustering algorithm by their study was aimed at web context recognition. Thus, k-means clustering was utilized as a technique for approximating the maximum-likelihood estimates for the clusters' means.

After clustering users based on usability features, the final step was to interpret the results using explainable AI techniques. These techniques help understand the decision-making process of black-box machine learning models, aiding in model improvement and gaining insights. By adopting explainable AI, the research aimed to provide a deeper understanding of the usability cluster classification for each user group, leading to more trustworthy AI solutions.

Explainable AI (XAI) aims at improving human understanding of the AI predictions and results. The terminology was used initially in simulation games to indicate how well a system accounts for the actions of AI-controlled characters [248]. Researchers have been studying explanation with respect to expert systems since the 1970s and the issue of explainability has always been a challenge. The persistent rise of AI across business spheres and its critical influence in decision-making processes, while not being able to deliver comprehensive details with respect to the chain of reasoning leading to a number of decisions, predictions, recommendations or actions taken, are directly responsible for the rebirth of this research topic. As such, new AI strategies that can make decisions comprehensible and explicable are required due to societal, ethical, and legal demands.

Decipherment of the black-box models is XAI's specialty, which also implies responsible AI because it can aid in the creation of transparent models. This should

take place without affecting the accuracy of the AI models; as a result, accuracy and interpretability must frequently be traded off in AI in general and in ML in particular. Model accuracy is highly relevant to the quality and amount of the training data, which naturally draws a connection to the data science discipline. Explainability plays a fundamental role in the justification of AI-based predictions or classifications. It helps with prediction verification, model modification, and for uncovering insights into the problem at hand, thereby leading to more dependable AI systems. The need for explaining AI systems is purported to stem from four (4) reasons. In spite of the fact that the four (4) reasons may appear to overlap, it is believed to capture the core motivations of model explainability. These are (1) Explaining to Justify (the reason for the specific outcome(s)); (2) Explaining to Control (gain insight into vulnerabilities or defects - debugging); (3) Explaining to Improve (a comprehensible model makes improvement possible by focusing on desired constructs); and (4) Explaining to Discover (revealing the unforeseen) [249]**.**

SHAP (SHapley Additive exPlanations)

SHAP (SHapley Additive exPlanations) is a game-theoretic method for interpreting machine learning models. It visualizes interpretations using SHAP summary plots and SHAP dependence plots. SHAP approximation techniques include Kernel SHAP, Deep SHAP, and Tree SHAP, designed for different types of models. Shapley values are capable of reframing knowledge workers' perspective and aid with obtaining insights into client behaviour and desires, thereby creating relevant persona profiles which leads towards the trajectory of prescriptive analytics. Shapley values have been used to interpret log anomaly detection systems; to understand client creditworthiness prediction; ascertain clients propensity to purchase an insurance policy, and predict the risk of churn with respect to an existing customer [250]. From a game-theoretic perspective, three (3) axioms were proposed by Shapley which describe the properties desired which a good solution is expected to be satisfied [251]:

1. Axiom 1 – Symmetry: When two players contribute equally to all possible coalitions, they should receive the same value or payoff.
2. Axiom 2 – Linearity: The total value or payoff of a coalition should be the sum of the values or payoffs of its individual players.

3. Axiom 3 – Carrier: This axiom states that if a player's contribution to a coalition is zero, then their Shapley value should also be zero.

A Shapley value receives a set function $2^M \rightarrow R$ as input; produces attributions $\emptyset_i$ for each player $i \in M$ that add up to $f_x(M)$.

$$\emptyset_i(f, x) = \sum_{z' \subseteq x'} \frac{|z'|!\,(M - |z'| - 1)!}{M} [f_x(z') - f_x(z' \backslash i)] \qquad (2\text{-}17)$$

The expression derives the Shapley value ($\emptyset$) for a given feature (*i)*, for example system utility (*s_utility*) for the blackbox model (*f*) – the segmentation model. The input item which is a single sample observation (i.e. a set of one user's usability score) is represented by *x*. All possible subsets (z') are iterated over which accounts for interactions between individual feature values. This makes the usage of Shapley values computationally expensive for larger features. In some cases, x' , the simplified data input (which is a transformation of *x*) is made use of. For usability metric, a set of subsets such as aesthetics score (*s_aesthetics*) and duration of system use (*duration*) with the remaining features treated as unknown. The model depends on a fixed size of features for inference, the values for non-members of the subset in focus are randomly generated during the calculation of marginal contribution of a feature of interest($\emptyset_i$). The $f_x(z')$ component of the formula indicates the combination of the blackbox model and the subset with feature of interest ($\emptyset_i$). Whereas $f_x(z' \backslash i)$ represents the combination of the blackbox model and a subset without the feature of interest. The difference ($[f_x(z') - f_x(z' \backslash i)]$) is indicative of the marginal value which is defined as the contribution of $\emptyset_i$ to the subset in focus (represented in percentages). For each permutation of subsets the process is iterative and subsequently weighted based on the number of players (or features) in the correlation which is represented by *M*. The $\frac{|z'|!(M-|z'|-1)!}{M}$ component of the formula is handles weighting and $[f_x(z') - f_x(z' \backslash i)]$ handles contribution measurement.

2.4. Results and Conclusions

This chapter discusses different methods of evaluating the user interface (UI) of a web-based systems or software application. The goal of web-based UI evaluation is to estimate a system's productivity and performance, identify issues or errors, improve and optimize the system's interactivity, efficiency, and productivity, and understand user behavior and experience. The chapter describes several

categories of UI evaluation techniques, including heuristic evaluation, checklist-based inspection, perspective-based inspection, cognitive walkthrough, and action analysis. Additionally, the chapter covers different types of user-based evaluation methods, such as interviews, questionnaires, and focus groups, and briefly mentions automated UI evaluation methods. The chapter introduces two UI evaluation models: the Interface Trustworthiness Quality Model and the Heuristic evaluation model. Finally, the essence of UI evaluation is discussed and gives ground for introducing a new approach to UI evaluation.

This chapter discusses the importance of web performance in providing a good user experience, quality user interface interaction and its impact on site traffic and business revenue. Key factor to web performance were discussed as well as pitfalls. The chapter also discusses the importance of usability and usability testing in web UI design. The study adopts the System Usability Scale (SUS) to measure usability and extends it to make up for utility and aesthetics shortcomings. The study also suggests mandatory user feedback to improve user experience and integrates sentiment analysis as a technique to evaluate user reviews. This study proposes a novel approach to evaluate the quality of web-based UI by adopting mathematical modelling to merge automated and user-based evaluation techniques. The evaluation metric for web UI quality (WUIQ) is formulated using Multi-Criteria Decision Making (MCDM) - Analytical Hierarchical Process (AHP), Statistical Analysis, and K-Means Cluster Analysis for user segmentation. K-Means clustering is used to segment users based on usability features, and the SHAP approach is adopted to interpret the cluster classification model results.

Finally, the chapter adopts data envelopment analysis (from an output-orientation perspective assuming variable returns to scale) which is a novel approach in management of developers and has not yet been applied as per studies conducted. This model is scalable and can be integrated with more outputs that can be obtained from developer actions set by the product manager. The proposed assessment of developers is a feedback control response to the changing user requirements to ensure developers are also productively engaged in improving the networked organizational system.

CHAPTER 3. SOFTWARE FOR SOLVING OF TASKS OF DEVELOPMENT OF WEB TOOLS FOR MANAGEMENT IN NETWORK ORGANIZATIONAL SYSTEMS

This chapter focuses on the development and deployment of the software (web-based tool) based on the proposed model and algorithms for decision support with respect to managing web-based tools for network organizational systems based on changing user needs. The implemented models and methods serve to meet the management needs of product managers and development teams within networked organizational systems, as a tool for managing the iterative process of improving user interface quality in accordance with the changing needs of end users and the updates within the web development ecosystem. It also serves as an information and reference system for decision support, and provides opportunities for understanding various classes of end users to improve system functionality which influences the work productivity within such organizational systems. Before the process of development, it is necessary to determine the main characteristics of the developed tools which embody the proposed algorithms and methods.

3.1. Software for Solving of Tasks of Development of Web Tools for Management in Network Organizational Systems

To realize the program built on the proposed set of methods and algorithms in Chapter 2, two (2) applications were developed. The main application (UI Eval – which is based on the proposed algorithm and registered as an intellectual property – in Appendix D – was built on the MERN technological stack. In the context of building a web application for managing iterative UI evaluation, the agile framework is well-suited to this approach. The web application would likely be built using the MERN stack, which is a popular stack for building web applications. MERN stands for MongoDB, ExpressJS, ReactJS, and NodeJS, and it is a full-stack JavaScript framework that allows for rapid development and iteration. At its core, the MERN technology stack is based on the popular Model-View-Controller (MVC) approach. The MVC architecture is a software engineering pattern that compartmentalizes an application into three (3) core components: Model, View, and Controller. A key advantage of using the MVC architecture is its ability to promote code reusability, maintainability, and scalability. By separating concerns into distinct components, developers can more easily modify or extend different parts of an application without affecting others. This separation also enhances collaboration among team members working on different aspects of a project. In addition, MVC helps improve the

overall organization of code, making it easier to debug and test individual components independently, leading to more robust and reliable software systems [252].

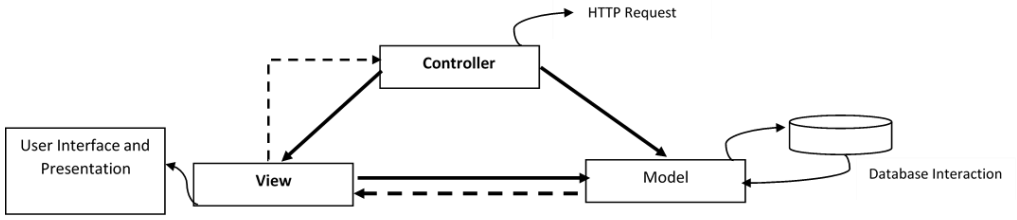


Figure 3-1 Model-View-Controller (MVC) Model Architecture

The interaction between an application built on the MERN stack and another app built on Streamlit involves a seamless flow of data and functionalities to create a comprehensive user experience (as presented in Figure 3-2). The choice of the above mentioned technology stacks are in line with the Stack Overflow 2023 developer survey conducted on over 90000 respondents which highlighted that MongoDB was the third most utilized database (25.52%); Node.js and React.js being the most used web frameworks (52% and 48% respectively), followed by Express (19.28%) being the fourth most popular[8]. This application handles user authentication, data processing, and business logic, providing a dynamic and interactive interface for users to interact with the system.

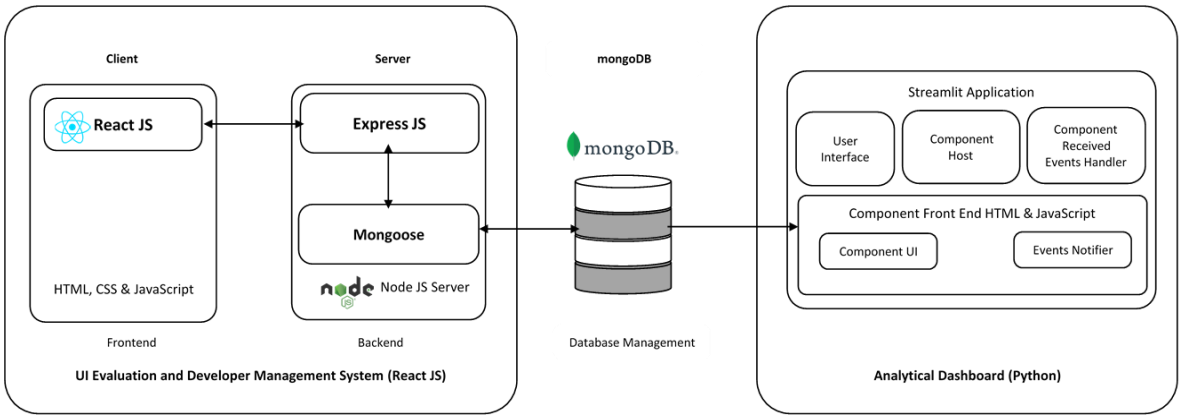


Figure 3-2 Overall Structural Model of Web Tool for Managing UI Quality in Networked Organizations

[8] 2023 Developer Survey, Stack Overflow, URL: https://survey.stackoverflow.co/2023/#technology (Accessed 01/02/2024)

React.js, a popular open-source JavaScript library, is used for developing single-page or mobile applications. Node.js, with its event-driven and non-blocking I/O model, facilitates real-time communication and efficiently handles large data volumes in web applications. Express.js, a lightweight and reliable framework, builds on Node.js to provide powerful server-side features like route navigation and HTTP caching, ideal for scalable backend systems [253]. Agile Software Engineering Methodology is a popular approach to software development that emphasizes flexibility and iterative development. The Agile methodology is based on the principles outlined in the Agile Manifesto, which prioritizes individuals and interactions, working software, customer collaboration, and responding to change [254].

The agile methodology, emphasizing collaboration and frequent updates, is particularly effective with the MERN stack, enabling continuous evaluation and updates based on user feedback. In Agile development, teams work in short sprints, delivering incremental updates guided by user stories, which focus on delivering value to the user. This process, combined with the use of MongoDB for its NoSQL architecture, ensures the application meets user needs while maintaining efficient record-keeping and providing business insights. Figure 3-3 presents the database schema of the implemented system.

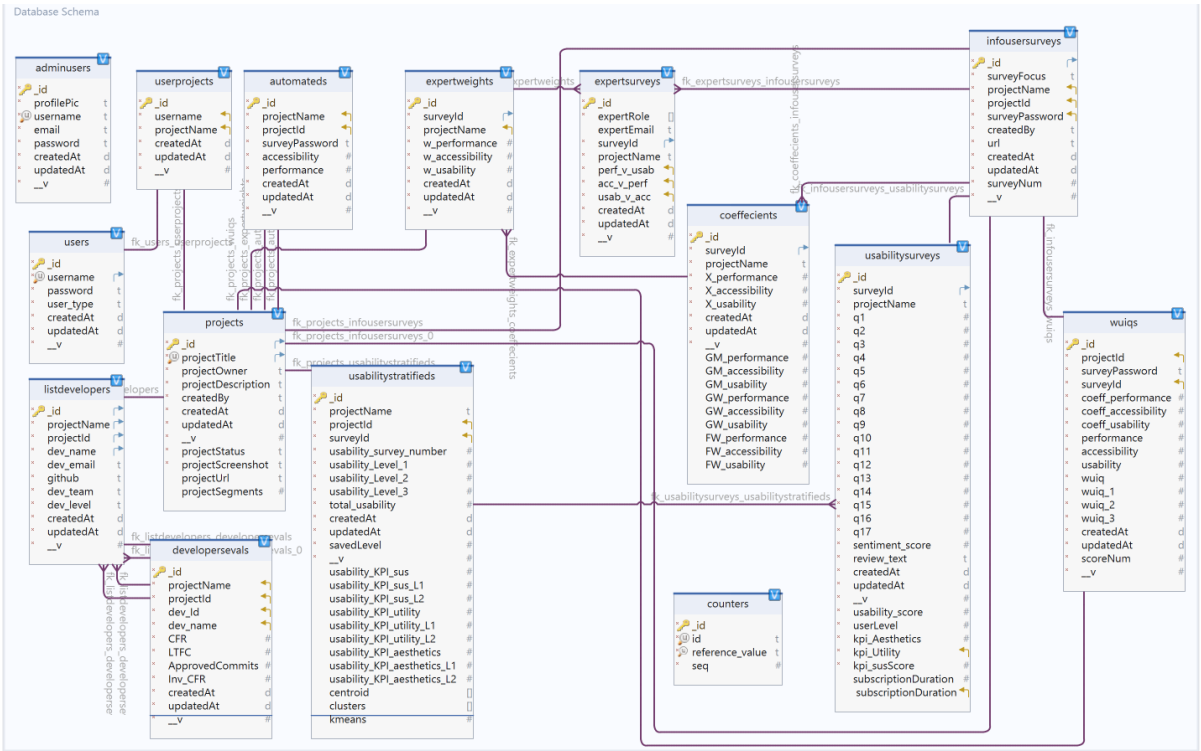


Figure 3-3 Database Schema for Web-Based Tool built on MongoDB

MongoDB is a NoSQL (an acronym for "Not just SQL") database (a non-relational database). NoSQL can be classified into the following five groups: (a) Graph Databases; (b) Object-Oriented Databases; (c) Column-Family Databases; (d) Key-Value Databases; and (e) Document-Oriented Databases [255]. MongoDB falls under the document-oriented (document store) database. Benefits such as: flexibility, optimized data storage (for example database-wide-locking) and retrieval make MongoDB the right choice for building the web tool for managing the iterative process of monitoring web-based UI and improving its functionality for all categories of end users [256].

As a means, for representing the interactions between classes, and JavaScript pages within the developed application, a dependency diagram is used. Dependency diagrams stem from dependency graphs which can be represented as directed graphs (digraph) which can be mathematically represented with a set of vertices (nodes) connected by directed edges which are indicative of the relationships between the nodes. Thus, the term "dependency" in this context refers to a relationship where one object relies on another. A dependency graph can be represented mathematically as follows:

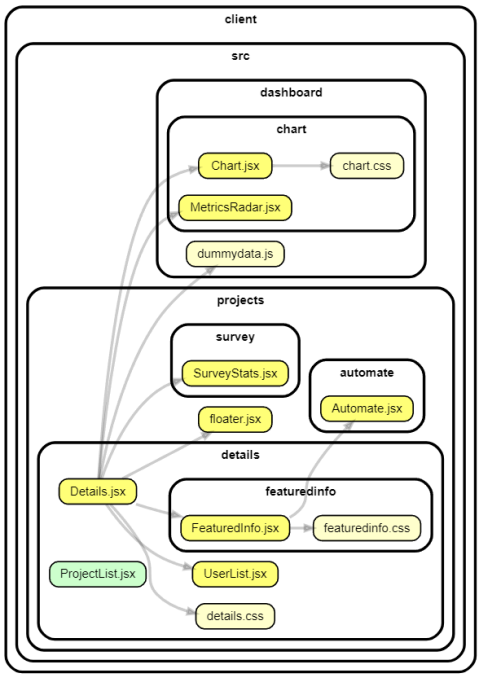
$$S \subseteq P \times P, where\ (page\ A, page\ B) \in S \tag{3-1}$$

With a set (P) of objects that has a transitive relation identified in formula 3-1 which models the dependency *"page A depends on page B"*. This dependency graph, can be formalized based on graph theory as:

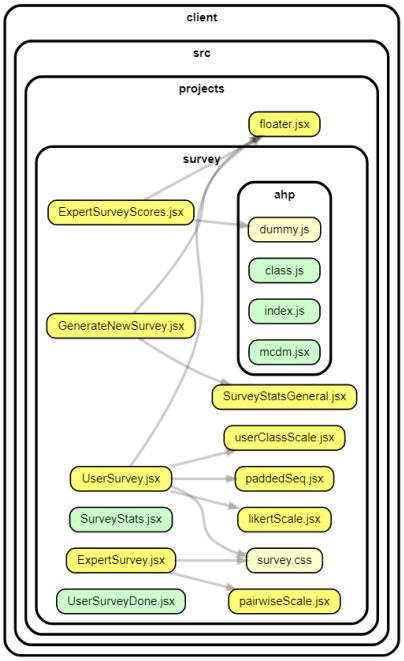
$$\boldsymbol{G} = (\boldsymbol{P}, \boldsymbol{T})\ with\ \boldsymbol{T} \subseteq \boldsymbol{S}, the\ transitive\ reduction\ of\ \boldsymbol{S} \tag{3-2}$$

Research has adopted dependency graphs to represent class dependencies within micro services which helps developers, testers, and product managers to optimize the workflow (tracking and managing), improve code quality, as well as to decompose, refactor, and analyze the codebase structure or architecture [257]. Figures 3-4 highlights examples of the derived unweighted dependency graphs from the developed application to aid in the software engineering workflow. Web hooks are an integral part of modern JavaScript programming and web APIs as they enable real-time and continuous portability of data by serving as a bridge between the user and the system. The figure 3-4 (a) presents the dependency map of the source folder interlinking the dashboard charts and metrics, project details, and survey statistics; Figure 3-4 (b) highlights the interconnection between various components such as

surveys – user survey, expert survey, the Likert scale for pairwise comparison algorithm, the analytical hierarchical algorithm (AHP).



(a) Project Dashboard



(b) Surveys (Expert and User)

Figure 3-4 Sample Dependency Graph

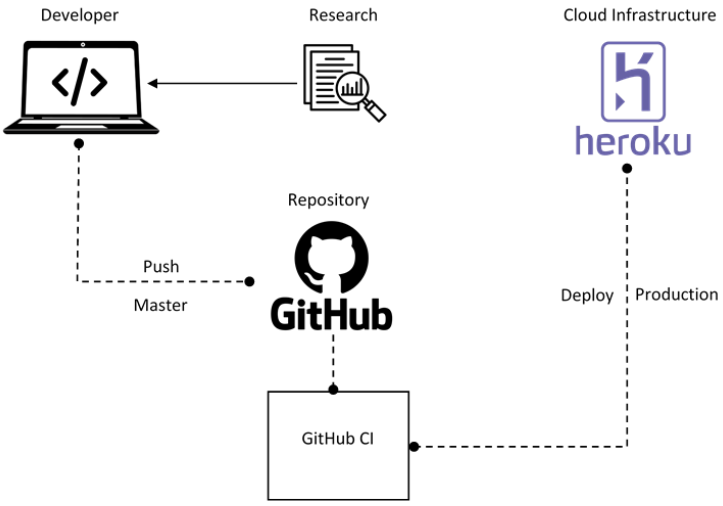


Figure 3-5 Proposed System Development Pipeline (CI/CD)

Figure 3-5 illustrates the pipeline adopted for development. Based on research conducted in previous chapters, development is undertaken, and code is pushed to the Master branch on the GitHub repository using the Git version control software. Git is essential in managing source code. As part of the CI/CD pipeline, research has

recommended the evaluation of metrics such as deployment time, response time, and ease of use with respect to the technologies and infrastructure utilized within the development pipeline. Finally, the code is deployed to any desired cloud server (Heroku Cloud Platform in this case).

For a more rigorous and detailed description of the process, it is necessary to use specialized modeling tools. Considering the pragmatic methodic approach of UI quality evaluation as proposed by the study, the IDEF0 framework is a suitable tool [258]. System architecture refers to the process of designing and organizing a software system's components, structure, and behaviors to meet specific functional and non-functional requirements. Structured Analysis and Design Method (SADT) is a visual modeling language that uses a hierarchical structure to represent system processes and data flows. IDEF0 Notation A0 and A1 are variants of SADT that are used to represent a system's functions and how they interact with each other. The relevance of SADT and IDEF0 Notation A0 and A1 in agile methodology lies in their ability to provide a structured and visual approach to system design and development [259]. In an agile environment, where iterative development is essential, these tools can help teams maintain a focus on system functionality and design, while also adapting quickly to changes.

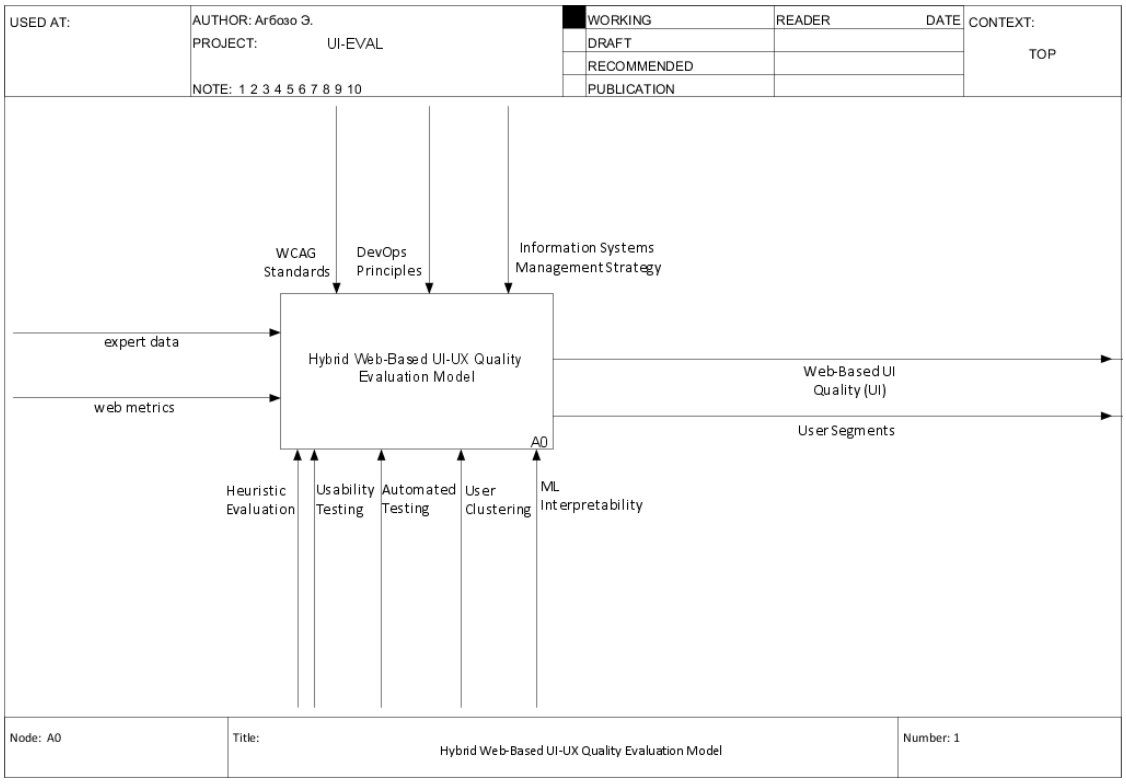


Figure 3-6 Structured Analysis and Design Method (SADT) – IDEF0 Notation of the Proposed Model (Level A0)

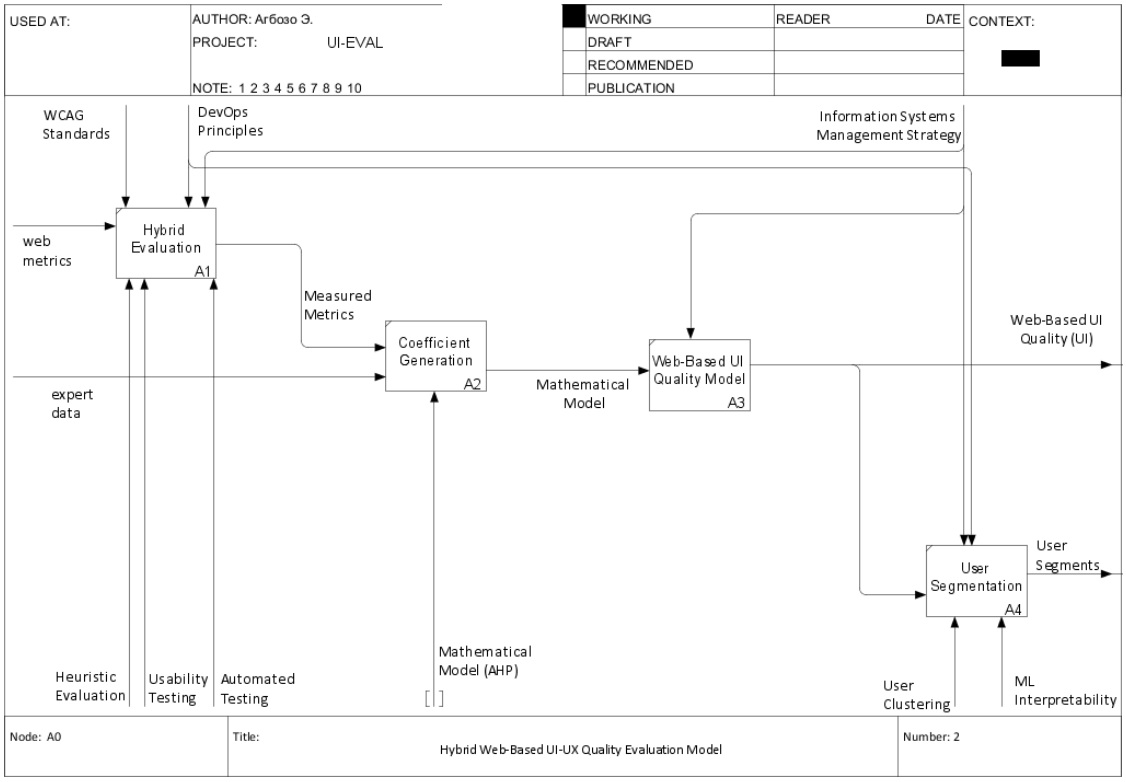


Figure 3-7 Structured Analysis and Design Method (SADT) – IDEF0 Notation of the Proposed Model (Level A1 - Decomposition of Block A0)

The structured analysis and design technique (SADT) is adopted to describe the system, process, technology and the hierarchy of functions of the proposed framework. SADT (Structured Analysis and Design Technique) is used to establish a framework for preventing algorithm failure and improving quality. The initial context diagram (Figure 3-6) is broken down into a subprocess (Figure 3-7), representing all components of the proposed unified framework. In A0, inputs are measured metrics for web accessibility, performance, and usability.

3.2. Solving the task of assessing the quality of the user interface

In order to achieve the aim of evaluating web-based UI quality, this study proposes a hybrid (automated and user-based testing) 3-dimension evaluation framework based on Performance, Accessibility and Usability. It must be noted that these dimensions, particularly the Usability dimension is an extended version of existing usability testing metrics. This research's algorithmic proposition was supported by developing a management tool for managing the process of web UI quality (WUIQ) evaluation. The algorithms developed in this study have undergone practical testing as part of the modules of a decision support system for managing

networked organizational systems taking into account adaptation to the changing user needs.

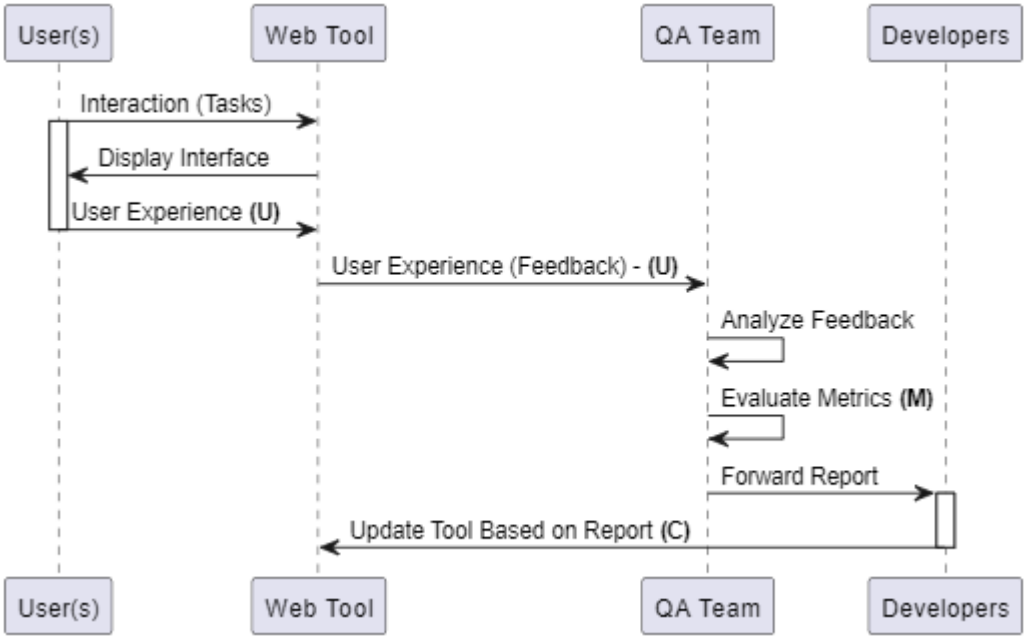


Figure 3-8 Sequence Diagram of Feedback Control with Evaluation Metrics for Information Systems in Networked Organizational Systems

To formalize the metrics and feedback control in improving user interface quality, a mathematical model to represent the relationship between networked information systems quality, user interface quality, and feedback mechanisms (Figure 3-8). Let $U(t)$represent the user interface quality at time (t); upon defining a set of metrics $M = \{m_1, m_2, \dots, m_n\}$ that quantify different aspects of user interface quality; then a control variable is introduced: $C(t)$ that represents adjustments made to the system based on feedback. The function $U(t) = f(M, C)$ is defined and relates user interface quality to metrics and control variables. This function captures how changes in metrics and control inputs affect user experience over time. The incorporation of a feedback control loop into the model to continuously monitor user interface quality and system parameters are adjusted accordingly: the function $C(t) = g(U, M_{target}, K)$ calculates the adjustments to control variables based on the gap between observed user interface quality $U(t)$ and the expected user interface quality ($U_{expected}$) as well as the gains (K) to regulate the feedback loop. With respect to the objective function $J = \int_0^T L(U, M, C)dt$ which quantifies the overall user interface quality improvement goal over a given time horizon (T). Finally, the loss function $L(U, M, C)$ that penalizes deviations from

desired user interface quality and incentivizes adjustments to control variables to optimize user interface quality.

Peculiarities of the Web Tool and Data Collection

To validate the hybrid evaluation framework proposed, this paragraph highlights an applied use-case based on data gathered from users of a Web 3.0 non-fungible token (NFT) marketplace –AtomicHub. NFTs are exclusive digital assets which can be in the form of an image, audio, video, or any file type which serves as a proof of ownership as well as authenticity verification of the asset held on the blockchain [260]. NFTs have been used to represent the ownership of physical artworks, land title deeds, property ownership documents, digital assets within online games, and even membership cards for clubs. NFTs are known to be financial assets due to their dependence on the cryptocurrency market. The NFT market according to a network analysis conducted concerning the year 2022 had seen a total of 17628425 transactions and is continually experiencing spikes in NFT creation and trading. In addition, numerous large corporations and organizations such as Microsoft, Barcelona football club, the National Basketball Association (NBA), IBM, as well as notable fashion brands capitalized on the NFT market to engage clients and reach a new target market [261].

The NFT market experienced significant growth, particularly during the middle of the COVID-19 pandemic in 2021, reaching its peak interest at the end of 2021 and the beginning of 2022, with daily turnover exceeding 200 billion USD; however, by October 2023, the daily turnover had declined to around 30 billion USD [262]. One of such NFT markets is the Worldwide Asset Exchange (WAX) blockchain which has significantly gained wide attention due to its unique features differentiating it from other known blockchain networks. It was designed primarily to for virtual asset trading and utilizes a proof-of-stake consensus algorithm.

Clustering of Users based on Experience with the Web Tool

For further understanding of user interaction with the system, the subsequent set of activities are conducted. The goal is to segment the results from the web usability aspect of the algorithm for an in-depth understanding of user preferences. To obtain the idea number of clusters (K) for the k-means clustering algorithm, the Elbow Method is adopted. This method is a heuristic applied in mathematical optimization. The Scree Plot highlights the ideal number clusters to select (K=2).

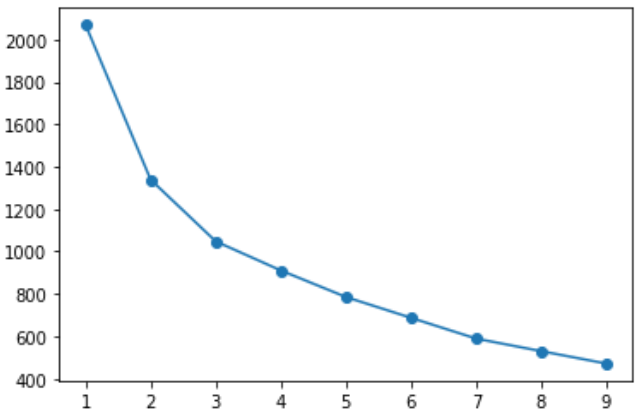


Figure 3-9 Elbow method (Scree Plot) for selection of the optimal clusters

Cluster (Segment)	Duration (in months)	Usability Score (%)
0	10.2	65.5
1	10.6	70.2

Table 3-1. Cluster Results – Segmented User Groups

The clusters obtained based on the segmentation of usability with k-means is highlighted in Table 3-1 while Figure 3-10 depicts clusters (K=2), where usability score is on the y-axis and duration of system usage (months) on the x-axis.

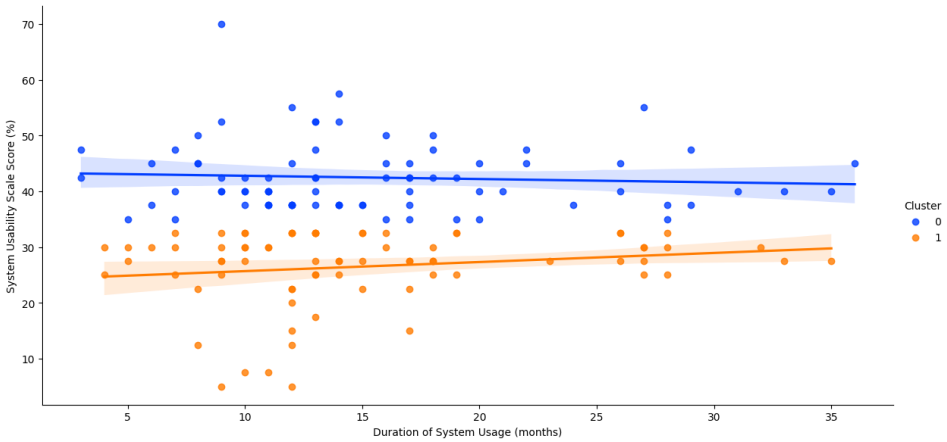


Figure 3-10 Results of Cluster Analysis (k=2)

The figure 3-11 illustrates a boxplot of usability clusters with usability sub-metrics such as utility, aesthetics, and subscription duration (on the y-axis).

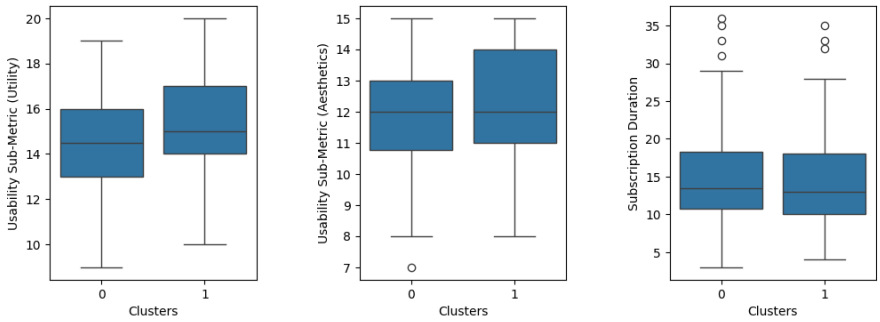


Figure 3-11 Results of application of the proposed models and algorithms - Box Plot (Web Usability Sub-Metrics by Clusters)

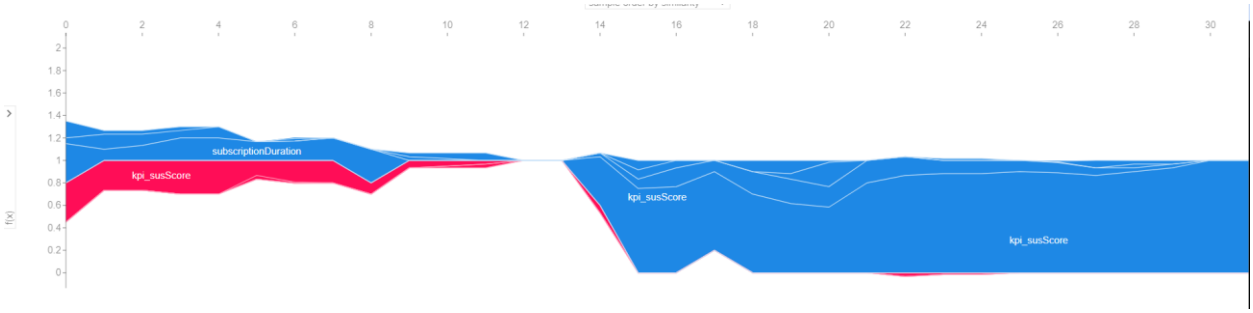


Figure 3-12 Interpretable ML - Force plot of Sampled User Data

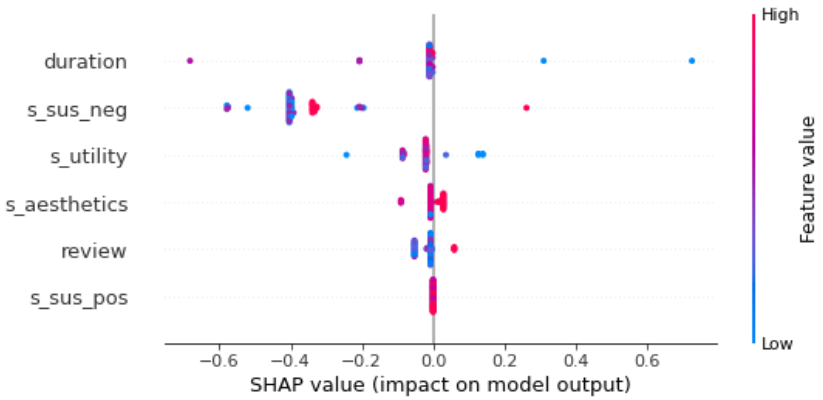


Figure 3-13 Interpretable ML - Beeswarm plot and histograms highlight the effect of features on classification (Cluster 0)

Figures 3-12 to 3-15 illustrate the features (independent variables/predictors) which contributes to moving the model output from the base value (the average of the model output over the training dataset) to the model output. Features that positively impact the forecast are highlighted in red, while those that negatively influence the forecast are shown in blue. In the case of the experiment of the data collected for the case study, where the expected value E[f(X)] = 0.535, the negative components of the system usability scale survey contributed primarily to both clusters, with the

duration of system usage not being a contributing factor for cluster 1 while the opposite is for cluster 0.

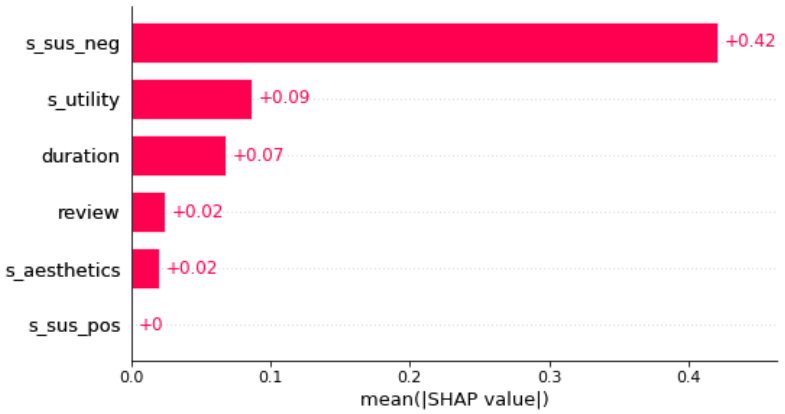


Figure 3-14 Interpretable ML - Feature (independent variables) Importance Plot (Cluster 1)

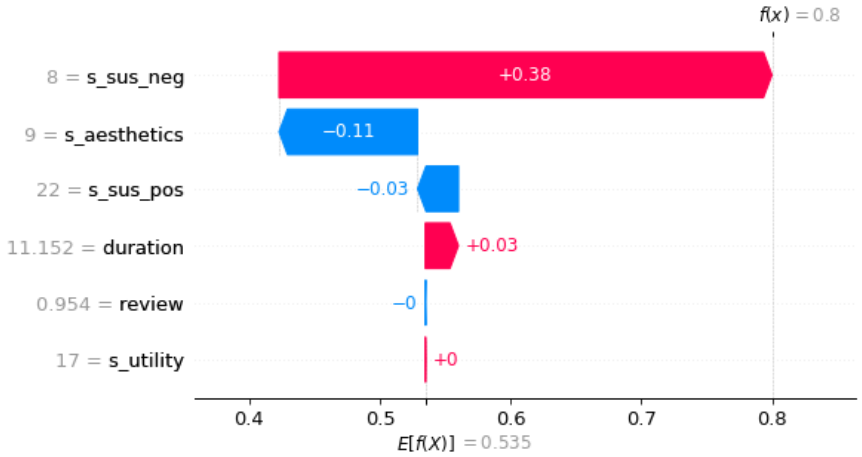


Figure 3-15 Interpretable ML -Feature Contribution to the Clusters (Cluster 0)

These results provide an overview for decision makers and serve as a feedback mechanism for improving upon networked organizational systems and furthermore contributing to overall improvement in business productivity.

An additional software was developed using Python and the Streamlit web framework which makes requests to the MongoDB database in the cloud. Streamlit is a lightweight open-source and user-friendly (ease of use) web-based Python framework which has minimal code capabilities and provides a streamlined front-end web application development approach [263]. This algorithmic proposition integrates machine learning and model evaluation to adaptively manage networked organizational systems, considering changing user needs. The analytical dashboard

provides insights, minimizes vulnerabilities, and reduces development costs, enhancing user-centric design of information systems. Previous studies have recommended future research to improve CI/CD pipelines through the integration of machine learning algorithms and this is gap is fulfilled in a peer reviewed study which published a portion of the results of this dissertation and approbated in 2023 [140].

Assessing the user interface quality of web tool

The goal of the proposed algorithms and methods is to develop web tools for managing networked organizational systems taking into account changing user requirements. As indicated in Chapter 1, networked organizations in more recent times have widely adopted cloud-based (web) information systems both for internal business process as well as interfacing externally with clients. With the proliferation of such web tools, numerous challenges are faced and one of such is the user experience of end users which is influenced by the user interface. As such, the dissertation explores the setting of tasks with regards to management of networked organizational systems from the perspective of evaluating the state of web UI quality as well as (proposed in Chapter 2). Results of the evaluation provide decision makers with the necessary perspective of their web infrastructure and developers contribution to make necessary improvements (a.k.a. Feedback)

The NFT marketplace (AtomicHub) for this experimental study operates as an organization with employees in nine (9) countries, who are led by Operations leads and Technical leads respectively. Thus, fitting the networked organization systems model. For this study, a random sample of users was selected from the company's Discord channel in August 2022 to gather data through expert surveys and user surveys. This focused approach allowed for more in-depth analysis within a specific user segment. Experimental tests were run on the system for the purpose of collecting automated testing data. In this sub-section, the obtained results from the case study for deriving web-based UI quality $WUIQ_t$ where t = 1 (for an iteration = 1, i.e. the first iteration) is as follows:

a. The formulation of the coefficient based on the pairwise comparison conducted by 11 experts – namely one (1) UI Designer, four (4) Fullstack Developers, two (2) Application Testers, and four (4) IT Project Managers)**:**

i. $\omega_P = \mathbf{0.36}$

ii. $\omega_A = \mathbf{0.27}$

iii. $\omega_U = \mathbf{0.37}$

This result indicates that system's stakeholders (i.e. providers) place more value on web usability than web performance and web accessibility respectively.

b. With respect to the results derived from the Automated Evaluation process with the help of the Google Lighthouse tool:

   i. Performance (P_1) = 0.25

   ii. Accessibility (A_1) = 0.97

c. With respect to the User-Based Evaluation process from 112 respondents, the results derived from the extended SUS questionnaire's formula is as follows:

   i. Usability (U_1) = 0.6184

d. The overall web UI-UX quality score is as follows:

$$WUIQ_1 = \sum_{i=1}^{\square} (0.25 \times 0.36) + (0.97 \times 0.27) + (0.6184 \times 0.37)$$

$$WUIQ_1 = 58\%$$

A web UI-UX quality score of 58% (for iteration t=1) indicates a below-average performance that requires improvement. To address this, a new round of automated and usability testing will be conducted (iteration t=2) to gather further insights. The coefficients obtained in this iteration will serve as a benchmark for future evaluations.

The software package implementation (based on the proposed set of algorithms) consists of two web-based information systems for managing the iterative assessment and improvement of the UI quality of web-based information systems within modern networked organizational systems. Figure 3-16 illustrates the detailed web usability metric over time at the level of stratification/segmentation depending on the set number of clusters. In addition, the rubrics (in line with different color coding) are indicated revealing the quality or shortcomings with respect to the three metrics (performance, accessibility, and usability).

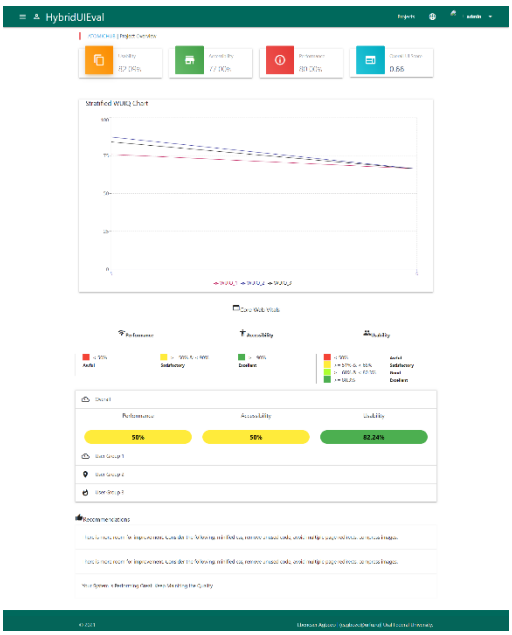


Figure 3-16 HybridUIEval – Project Report and Status Dashboard

Finally, recommendations based on the WCAG and WAI guidelines for the developers and web administrator are provided to aid in decision making for improvement of the user interface quality. In order to iteratively measure the state of the information system in the networked organization, the administrator creates expert surveys and user surveys sub-projects (iterations) within the main project (web information system in focus). These surveys generate URLs and passwords to be shared with all respondents. For the user surveys, the metrics from the extended usability metric are calculated automatically upon a user submitting their survey (Appendix B).

3.3. Results and Conclusions

This chapter practically implements the methods and algorithms proposed by the study for the management of networked organizational systems considering changes in user requirements. A hybrid evaluation framework for web-based UI quality that utilizes both automated and user-based testing in the dimensions of Performance, Accessibility, and Usability was deployed. The proposed algorithm is supported by a management tool built using the MERN stack, which allows for rapid development and iteration in an agile software engineering methodology. This section also discussed feedback through web UI quality evaluation as necessary component of the management of networked organizations because it helps continuously monitor and improve user experience which influences business

workflow. The MERN technology stack was adopted to build the management platform which combines algorithms for evaluating web-based UI and improving the system's ability to perform tasks effectively, in the long run improving user experience (UX). In addition, an analytical dashboard which was built on the Streamlit Python framework and interconnected with the main database of the web-based solution to extract knowledge for analytical purposes. To validate the hybrid evaluation framework, a case study was conducted on a web 3.0 non-fungible token (NFT) marketplace, utilizing k-means clustering to derive an optimal number of clusters for an in-depth understanding of user preferences. These results serve as a feedback mechanism for improving upon systems and managing the web tools and developers of networked organizational systems.

Overall, this research presents a comprehensive approach to web-based UI quality evaluation that can help decision makers improve networked organizational systems through the assessment of web tools to adapt to the needs of their users and improve business productivity.

3.4. Generalized technique for using the developed models and methods in managing network organizational systems

Despite the proposed algorithms and methods being presented for the context of networked organizational systems, it is important to understand that the solutions presented are scalable and can fit any given modern firm size. Figure 3-17 visualizes the flowchart diagram that indicates the administrators' actions and interactions with the main functionalities of the proposed web-based system for managing UI quality in networked organization systems. The flowhart diagram contains four (4) objects: *Projects*, *ExpertSurvey*, *UserSurvey*, and *AutomatedTest*, with actions which are sequentially invoked after logging into the system.

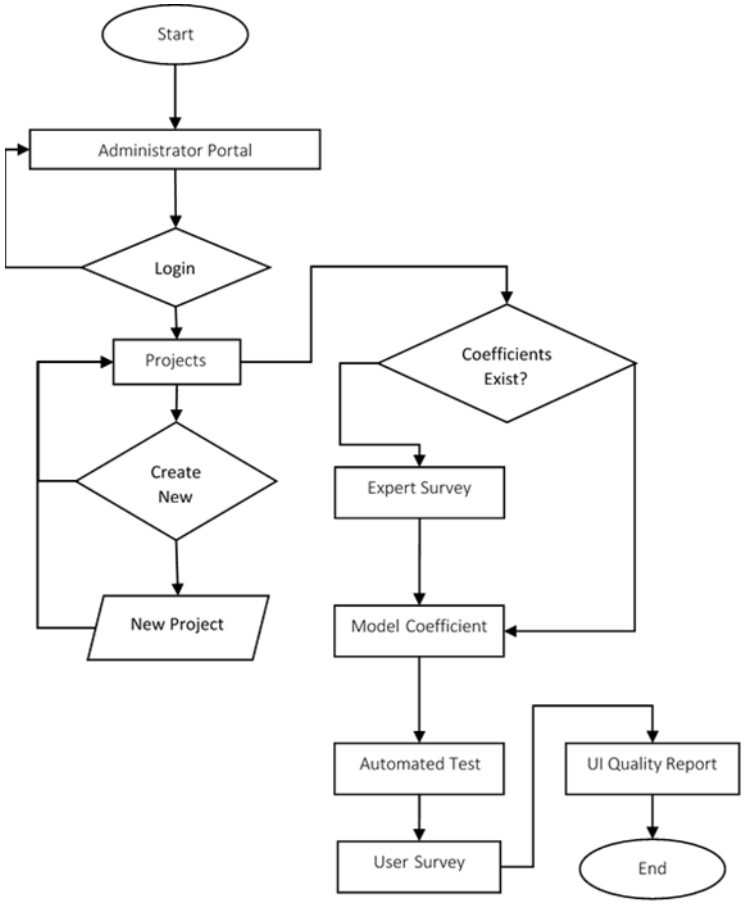


Figure 3-17 Schema of Administrator Actions in Proposed System

An algorithm for assessing the quality of a user interface as a tool for managing network organizational systems

Today, most UI evaluations are conducted remotely because of the diffusion of online technology and its relevance in modern day livelihood, as such remote

user-based testing has been posited to be cost effective and time saving [264]. Within one of the contemporary application development (software engineering) processes known as DevSecOps (Software Development, Security, and Operations), user-based testing is encouraged as an approach which provides UI insights at a granular level in the event of system modifications. In their work, the researchers noted that Usability test is highly encouraged to be performed "early and often" in order to ensure corrective measures to be taken into account when needed. It was also pointed out that a lack of usability testing produces a great change in use-difficulty. User-based testing has been adopted in the evaluation of the ease of use of university websites in Iraq [198]. User-based testing methods encompass A/B testing, individual surveys, eye tracking, remote user testing, and focus groups [265]. These techniques are all aimed at uncovering design flaws and incapability of UI to perform their designated tasks.

From a control theoretic perspective, feedback is essential to improve system performance and align the networked organizational system with their desired goals. Previous research has highlighted the stepwise procedure of usability control as follows: (a) setting desired web service indices, usability diagnosis – which involves the modelling of user activity, followed by corrective adjustments which is informed by diagnosis report; thereby observing feedback control in improving information systems [266].

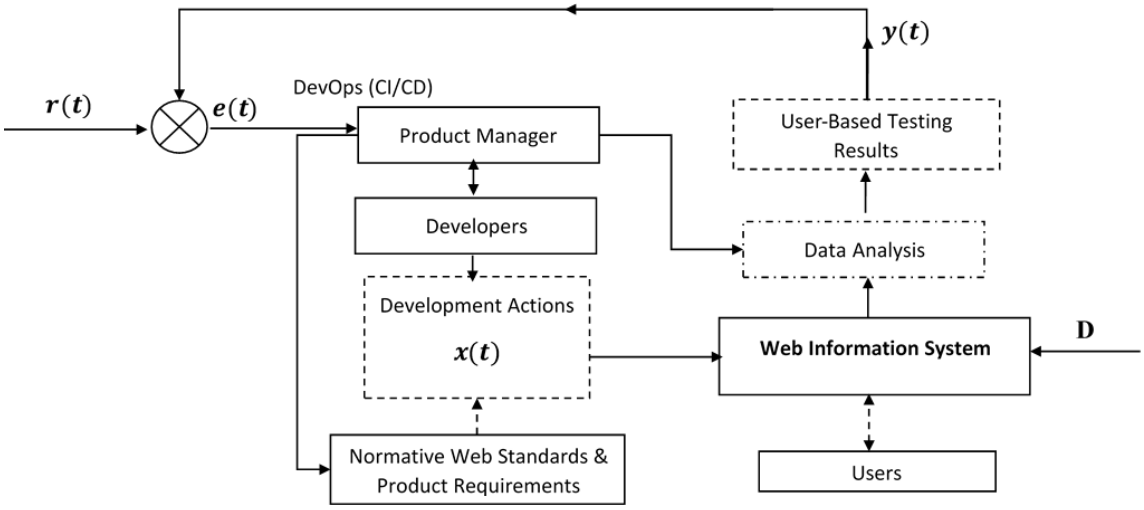


Figure 3-18 User-Based Testing as a Function of Feedback Control to Manage Information Systems of Networked Organizational Systems

Figure 3-18 illustrates the ability of networked organizational systems to leverage user feedback and data analysis to continuously improve the usability of web information systems through user-based testing. Gathering knowledge from

previous studies on feedback control for enhancing quality of service of software systems and teams, it is evident that the integration of user interface quality metrics and team assessment as a control mechanism for improving the quality of networked information systems. The modern networked organizational system is the main focus of the research and the solutions proposed are applicable to all modern organizational systems due to the presence of web-based information systems as a central component of harmonizing business processes. Identification of requirements for implementation of web tools for managing networked organizations taking into account changing user needs is impossible without a clear understanding of its structure. It must be understood that in modern networked organizational systems, web-based infrastructure are a central component for managing business processes (internally) and interacting with customers (externally).

After deploying applications, systems are monitored primarily with respect to backend server activities such as downtime, system logs. This is because product owners are more concerned with the application performance and less focus is given to the UI (which is the interface for interacting with the system itself). Research has shown that poor UI leads to poor user experience which has an effect on productivity, effectiveness in performing set tasks, and these can influence the business over time. Firms have had to abandon information systems due to their UI complexity which led to user fatigue; thus the aesthetics of web UI play an important role in the entire system's utility [267]. For such reasons, it is essential that the UI of the web systems are monitored over time to ensure effective usage.

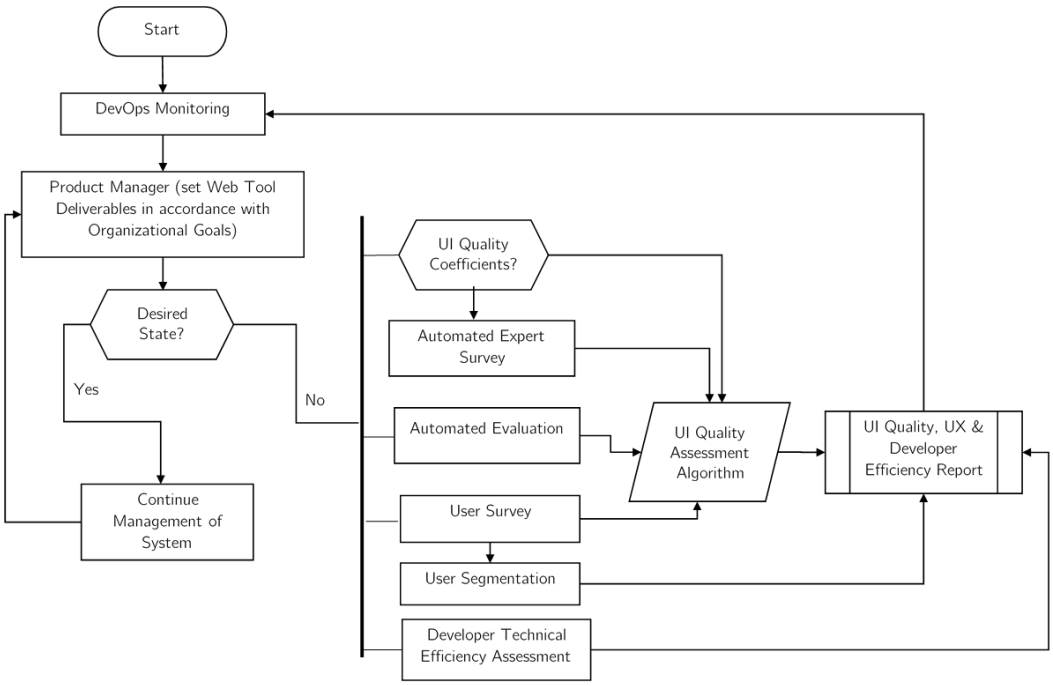


Figure 3-19 Structural and Functional Organization of the Support System of Web Tools for Managing Networked Organizational Systems Taking into Account Adaptation to Changing User Needs

Figure 3-19 depicts a flowchart for a system and development infrastructure management algorithm aimed at developing web instruments for the management of networked organizational systems considering adaptation to changing user needs. It consists of a combination of all algorithms and methods proposed in the study. The process occurs post-deployment and starts with the DevOps Process monitoring feeding into a parallel process of user interface quality assessment (dependent on user survey and expert survey), user segmentation and the developer technical efficiency. This structured approach ensures that the UI is continuously evaluated and improved based on comprehensive metrics and user segmentation data, ultimately aiming to improve the user experience.

Technique for assessing the quality of user interface in software development management

Assessing developer efficiency serves as a pivotal feedback mechanism in the pursuit of enhancing UI quality. By systematically evaluating developers' effectiveness in crafting user interfaces, organizations gain invaluable insights into the efficiency of their development processes and the overall quality of the end-user experience. Through metrics such as code review completion time, feature

implementation velocity, and error (bug) resolution rates, teams can pinpoint areas for improvement, identify bottlenecks, and streamline workflows to deliver more polished and user-friendly interfaces. This feedback loop fosters a culture of continuous improvement, empowering developers to iteratively refine their practices, optimize codebase architecture, and prioritize enhancements that directly impact UI usability and satisfaction. Ultimately, by harnessing developer efficiency as a feedback mechanism, organizations can iteratively elevate UI quality, enhance user engagement, and drive overall product success.

Agile methods are widely adopted due to the focus of resources and time on changing requirements which aims for minimizing the change response time [268]. With respect to the management of development teams, efficiency metrics are drawn from the DevOps Research and Assessment (DORA) metrics which is comprised of (a) Throughput Metrics – which are metrics that gauge the frequency with which an organization implements new software or upgrades existing software (metrics include lead time for changes (LTFC) and deployment frequency); and (b) Stability Metrics (metrics include Change failure rate (CFR) and Mean time to recover (MTTR)) [269]. As indicated by studies, the DevOps framework targets the improvement of deployment frequency, the reduction in failure rates and speed up the meantime for recovery in case of system downtime.

Deployment Frequency (f_{deploy}) - The frequency of deploying software to production within a specific time frame, reflecting how many times code or software is released to production [270]. Research has reported that a high deployment frequency reflects the organization's capacity to deliver new software and updates swiftly and reliably, in contrast a low deployment frequency may indicate challenges in meeting the demand for new features and change [269]. Let *D* represent a set of deployments from a given frame of time t_0 to t_n- represented in formula 3-4 as:

$$f_{deploy} = \frac{|D|}{t_n - t_0} \tag{3-3}$$

Lead Time for Changes (LTFC) – This metric has been identified as the delay between development and production. This metric measures the time it takes for software development changes to be deployed to users after they are written, typically in days [269]. LTFC reflects the gap between committing changes to a central code repository and deploying them to production. To represent LTFC mathematically, let *C* be a set of commits to the repository and *D* be a set of deployments. Let *K* be a pair of commits and deployments *(c, d);* where $c \in$ C, and

d ∈ D; where a set of commits can be associated with a deployment. Thus, for each set of X_T (t_d,t_c) for each *(c, d)* ∈ X; with deployment time (t_d) and code commit time (t_c), as well as *T* as a set of times (*t*) for each (t_d,t_c) ∈ X_T where $t = t_d - t_c$. Thus, lead time for changes is represented as:

$$LTFC = \frac{1}{|T|}\sum_{t \in T} t \tag{3-4}$$

Change Failure Rate (CFR) – The metric evaluates the proportion of deployments in an organization's software or IT systems that fail or lead to unintended consequences, such as containing a bug [269]. A low change failure rate reflects successful implementation of changes without disruptions, whereas a high change failure rate suggests challenges in managing and deploying changes effectively. To represent CFR mathematically, let *C* be a set of commits to the repository and *F* be a set of failures. Let *K* be a pair of commits and failures *(c, f);* where $c \in C$, and $f \in F$ (where,$c \Rightarrow f$); with D_f as a set of all pairs *(d, f)* where deployments (d) contains commits (c) and *(c, f)* $\in K$. With the set D_u representing all deployments (d) considering that *(d, f)* $\in D_f$ and f represents any random failure, CFR is represented as:

$$CFR = \frac{|D_u|}{|D|} \tag{3-5}$$

Research has identified that the management of developers through the recording and analysis of such metrics contribute to the detection of flaws within the code deployment (system update) strategy, minimizes errors and increase the confidence of users in the information system [270]. These benefits are motivating factors for inclusion into the set of algorithms for managing networked organizational systems based on changing user needs.

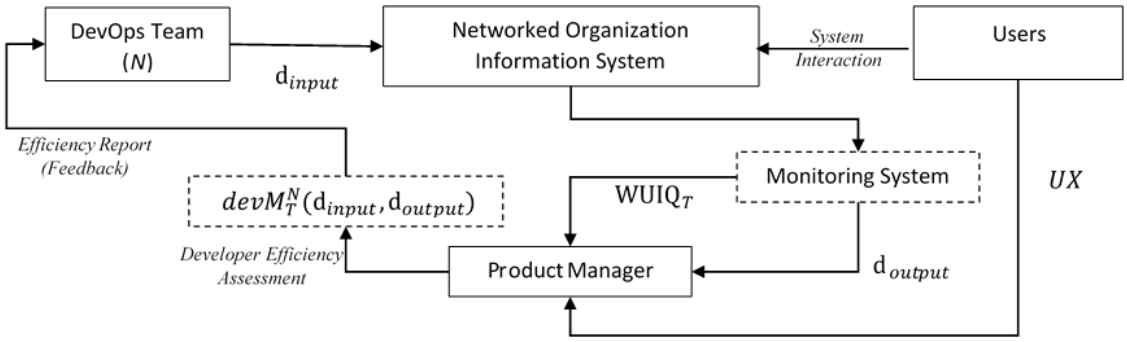


Figure 3-20 Schematic Representation of Management of Networked Organizational Systems considering Changing User Requirements

In light of all the knowledge gathered by research, data collection and observation through the scientific method, the characterization of the organizational system for testing is represented in Figure 3-20. The schema includes *N* developers which contribute to the development of the information system. Let the resources contributed towards the development of the system be represented as d_{input} which the total number of approved code commits (f_{deploy}) is before the next evaluation phase (t_{n+1}, where$\mathrm{t}_n \in \mathrm{T}$ and T is a set of all iterative evaluations times). End users interact with the web information system and all necessary data proposed in Chapter 2 is collected over a period until iterationt_{n+1} by the implemented monitoring system (which is composed of the algorithms and methods) proposed by this study. Upon conducting an evaluation over a period of time for iterationt_{n+1}, the product manager receives reports on the web user interface quality (WUIQ_T) which was mathematically modelled and proposed as well as developer efficiency metrics ($devM_T^N$). $devM_T^N(\mathrm{d}_{input}, \mathrm{d}_{output})$ - comprised of a pair of developer input metrics (d_{input}) and output metrics (d_{output}). Thus, developer efficiency evaluation and web UI quality assessment serve as a feedback mechanism to improve networked organizational systems considering the changes in user requirements.

To improve UI quality of web tools of networked organizational systems using, this aspect of the study focuses on adopting a non-parametric analysis method which measures efficiency of agents within a given system. One of such methods, Data Envelopment Analysis (DEA), involves applying DEA to evaluate agents' efficiency which will influence the optimization of the performance of various aspects of the user interface in the networked organizational system's web-based application. DEA is a nonparametric technique that is based on linear programming developed in the research of Charnes, Cooper & Rhodes that allows for the relative comparison of multiple decision-making units (DMUs) based on their efficiency in transforming inputs into outputs [271]. DEA improves evaluative features of mathematical programming by assessing actual events and contributes to higher management information. DEA converts a number (minimum) of input units to a maximum number of outputs when evaluating the efficiency of a required sample. In addition, DEA is capable of estimating maximum potential output with respect to a set of inputs, can been used in efficiency estimation, and can be used in capacity utilization estimate. Thus, DEA is the right technique to be adopted in the proposed model to assess developers within the organizational system [272].

With respect to this study, in the context of deploying web-based applications in networked organizational systems, these information systems are monitored primarily with respect to backend server activities such as downtime, system logs. This is because product owners are more concerned with the application performance and less focus is given to the UI (which is the interface for interacting with the system itself). The UI quality score as a feedback mechanism has the potential of improving decision making in development and improvement of the web application, the use of Data Envelopment Analysis (DEA). In DEA, the goal is to measure the relative efficiency of operating units. In this case, each expert on the DevOps team is an operating unit (or decision making unit (DMU)). The relative efficiency is dependent on input measures and an output measure (which is the quality of the UI).

Figure 3-21 illustrates a summarized overview of the series of steps undertaken to implement DEA for any given context. DEA involves the following steps: (a) input and output variables determination; (b) choosing optimization orientation (whether input minimization or output maximization); (c) weight restriction (where necessary); (d) applying the available data (cross-sectional longitudinal).

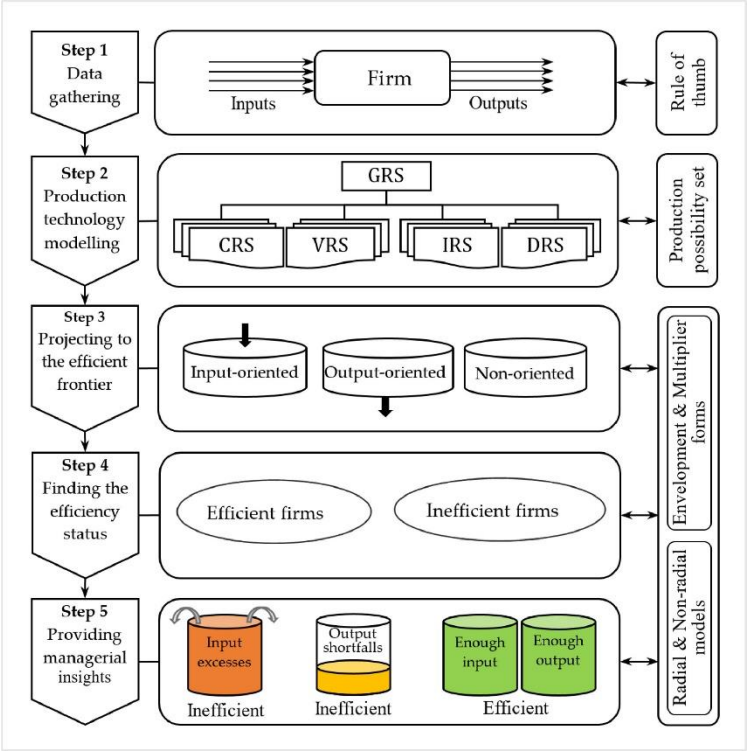


Figure 3-21 Schema of DEA Procedures (Summary) [273]

The steps can be further broken down as follows [273]:

(a) Step 1: Define the assessment structure by identifying the operating units (DMUs) and performance factors (inputs and outputs), then gather data for each DMU.

(b) Step 2: Specify the production technology and returns to scale (RTS) based on competitive levels in the markets and industries under analysis.

(c) Step 3: Determine whether to use radial or non-radial settings for efficiency and economic measurement. Radial settings include input- and output-oriented models, where the former seeks to reduce input usage while the latter aims to increase output production. These measures are equivalent under constant returns to scale (CRS) but differ under variable returns to scale (VRS).

(d) Step 4: Identify best practices and technical inefficiencies using DEA models in either multiplier or envelopment forms.

(e) Step 5: Interpret the results and findings to provide insights for decision-makers and top management, aiding strategic planning and resource allocation across the organization.

With respect to the progression of efficiency assessment, efficiency was measured as a ratio of output to input but research identified flaws in the fact that efficiency assessment must capture the concept that multiple inputs are essential in producing single or multiple outputs (as such, formula 3-7 was introduced) [274].

$$Efficiency = \frac{Output}{Input} \tag{3-6}$$

$$Efficiency = \frac{Weighted\ Sum\ of\ Output}{Weighted\ Sum\ of\ Input} \tag{3-7}$$

To ensure inputs and outputs are positively weighted values, Charnes proposed non-negativity restrictions, thus efficiency scores range between 0 and 1 [274]. Therefore, less productive units will have an efficiency score less than 100%.

Beyond Farrell's contributions to the development of the topic, multiple researchers expanded the models to its present form. The two (2) standard DEA models are known as CCR (Charnes–Cooper–Rhodes) and the BCC (Banker–Charnes–Cooper) [273]. With respect to the efficiency frontier with respect to the CCR model (under constant returns to scale), as illustrated in Figure 3-22 where the most efficient DMUs are calculated and lie on the diagonal line (the production

frontier) and other DMUs lie beneath. With respect to the BCC model (which implements Variable Return to Scale (VRS), DMU efficiency is calculated where the most efficient DMUs lie on the convex line (Figure 3-22), thus creating an efficient frontier which passes through the area of DMUs (production possibility set).

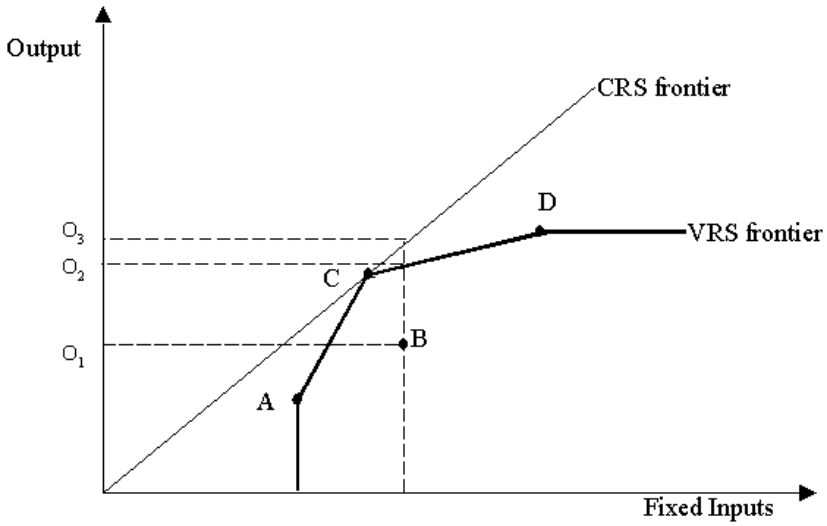


Figure 3-22 Production Frontier Plots [272]

For each frontier model, DEA can be oriented towards input-orientation or output-orientation. The input-oriented model focuses on minimizing inputs while maintaining or exceeding specified output levels. Output-oriented models aims to maximize outputs while taking into consideration no more than the observed amount of any input. The CCR and BCC models are represented respectively as follows:

$$Max\theta_0 = \sum_{j=1}^{m} u_j y_{j0}$$

Subject to:

$$\sum_{i=1}^{s} v_i x_{i0} = 1 \qquad (3\text{-}8)$$

$$\sum_{j=1}^{m} u y_{kj} - \sum_{i=1}^{s} v_i x_{i0} \leq 0$$

$$v_i \geq 0, u_j \geq 0, u_0 \; free \; in \; sign$$

$$Max\theta_0 = \sum_{j=1}^{m} u_j y_{j0} + u_0$$

Subject to

$$\sum_{i=1}^{s} v_i x_{i0} = 1 \tag{3-9}$$

$$\sum_{j=1}^{m} u y_{kj} - \sum_{i=1}^{s} v_i x_{i0} + u_0 \leq 0$$

$$v_i \geq 0, u_j \geq 0, u_0 \; free \; in \; sign$$

The impact of scale assumptions on capacity utilization is illustrated in Figure 3-22, where four (4) data points (*A*, *B*, *C*, and *D*) are used to estimate the efficient frontier and capacity utilization levels under both scale assumptions. Note that only fixed inputs are considered in the figure. Under CRS, the frontier is consistently defined by point *C*, indicating full capacity output for all points along the frontier, with others indicating capacity underutilization. In contrast, under variable returns to scale, the frontier is defined by points *A*, *C*, and *D*, with only point *B* showing capacity underutilization. Consequently, the capacity output corresponding to variable returns to scale is lower than that corresponding to constant returns to scale [272]. Capacity utilization is determined by comparing actual output to the frontier level of output. Except for point *C*, which exhibits full capacity utilization under both assumptions, capacity utilization is consistently lower (indicating more underutilization) when assuming constant returns to scale compared to variable returns to scale. Also at point *B*, the ratio of *O1/O3 is less than O1/O2*. Therefore, using a constant returns to scale frontier is likely to overestimate capacity output and underestimate capacity utilization compared to using a variable returns to scale frontier.

A subset of efficiency assessment with respect to DEA, Technical efficiency (TE), measures how well a number DMUs successfully obtaining a maximum output based on a given input. It evaluates output in relation to an efficient isoquant curve's output. Efficient DMUs (developers in the case of this study) develop at the production frontier or in quantities which are efficiently equal [272]. Figure 3-23 illustrates Farrell's depiction of efficiency based on a standard example with DMUs that have two (2) inputs (*x1* and *x2*) in obtaining an output (*y*), under the CRS

assumption. The *SS'* curve characterizes the unit isoquant of fully efficient DMUs and allows for the measurement of technical efficiency (TE).

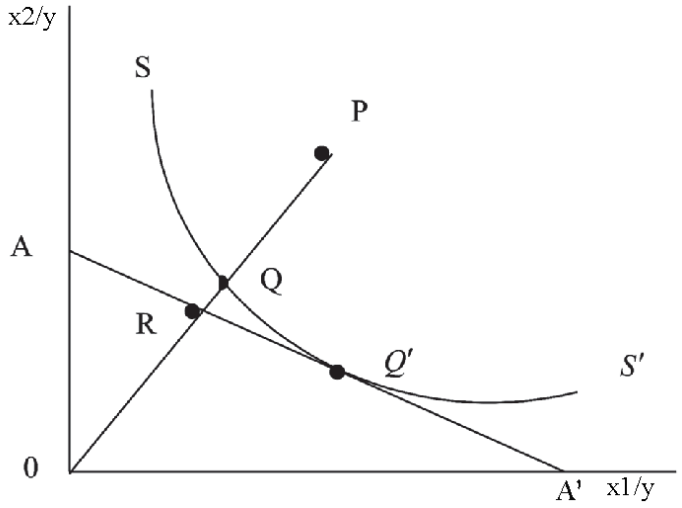


Figure 3-23 Technical Efficiency Measure (according to Farrell) [275]

When a DMU utilizes inputs quantities, depicted as point *P*, in obtaining a unit of output, then the technical inefficiency of the given DMU is denoted as the distance *QP* (i.e. the amount such that all given inputs are proportionately reducible without a decrease in the output). This is expressed percentage-wise as *QP/OP*, which is a percentage where all the inputs are optimally reducible to obtain technically efficient output/production. When measuring efficiency, Farrell provided three (3) definitions of efficiency [275]:

(a) Technical efficiency: To achieve the observed outputs with respect to the observed input quantities while maintaining the observed input ratios (*OQ/OP*), the required inputs must align with best practices. Conversely, *Technical inefficiency = 1 – OQ/OP*.

(b) Price/Allocative efficiency: The costs incurred to produce the observed output at observed factor prices, assuming technical efficiency, are compared to the minimized costs at the frontier point *Q*, relative to the output ratio; *OR/OQ*.

(c) Overall efficiency: It refers to the costs associated with producing observed output when both technical efficiency and price efficiency are assumed, relative to the observed costs.; *OR/OP = (OQ/OP) (OR/OQ)*.

Focusing on the context of this research where the goal is to improve networked organizational systems taking into consideration the changing user requirements, two (2) solutions have been proposed: (a) UI quality evaluation, and (b) efficiency

assessment of developers. The goal of these proposed methods are to serve as feedback mechanisms to improve the overall efficiency of the networked organizational system.

Figure 3-24 illustrates the model schema to be adopted for technical efficiency assessment of developers. For a networked organizational system, taking into consideration the Development team which is a set of DMUs$\{1, \dots, N\}$, who receive a set of input resources (x_i) to perform a set of control actions ($K_n^T where\ n \geq 1$, T is representative of time) on the web-based information system. Users within the networked organizational system interact with the system, and over time (T) the web user interface quality algorithm is applied as proposed by the study to measure the UI quality score ($WUIQ_T$) as feedback for system improvement. In addition, a set of measurable output metrics (y_i) with respect to development of the information system are obtained as a result of the developers' control actions (K_n^T) and user metric assessment ($WUIQ_T$). Thus, DEA is used to assess developers (as DMUs) to improve the state of the system and networked organizational system's efficiency. Thus, the goal of using DEA in this context is to adopt an output-oriented model where valuable insights will be provided as to how efficiently DMUs (i.e. developers) can translate their available resources (inputs) into desired results (outputs).

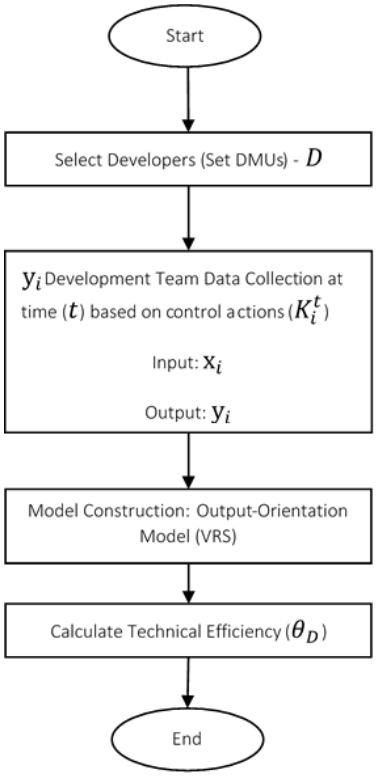


Figure 3-24 Technical Efficiency Assessment of Developers

Adopting metrics from the DevOps Research and Assessment (DORA), considering a set of developers$\{D_1, D_2, D_3, D_4, D_5\}$, with their individual input and output metrics, the following metrics are used as input and output measures and can be obtained from modern development ecosystems such as decentralized repositories which track, yet can be extended by future studies:

(a) Input Metric (x_n):

x_1 - Frequency of approved deployment.

(b) Output Metrics (y_n):

y_1 - Inverse Lead Time for Changes (LTFC)

y_2 - Inverse Change Failure Rate (CFR)

The selected metrics are further discussed in Section 3.1. While maintaining a set of fixed levels of inputs, the output-oriented approach aims to maximize outputs [272]. In the context of developers' efficiency assessment with outputs (Inverse LTFC and Inverse CFR) and input (Frequency of approved deployments), the output-oriented DEA aims to determine how efficiently developers utilize their input resources to produce the desired outputs. In addition, the proposed technical efficiency model for this context assumes Variable Returns to Scale (VRS) because it accommodates potential variations in scale efficiencies among developers.

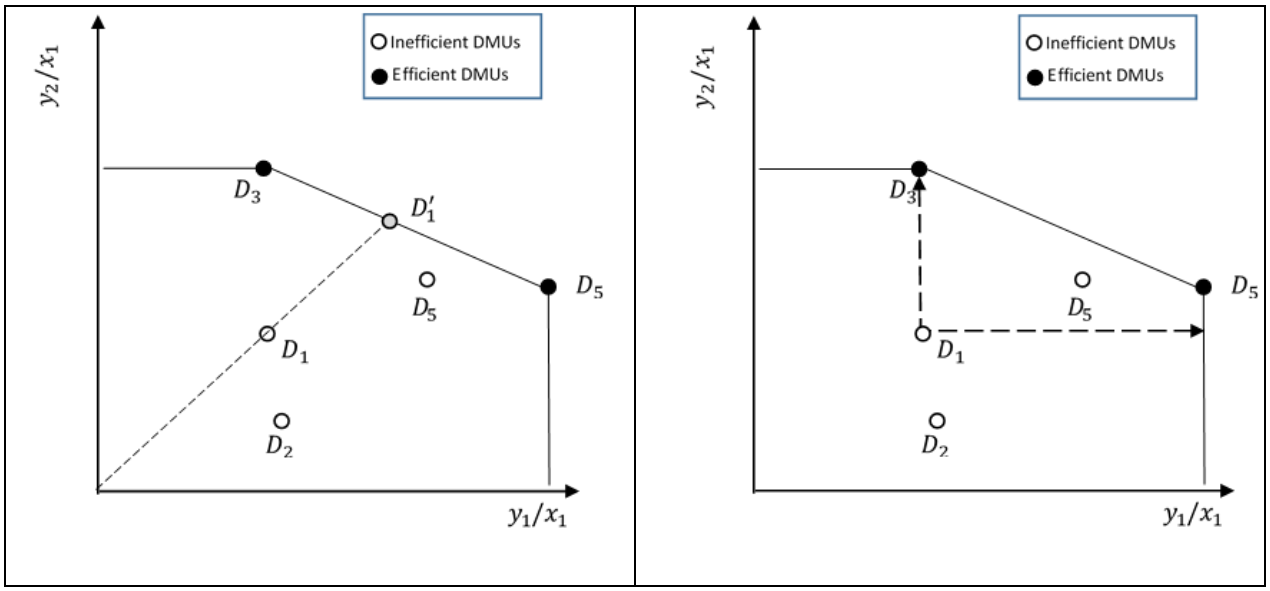


Figure 3-25 Output-Oriented DEA – Single Input with Dual Output (Left: Radial Model, Right: Slack-Based Model)

Figure 3-25 illustrates two diagrams which highlight the output-oriented DEA model to be adopted in this study. The diagram to the left highlights a dashed line which is indicative of the radial method to measure the effort to be made by developers to reach the efficiency frontier. Thus, developer D_1 can attain the efficient frontier (i.e. from D_1 to $D_1^{'}$) after increasing its output shortfall through maximizing development activities. The image on the right highlights the example of measuring the slack-value – where the horizontal arrow from the inefficient DMU $D_1$to the production frontier indicates how much of y_1 is required for D_1 to attain efficiency; in like manner, the vertical arrow from the inefficient DMU $D_1$to the production frontier indicates how much of y_2 is required for D_1 become efficient.

The study also deploys the proposed tracking of developer metrics in the software program as a feedback mechanism to improve the organizational system. Since the contribution of developers contribute to the quality of the end product, as well as receive feedback from testing and users, it is important that their metrics are taken into account. A reporting functionality has been included to keep records of each developer's performance metrics to be used in understanding the level of productivity and efficiency over time. Upon reporting the developer efficiency metrics iteratively, the panel provides the time series graph of the metrics which depict developer productivity over varying sprints (Figure 3-26).

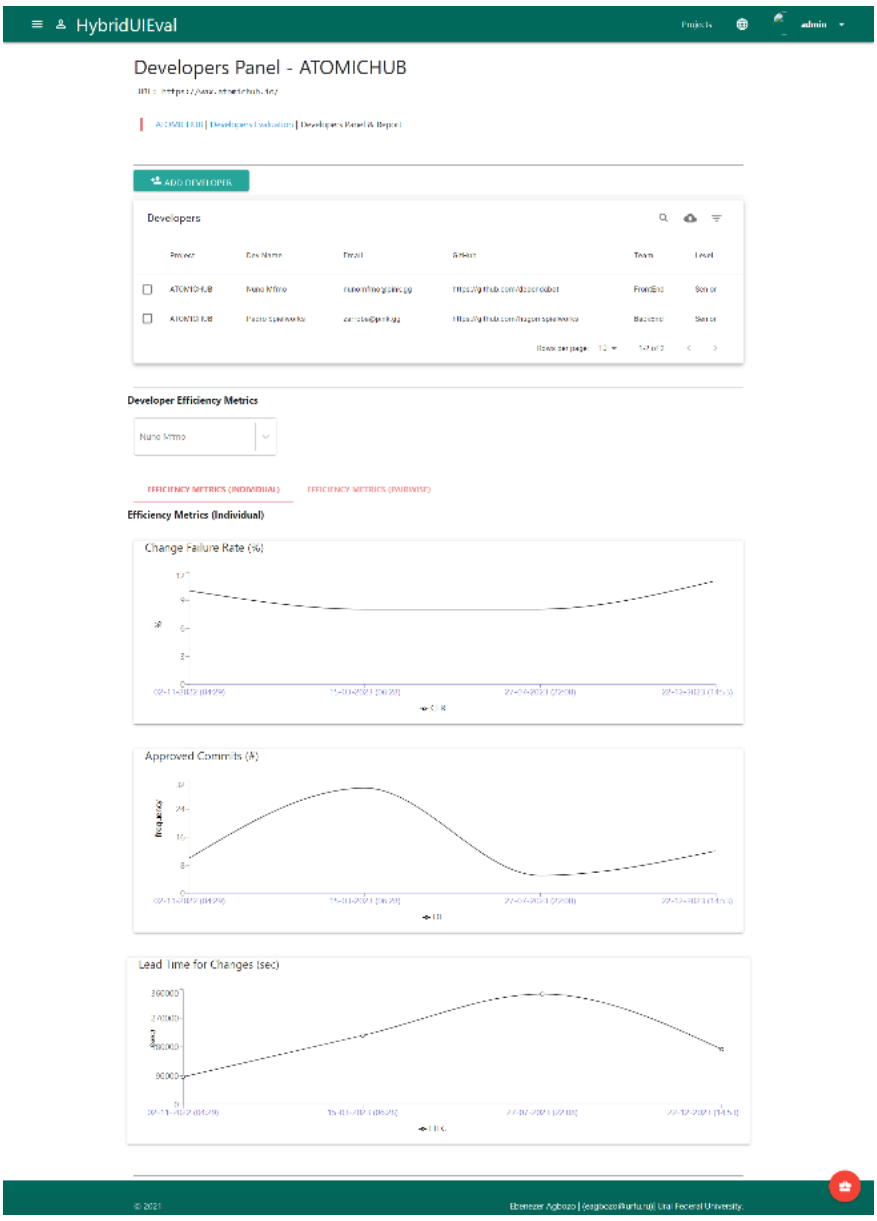


Figure 3-26 HybridUIEval – Development Team Management (Developer Efficiency Dashboards)

The results discussed in this sub-section have showcased the implemented software based on the proposed algorithms and methods from the previous chapter. It contains all components for managing a networked organizational system based on the changing user needs. These include the management of user interface evaluation, management of developers and their assessment over time. The deployed solution is scalable and in accordance with changing organizational needs.

CONCLUSION

The purpose of the dissertation work was to develop and test methodological and instrumental tools for evaluating web user interface quality for web information systems in order to support for web user interface design, development and improvement.

Despite the existence of a number of automated web UX and UI testing tools, there is a gap in the area of tracking visual changes to the interface, as such it is recommended for future studies to incorporate visual change assessment.

To summarize the results of this dissertation, the following points highlight the core achievements of this research:

1. Studied the current state of experimental research on web engineering that is focused on user-based UI testing and automated UI testing.
2. Studied and mastered the modern level of technical and software tools for obtaining and processing user-based and automated web data for evaluating the quality of UI.
3. Developed a set of modern methods for evaluating web UI quality as well as segmenting usability data to deeply understand users' preferences.
4. Developed hybrid web engineering methodological approaches for obtaining and processing user-based and automated web data for evaluating UI quality.
5. Developed methodological bases for adaptation of UI quality evaluation tools in experimental work.
6. Developed a specialized and patented information system for managing the process of web UI quality evaluations over time.

Recommendations, prospects for further development of the topic.

With respect to future development of the research, it is recommended that research focuses on integrating generative AI models in improving UI quality as well as extending the DORA metrics to include automated metric collection for improving the user experience adaptation model.

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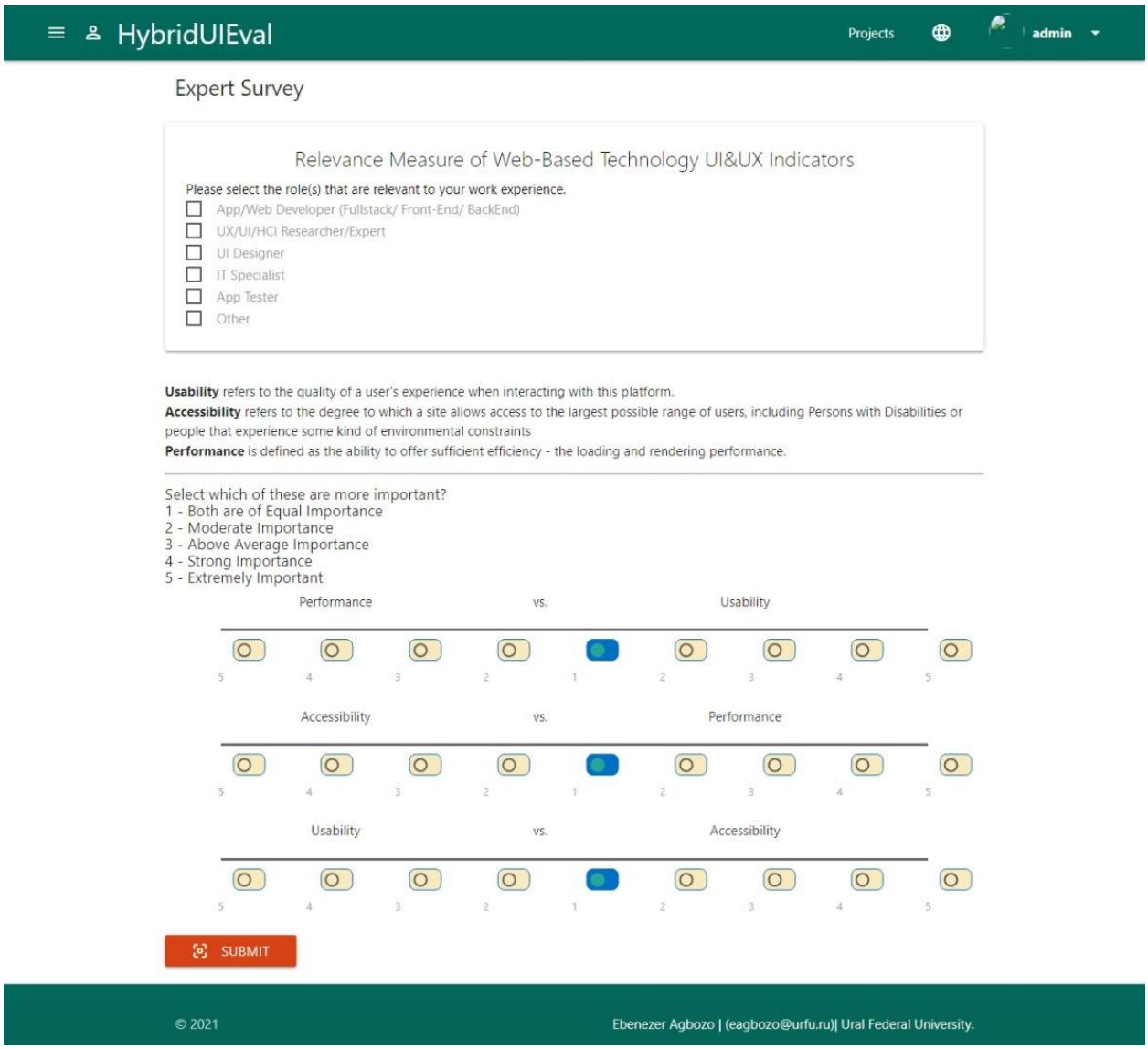
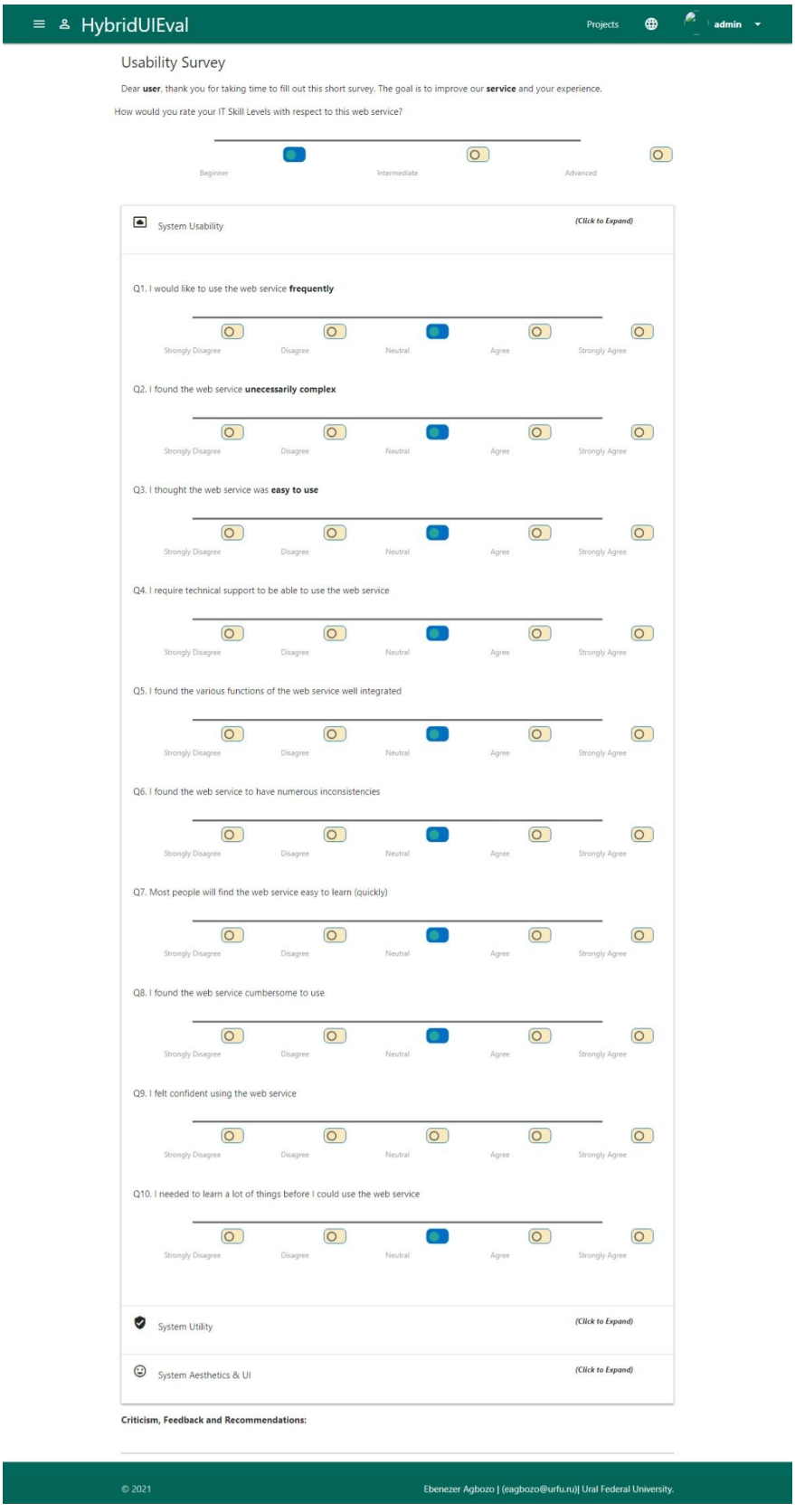
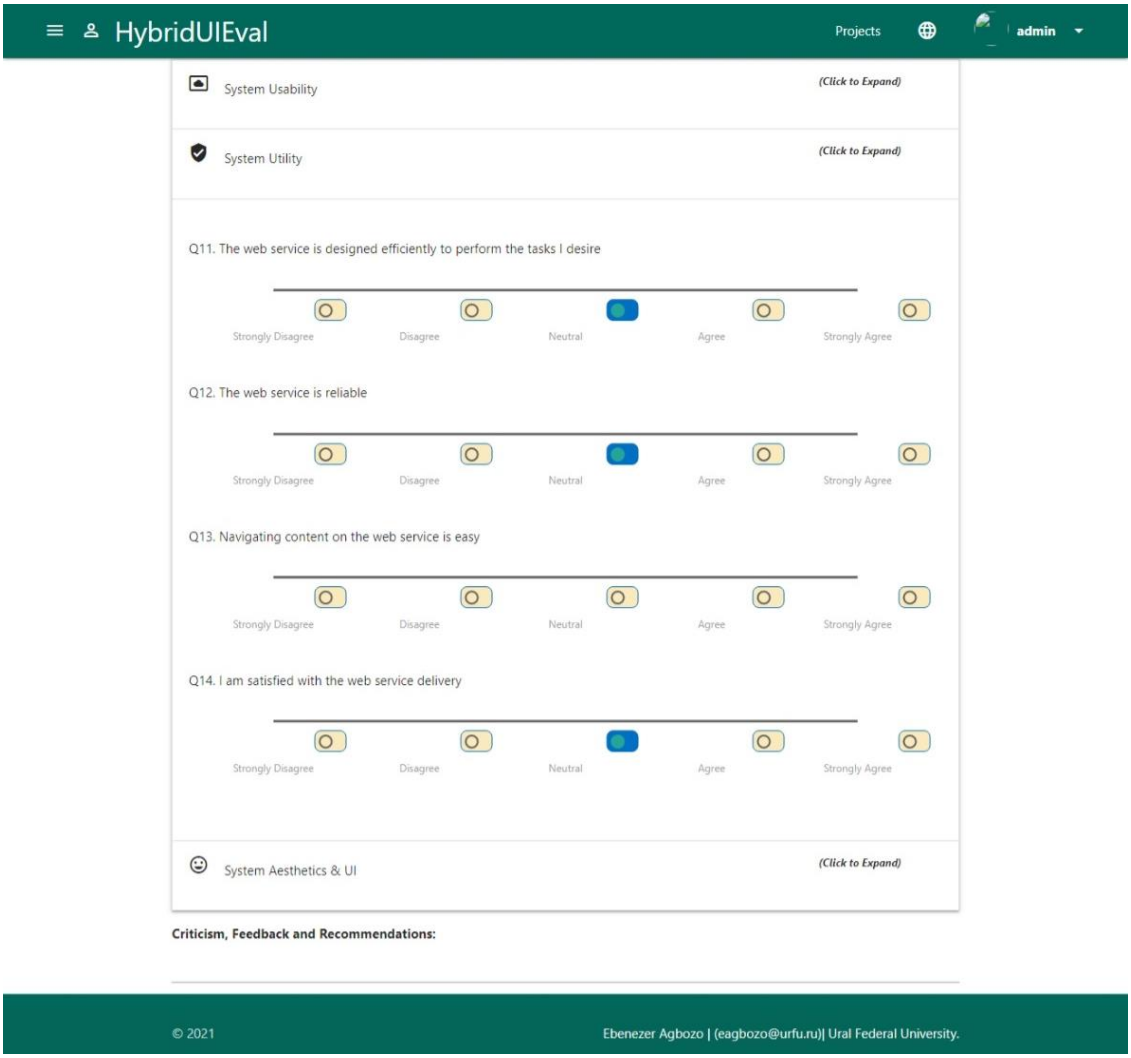
APPENDIX A. EXPERT QUESTIONNAIRE



APPENDIX B. EXTENDED USABILITY SURVEY




HybridUIEval
Projects
admin
System Usability
(Click to Expand)
System Utility
(Click to Expand)
Q11. The web service is designed efficiently to perform the tasks I desire
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Q12. The web service is reliable
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Q13. Navigating content on the web service is easy
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Q14. I am satisfied with the web service delivery
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
System Aesthetics & UI
(Click to Expand)
Criticism, Feedback and Recommendations:
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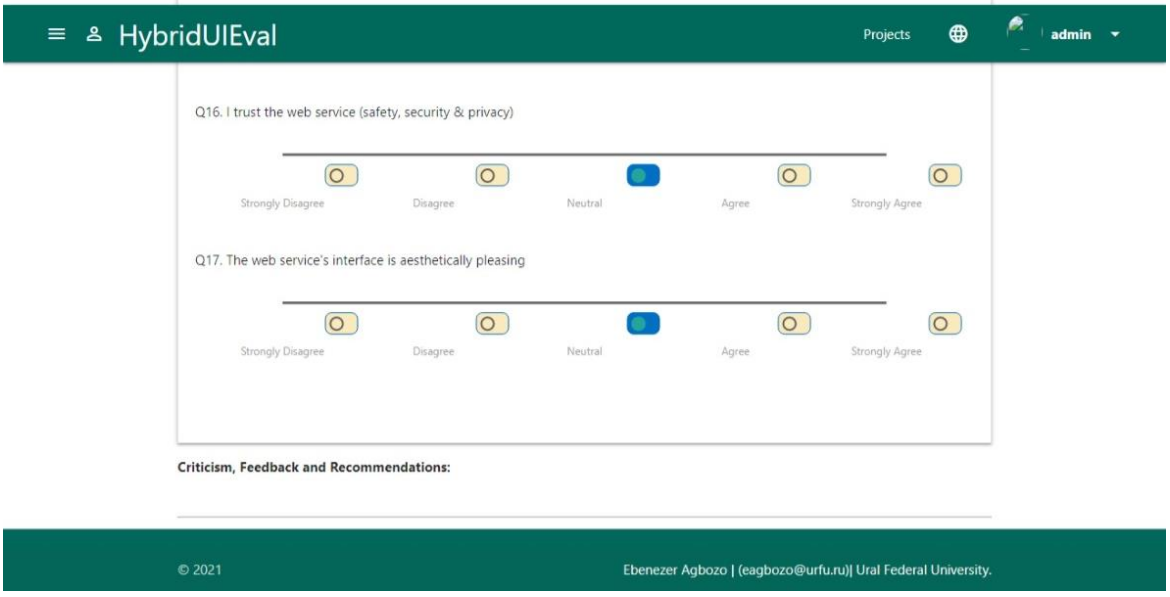
Ebenezer Agbozo | (eagbozo@urfu.ru)| Ural Federal University.


HybridUIEval
Projects
admin
Q16. I trust the web service (safety, security & privacy)
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Q17. The web service's interface is aesthetically pleasing
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Criticism, Feedback and Recommendations:
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APPENDIX C. STATE REGISTRATION CERTIFICATE OF INTELLECTUAL PROPERTY (SOFTWARE)

РОССИЙСКАЯ ФЕДЕРАЦИЯ

СВИДЕТЕЛЬСТВО

о государственной регистрации программы для ЭВМ

№ 2022617723

HybridUIEval - Система гибридной пользовательского интерфейса оценки для системах основана веб-технологий

Правообладатель: ***Федеральное государственное автономное образовательное учреждение высшего образования «Уральский федеральный университет имени первого Президента России Б.Н. Ельцина» (RU)***

Автор(ы): ***Агбозо Эбенезер (GH)***

Заявка № **2022616881**
Дата поступления **19 апреля 2022 г.**
Дата государственной регистрации
в Реестре программ для ЭВМ ***25 апреля 2022 г.***

Руководитель Федеральной службы по интеллектуальной собственности

документ подписан электронной подписью
Сертификат 6f8c80075[illegible]
Владелец Зубов Юрий Сергеевич
Действителен с [illegible] по 26.05.2023

Ю.С. Зубов

APPENDIX D. IMPLEMENTATION OF RESEARCH RESULTS

Общество с ограниченной ответственностью
"Мебельная компания "Альтерна"
(ООО "Мебельная компания "Альтерна")
620010 г. Екатеринбург, ул. Дагестанская д.41, тел.8 (343) 226-11-12
ИНН/КПП 6674311518/667901001
ОГРН 1086674025283

Акт внедрения программы для ЭВМ

1. Место внедрения:
ООО «Мебельная компания Альтерна»

2. Наименование программа для ЭВМ:
HybridUIEval, Свидетельство о государственной регистрации программы для ЭВМ № 2022617723, РОСПАТЕНТ, дата государственной регистрации 25.04.2022 г.

3. Авторы, место разработки.
Агбозо Эбенезер, старший"Аналитика больших данных и методы видеоанализа" ИРИТ-РТФ УрФУ преподаватель кафедры.
Программа для ЭВМ разработана на кафедре "Аналитика больших данных и методы видеоанализа" при подготовке кандидатской диссертации Агбозо Э. на тему " Развитие веб-инструментария управления сетевыми организационными системами с учетом его адаптации к изменяющемуся пользовательскому опыту".

4. Форма внедрения:
Представленная программа для ЭВМ использована для оценки качества пользовательского интерфейса информационной системы компании.
Получены следующие результаты.
а) сокращение времени на оценку качества пользовательского интерфейса по сравнению с применяемым в компании методом.
б) определение характеристик программного продукта, модификация которых позволит улучшить качество пользовательского интерфейса в соответствии с требованиями пользователей (экспертов).
в) визуализация и интерпретация результатов программы оценки облегчает понимание возможных путей улучшения пользовательского интерфейса и позволяет уменьшить время на принятие решения и постановку задач по доработке тестируемого программного продукта.

Оценка программы для ЭВМ HybridUIEval показала, что её внедрение в деятельность компании может повысить эффективность работы ИТ отдела по совершенствованию информационной системы компании.

Управляющий _____ ИП Черныш Алексей Николаевич

Дата: 14 мая 2024 г.

УТВЕРЖДАЮ
Директор по образовательной деятельности
ФГАОУ ВО «УрФУ имени первого Президента России Б.Н.Ельцина»

_____Князев С.Т.

«__» _____2024 г.

АКТ

о внедрении результатов диссертации Агбозо Эбенезера на тему " Развитие веб-инструментария управления сетевыми организационными системами с учетом его адаптации к изменяющемуся пользовательскому опыту"
в учебный процесс кафедры "Аналитика больших данных и методы видеоанализа" ИРИТ-РтФ УрФУ

Мы, нижеподписавшиеся, подтверждаем, что основные научные положения, выводы и рекомендации кандидатской диссертации Агбозо Эбенезера на тему " Развитие веб-инструментария управления сетевыми организационными системами с учетом его адаптации к изменяющемуся пользовательскому опыту" внедрены в учебный процесс кафедры "Аналитика больших данных и методы видеоанализа" при изучении дисциплин "Инновации в бизнесе и ИТ", "Разработка веб-приложений", "Методы принятия управленческих решений", программы магистратуры по направлению подготовки 09.04.03 Прикладная информатика.

Директор ИРИТ-РтФ УрФУ _____ Обабков И.Н.

Заместитель директора института
по развитию образовательных технологий
ИРИТ-РтФ УрФУ _____ Алферьева Т.И.