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A framework for evaluating web based Applications quality based on usability

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A framework for evaluating web based Applications quality based on usability

By

Samuel Ashagrrre

August, 2020
Bahir Dar, Ethiopia
A framework for evaluating web based Applications quality based on usability

By

Samuel Ashagre

A thesis submitted to the school of graduate studies of Bahir Dar Institute of Technology, BDU in partial fulfillment of the requirements for the degree of Masters in Software Engineering program in the Faculty of Computing

Advisor Name: Gebeyehu Belay (Dr of Eng)
Bahir Dar, Ethiopia
August, 2020

DECLARATION

I, the undersigned, declare that the thesis comprises my own work. In compliance with internationally accepted practices, I have acknowledged and refereed all materials used in this work. I understand that non-adherence to the principles of academic honesty and integrity, misrepresentation fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the University and can evoke penal action from the sources which have not been properly cited or acknowledged.

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We hereby certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Master’s of science in “Software Engineering”.

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ABSTRACT

A web application is an application that is accessed over a network connection using HTTP, rather than existing within a storage medium. Web applications are hybrid between a Web site and a standard application and provide different rich features to potentially millions of Web users simultaneously, which mere Web sites alone cannot offer. However, organizations need to develop a web application, which can achieve the quality criteria expected to be fulfilled. The main goal of the research thesis was to develop a web applications quality evaluation framework from the students’ perspective. For this purpose, we have extensively studied various literatures on existing quality evaluation models, essential success factors to identify necessary quality factors, sub factors and criteria. partial list Square-Structural equation modeling with PLS algorithm was applied to determine and evaluate the highest and lowest contributing factors for web application quality. A survey with 400 respondents has been conducted to validate the proposed framework. From the study we found out that as we can observe from the path coefficients, the path weight of positive .553 shows that learnability have a positive effect on usability, understandability at the path weight of positive .093 shows that it has positive effect on usability, user interface aesthetics at a path weight of positive .187 shows that it has a positive effect on usability, attractiveness at a path weight of positive .255 shows that it has a positive effect on usability, operability at a path weight of positive .196 shows that it has a positive effect on usability, the R-square value is 0.729, meaning that about 73% of the variance in usability is explained by the model. user satisfaction evaluation was conducted on the proposed framework tool it was found that participants were satisfied with proposed framework where mean value for positive feedback is 85.75% even if this is a good result the user interface design can be improved. the study helps to identify the important quality factors for academic web application, which makes it usable and successful. a quality evaluation framework consisting of high-level and low-level quality factors is developed. The results of the thesis can be used for designing web application with improved quality based on the usability attributes. The thesis has significance impact on the quality from usability perspectives, as the results will help academic organizations to improve their web application user’s degree of satisfaction.
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<td>retrofit design science methodology</td>
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<td>MiLE</td>
<td>Milano Lugano Evaluation Method</td>
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<td>IEEE</td>
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CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

Web applications are hybrid between a web site and a standard application and provide different rich features to potentially millions of web users simultaneously, in which web application alone cannot offer. The growing demand for use of internet is a big reason to produce and maintain high quality web-based applications. (Offutt & J, March/April, 2002) states that the world wide web was originally designed to present information to web surfers using simple sites that consisted primarily of hyper- linked text documents but modern web applications run large-scale software applications for e-commerce, information distribution, entertainment, collaborative working, surveys, and numerous other activities.

Modern web applications are very complex when they are compared with traditional software systems. Fundamentally, web-based applications are not different from other software in terms of technologies used but they still lack engineering approach for building web based applications systems. Conventional software mainly focuses on functionality of software whereas web-based applications are foremost concern with non-functional aspects i.e. quality aspects of web application. This is also one of the reasons for shifting towards non-functional or quality aspects. Web-based applications possess wide variation in quality characteristics due to limitations of applicability of the existing quality frameworks and its existing significance. Most of the web quality models and frameworks have their roots in ISO 9126 model, which is the framework, provided for software. In general, quality models should be developed keeping different perspective in mind (Nimish et al., 2015).

Web development has been done at a fast pace in recent years for wide ranges of purposes in different domains such as education, government, museum, business,
entertainment and health (Rocha, Á, 2012) (Wickset al.,2009). There are millions of web application today but a small percentage of these web application reach far above the ground level in satisfying their users’ requirements and needs. Some of the reasons contributing for this problem are related to the rapid advancement in web technologies, the easy use of web-oriented languages and the tolerance of browsers to display incorrect code. Other reasons contributing to the problem are limited experience and background of designers and developers, less time and resources allocation for web application design and development projects (Chingang et al.,2010). Despite the fact that many web applications lack the quality of satisfying their user’s needs, the reliance to use web application for different purposes such as finding information, shopping online, communicating with people or performing other different tasks has augmented. Moreover, existing web application in different domains have become application oriented and they are not just only document oriented any more (Nem02). Subsequently, there are increasing concerns and challenges about web application design, implementation and evaluation techniques (Kumaret al.,2015).

(Murugesan, 2008) stated that web development is a difficult process that must comprises of a large number of heterogeneous interacting components. an ad-hoc development approach to building complex web systems quickly leads to poorly designed web application that may cause disasters to many organizations. Progressively according to (Deshpande et al., 2002), Web Engineering is a new discipline that address challenges of the web and it is the application of systematic and quantifiable approaches to development and maintenance of web-based information systems.

Web application quality is one of the most important issues in a web-based application, as quality depends on the parameters that depend on the design of any system and now a day’s web technology has become a promising technology to design and develop complex web-based applications. However, the continuous progression and advancement in web technologies make them more powerful but the important aspects of assuring quality of such applications are still neglected.
(ISO/IEC 25010, 2011) defined that the quality of software products can be described in terms of quality characteristics. However, the direct measurement of these characteristics is not practical but it is possible to assess these characteristics based on the measurement of lower abstraction attributes of the product. We consider an attribute as a direct or indirect measurable property of a web application. In addition, we can use a quality model in order to specify such characteristics and attributes. (Kumar et al., 2015) stated that many methodologies have been defined to support the disciplined development of web applications, however these methodologies are not feasible mainly due to short time-to-market and resource constraints. So existing web applications often lack in design quality, performance and other non-functional quality attributes. In this context, stakeholders should consider which are the high level and low level attributes that influence the product quality and quality in use. Specifically, some characteristics influence product quality as those prescribed in the ISO 9126-1 standard.

According to (Hieatt, E. & Mee, R, 2002), developers of web-based applications often neglect testing of web-based applications due to market pressure and very short time-to-market, as it is considered too time-consuming and lacking a significant payoff. Unfortunately, evaluation of web application is too often neglected by many institutions and developers test systems only after they fail. In addition, according to (Murugesan et al., 2001), even if the web is playing a central role in diverse application domains such as business, education, industry, and entertainment, we need sound evaluation methods for obtaining reliable information about the sites quality. These methods should identify which attributes and characteristics should be used to obtain meaningful indicators for assuring specific evaluation goals given a user viewpoint.

(Lew et al., 2009) stated that research works determining quality for web applications requires a method and orientation beyond traditional quality models and the researcher’s addresses that many research works have pointed to usability as a key component of web application quality. (ISO 9241-11, 2018) describes usability as the extent to which a product can be used by users to accomplish specific goals with different criteria’s such as effectiveness, efficiency, and satisfaction, in a specified context of use. For conventional
or traditional software applications, usability may be a nice to have, but for web applications, it is critical due to the shifts in user expectations. There has been little focus to evaluate software usability from an end-user perspective using quantitative methods. In this research thesis, we propose a framework for web application usability evaluation from an end-user viewpoint.

In this thesis work, we present the web applications quality evaluation framework, which helps to evaluate the quality of academic web applications by considering usability attribute. According to (S. B. Shum & C. McKnight, 1997), web application usability can be studied from different perspectives and tools; therefore, in this research work, the framework is developed and evaluated from the student users' perspective. (Aamiret al., 2013) stated that amongst other quality factors like availability, functionality and portability. Though our model can be applied for assessing some aspects of web application, we focus on those that are perceived by the user (learnability, user interface aesthetics, operability, understandability, attractiveness). In this sense, we emphasize the web site factors from a student viewpoint.

1.2. Statement of the problem

(José et al., 2014) described that there are many researches which have been conducted before to evaluate and propose general models for assessing web quality such as ISO, WebQEM, SERVEQUAL, WQM etc. that exist in literature but they are difficult to apply to specific cases due to their generic nature and the need of the software industry for specific quality models capable of doing specific and specialized evaluation on individual components or application domain. In addition, due to their diverse nature and large number of reusable components, web applications make traditional measurement models less relevant, and the fields of evaluating quality of framework is not yet mature. Therefore, this work developed a tailored web applications quality evaluation framework, which is originated from the basic models of (ISO/IEC 25010, 2011) with specifically focusing on usability perspective of web applications in academic domains. In this research thesis, the (ISO/IEC IS 9126-1, 2001) model is used as a base model because it
can be concluded that the (ISO/IEC IS 9126-1, 2001) is suitable to be used in the evaluation of e-learning because it is widely used in the software engineering community and has been adapted to different domains and contexts and is easy to use and understand by its users (Rachida D & Moncef B, 2016).

amongst other quality factors like reliability, availability and security, usability is one of the most crucial factors for acceptance of any web application due to Immense user involvement so the framework considers quality of web applications from usability attribute and its sub factors in academic domain from the point of view of student users (Aamiret al., 2013). The thesis work reviewed existing quality evaluation models and frameworks and developed a comprehensive academic web applications evaluation framework that fits the context of developing countries. The framework is validated using structured equation modeling through a survey of 400 respondents consisting of students in Bahir Dar University in Ethiopia.

(Tekaet al., 2017) stated that HCI/UCD and usability methods are developed within the context of developed countries and might not fit for the developing country’s context and experience (Preeceet al., 2015). These methods need to be applied to the context and the environment. For example, according to (Preeceet al., 2015) usability heuristics methods developed by Nielsen are developed with respect to the western context and experience and adopting as they are to the developing world does not work. this research thesis proposed and evaluated a web application evaluation framework that fits the context of Ethiopia.

The main aim of the research thesis is to develop a usability based web application quality evaluation framework from the student’s perspectives. In addition, there are limited researches conducted on evaluating and proposing a quality evaluation framework for academic web applications in Ethiopia.

To achieve the objectives of the research thesis conducted the followings series of formulated research questions needs to be answered:

- What are the characteristics of existing web application quality evaluation models and frameworks?
1.3. Objectives of the study

1.3.1. Main Objective

The general objective of the research thesis conducted is to propose a usability based quality evaluation framework for web applications that provide academic services. The framework is validated using BiT E-Library web application that provides educational services in Ethiopia.

1.3.2. Specific Objectives

- To determine usability factors that influence web applications quality
- To develop a comprehensive usability based quality evaluation framework for web applications based on other web frameworks, models and literature that is suitable for use in developing countries context.
- To validate the framework developed by using partial least square structured equation modeling.

1.4. Scope

The developed web application quality evaluation framework integrates the best factors for web applications quality from usability perspective but it is commonly intended for web applications, which provide educational services. Web application usability can be studied from different perspectives and web application usability evaluation tools can be
designed based on the different perspectives therefore in this research work the framework is developed from the student’s perspective. Data was gathered on different usability quality sub-factors, it is analyzed using pls-Algorithm, and finally a design of a framework is developed for use in evaluating web applications. The scope of the developed quality evaluation framework includes evaluation of academic web applications from student userviewpoint and in this thesis research, the researcher concentrated on the quality of web application quality based on its usability characteristics.

1.5. Significance of the Study

The research thesis work conducted is important to study the evaluation frameworks for improving the quality of academic web applications from usability viewpoint. Evaluating quality of a product requires having a good evaluation framework that consists of essential quality characteristics and evaluation methods. There is no one element that determines the success of a web application, rather the success of a web application is ultimately based on the characteristics and tasks of the web application parts working together to create a web application that can be found, interact with users and provide user satisfaction.

The introduced academic web application quality model shows an approach to the measurement of web application quality helps to prevent web application quality bias due to subjective interpretations that occurs by defining web application quality requirements using a model.

Growing demand for web-applications improved the need to develop various web quality frameworks. However, most of the research being conducted is making them powerful and less focus has been provided to ensure their quality. The existing academic web application quality literature simply does not have any commonly agreed-upon standards for web application evaluation. The proposed new framework is expected to benefit developers from adopting direction on web application quality evaluation and it can be used as evaluation guide to help them identify the strengths and weaknesses. This
research thesis made an initial attempt to propose a new web application evaluation framework based on these characteristics and sub characteristics.

1.6. Organization of the Thesis

Chapter 1 introduces research Introduction, objectives, methodology, scope, significance contribution and thesis organization.

Chapter 2 introduces a widespread literature review that presents the concepts and issues regarding the quality of web application. In addition, it discusses the factors related to web quality. Furthermore, the related research that deals with the quality issues of web application are introduced. Finally, a brief literature review on web application quality is presented.

Chapter 3 presents the methodology that is used to develop the quality evaluation framework.

Chapter 4 presents the proposed conceptual framework for evaluating the quality aspects of web application.

Chapter 5 presents detailed analysis, Evaluation and discussion of the proposed framework using the case study.

Chapter 6 concludes the thesis by highlighting and summarizing the thesis research and its contributions. It also discusses future recommendations that should be done in this area.
CHAPTER TWO
LITERATURE REVIEW

2.1. Overview

The chapter commences with the identification of the determinants of web application quality systems followed by literature review targeting studies. After clear description of the existing web application models and frameworks of evaluation, the key factors of web application quality are revised and a conceptual model is presented and evaluated. The aim of this review is to summarize, analyze various research studies and identify different research gaps regarding quality from usability standards and models, usability evaluation methods and application domains of usability.

Defect management and quality attributes are the two most commonly known main approaches to software quality: But we will focus on quality attributes of web based applications. (Rocha, Á, 2012) developed Framework for a global quality evaluation of a web application, which aims to propose an abstract structure for a general quality evaluation of a web application. Suggests that the quality of software means fulfilling the needs and requirements of the user and other stakeholders. It is important that the software applications can be evaluated for every relevant quality characteristic using validated evaluation criteria.

According to (Kalpna S & Anju S, October 2017), the concept of usability emerges from the term user friendly. Software usability is the ease of use of the web application. Usability is one of the most essential software product quality attribute. (ISO/IEC IS 9126-1, 2001) describes usability as a set of attributes that bear on the effort needed. The (ISO/IEC IS 9126-1, 2001) redefines usability as the capability of the software to be understood, learned, used and liked by the user, when used under specified conditions. It shows that usability has 5 attributes: understandability, learnability, operability, attractiveness, understandability and user interface aesthetics.
Web based applications quality and performance evaluation is being performed more times than before because of the popularity of web applications. For example, (Tsao et al.,2016) evaluated the efficiency of online shopping web application while (Chou et al.,(2014))(Kaur, A & Dani, D, 2014)(Abdallah, S & Jaleel, B, 2015), (Silvestre et al.,(2015)) has evaluated different web based applications quality.

As the authors(Rim et al.,2018)stated that evaluating the quality of web sites isa key to browsing interesting sites for surfing, a web is regarded as a scientific showcase for considering an institution. In some cases, themost common strategy adopted by some approaches is to know the typeof web site to propose an interesting set of criteria. For example, a web site that provides payments transaction (Chen et al.,2013) will not be evaluated with the samecharacteristics as an academic one(Violante et al.,2015).

(Rim et al.,2018) presents a research that provide a Literature Review to identify the purposes of recent researches and determine the affected categories and it also proposes a process of extracting criteria featuring web sites from a list of studies.

2.2. The concept of web applications qualityand Evaluation

(ISO/IEC IS 9126-1, 2001) states that a quality model is the set of factors, and the relationships between the factors that provides the basis for specifying quality requirements and evaluation. ( ISO/IEC 25010, 2011) described the quality of a system as the extent to which the system satisfies the stated needs of its various stakeholders such as developers, testers and end users. The quality models categorize product quality into high-level factors, which in some cases are further subdivided into lower level factors. As stated by the authors the hierarchical decomposition provides a convenient breakdown of product quality.

According to(ISO/IEC IS 9126-1, 2001) the quality-related measurable properties or attributes of a system are called quality properties, with its associated quality measures. To arrive at measures of the quality factors or sub-factors, unless the factors or sub-factors can be directly measured, it will be necessary to identify a collection of properties that together cover the factors or sub-factors, obtain quality measures for each, and
combine them computationally to arrive at a derived quality measure corresponding to the quality factors or sub factors.

Figure 2 shows the relationship between quality characteristics and sub characteristics, and quality properties.

![Diagram of quality models](image)

**Fig 2.1: Structure used for the quality models (ISO/IEC IS 9126-1, 2001)**

According to (Lilburne et al., 2004), quality of web application could be measured from the programmers, and end-user’s perspectives. The web application quality from developers focus on code analysis, security, and etc. Whereas the users focus on usability, reliability, learnability and etc. (Michet et al., 2003) introduced a web application quality model which shows an approach to the measurement of web application quality. Finally, web application quality is prone to bias due to subjective interpretations that occurs unless it is quantified by a model, which defines web application quality requirements.

In accordance with the evaluation criteria mentioned above, this study will provide a framework for evaluating academic web application from the usability perspectives.
1.3. Web Application Quality Evaluation Methods

There are various types of evaluation methods to examine usability-related aspects of a system. According to (Macket et al., 1994), the evaluation methods can be classified into four categories. The categories are:

- Automated: - in this method usability, measures are computed by running a user specification through evaluation software.
- Empirical: - in this method, usability is assessed by testing the interface with real users.
- Formal: - this method focuses on using exact models and formulas to calculate usability measures.
- Informal: - this method is based on rules of thumb and the general skill, knowledge and experience of the evaluators.

(R. Benbunan-Fich, 2001) on the other hand, categorized usability evaluation methods into four categories as:

- Objective performance: - measures the capability of the visitors using the web application in terms of time taken to complete specific tasks through the system.
- Subjective user preferences: -measures the users’ preferences to the system by asking them to elicit their opinions or use a questionnaire for rating the system.
- Experimental: -based on controlled experiments to test hypotheses about design and their impact on user performance and preferences.
- Direct observation: -inspect and monitor the users’ behavior while they are interacting with the system to detect usability problems.

According to (Murugesan, 2008), the development of a web system is a continuous process with an iterative life cycle of analysis, design, implementation, and testing. In addition to this measurements (Hasan, L, 2009), categorized the assessment pattern into user, evaluator, and tool-based UEMs. By extending Hasan, L, 2009) work, we have proposed the following taxonomy of evaluation method:
2.3.1 Web application Evaluation Methods

Web application evaluation methods measure a limited number of web application, manually or automatically, based on assigned criteria to achieve a high-quality web application.

2.3.1.1. User-based Usability Evaluation Methods

(Folmer, E. & Bosch, J, 2004) stated that the whole process of design for usability, user testing, and redesign is called user centered design and it is used to describe the entire test, including planning and conducting the evaluation and presenting the results in addition(Hasan, L, 2009) stated that user evaluation approach includes a set of methods that requires users to perform some tasks on a selected system. The most widely used and useful method in this category is user testing. (Lárusdóttir, M. K, 2009) stated that the goal of a usability evaluation as measure of the usability of the system and identify usability problems that can lead to user confusion, errors, or dissatisfaction.

2.3.1.1.1 User Testing

(Stone et al., 2005) stated that when users use a system, they work towards accomplishing specific goals in their minds. Which is an abstract end result indicating what is to be achieved, and it can be attained in numerous ways.

2.3.1.1.2 The Think-aloud Method

(Lárusdóttir, M. K, 2009) and (Nielsen, J, 1993) regard thinking aloud as the single most valuable usability evaluation method, and Basically, this method involves an end user using the system while thinking out loud. The strength of this method depends in the wealth of collected qualitative data that can be obtained from a small number of users. However, to some extent, thinking aloud may give an incorrect impression of the actual
cause of usability problems if too much weight is given to the users’ justifications (Nielsen, J, 1993).

2.3.1.2. Evaluator-based Usability Evaluation Methods

According to (Lárusdóttir, M. K, 2009), Evaluators inspect the interface and assess system usability using interface guidelines, design standards, users’ tasks, or their own knowledge, depending on the method, to find possible user problems. States that inspectors can be usability specialists or designers and engineers with special expertise. (Hasan, L, 2009) grouped many inspection methods in this category, such as cognitive walkthrough, guideline reviews, standard inspection, and heuristic evaluation.

2.3.1.2.1 Heuristic Evaluation

Many evaluators evaluate the application and decide whether it meets a list of usability principles or heuristics. (Hasan, L, 2009) stated that heuristic evaluation is a very efficient usability engineering method, and it is valuable when time and resources are scarce. There are two sets of guidelines that are widely used in heuristic evaluation, (Nielsen, J, 1993) heuristics and followed by (Lárusdóttir, M. K, 2009).

In principle, heuristic evaluation can be conducted by only one evaluator, who can find 35% of total usability problems (Nielsen, J, 1993) but another view by (Mat06) believes that better results are obtained by having five evaluators and certainly not fewer than three for reasonable results.

2.3.1.3. Automatic web application Evaluation Tools

Automatic evaluation tools are software that automates the collection of interface usage data and identify problems. The first study of automatic tools was conducted by (Ivory et al., 2002), who concluded that more research was needed to validate the embedded guidelines and to make the tools usable. However, the web developers and experts cannot
only depend on the tools alone to improve web applications. (Brajnik, G, 2004) listed several web-testing tools such as Bobby, LIFT, TOPAZ, WebCPO, and WebTango.

2.3.2. Web Evaluation Methods (WEMs)

2.3.2.1. Web Analytics Tools

(Fang, W, 2007) defined web analytics as the measurement, collection, analysis and reporting of data for the purpose of optimizing web usage. Web analytics tools calculate statistics about the detailed use of a site. (Hasan, L, 2009) stated that the data collection methods for web analytics are server-based log files and client-based page-tagging. The most widely used web analytics tools are google analytics and alexa.

(Micali, F & Cimino, S, 2008) stated that software quality evaluation was given high emphasis than quality evaluation of web application and web applications. Recently however, there have been significant developments in web engineering. Based on the basic software quality evaluation models. In this section, some of the existing related web application quality models are discussed.

2.4. Generic Web Quality Evaluation Models and Frameworks

(José et al., 2014) stated that the basic models are hierarchical in structure and can be adapted to any type of software product and are oriented to the evaluation and improvement. Some of the most important are models are (ISO 9126, 1991) and (ISO/IEC 25010, 2011) whereas tailored quality models began to appear the year 2001. According to (José et al., 2014), the main characteristic of tailored quality models is that they are specific to a particular domain of application and the importance of features may be variable in relation to a general model. The tailored models are developed from the basic or generic models, especially the (ISO/IEC IS 9126-1, 2001) and (ISO/IEC 25010, 2011), with modification of high level and low level characteristics and the goal to meet needs of specific domains or specialized applications.
Figure 2.2 shows the evolution of quality models and their category into: The basic models whose objective is the total and comprehensive product evaluation and the tailored quality models whose objective is oriented to evaluations of components.

2.4.1. Web -QEM
The quality characteristics in this model are based on the (ISO/IEC IS 9126-1, 2001) model and therefore its characteristics include usability, reliability, efficiency and functionality (Mendes, E & Mosley, N, 2006).
This model gives a domain specific approach and a step-by-step procedure to accomplish the evaluation of the chosen web application. Further, the model provides the method that should be used in each of the steps, as shown in figure above. It uses the Logic Scoring Preference (LSP) method. LSP is a method used to quantitatively measure attributes of a product through logic scoring (Yip et al., 2005). Although users and customers participate at the earlier stages of the assessment to help the identification user requirements, the rest of the evaluation process engages only experts.

2.4.2 ISO 9126-1 quality standard model

The quality of software products can be described in terms of quality characteristics as defined in the (ISO/IEC IS 9126-1, 2001) standard. (Komiyama Toshihiro, 2011) expounds on the (ISO/IEC IS 9126-1, 2001) where quality is defined as the totality of characteristics of an entity that bear on its ability to satisfy stated needs. However, the
state of the art in software measurement states that the direct measurement of these characteristics is not practical.

Despite the (ISO/IEC IS 9126-1, 2001) standard being initially developed to evaluate quality in software engineering, several researchers have cited that it is also widely used in the evaluation of web applications. Here a web application is treated same way as a software. The (ISO/IEC IS 9126-1, 2001) series of standards address software quality from product perspective through its four parts. Part one of this model was revised to specify a quality model that distinguishes three different approaches to software quality: internal quality, external quality, and quality in use. Internal quality attributes refer to the system properties that can be assessed without executing, while external refers to the system properties that can be assessed by observing during its execution they are experienced by users. Internal quality is defined as the totality of a product that determine its ability to satisfy stated and implied needs when used under specified condition (Mendes, 2006).

Fig 2.4. Quality in the lifecycle ISO 9126 (ISO/IEC IS 9126-1, 2001)
2.4.4. ISO/IEC 25010 Model

(ISO/IEC 25010, 2011) stated that this model is part of International Standard’s Systems and software Quality Requirements and Evaluation framework. It is a revision of the ISO/IEC9126 which is withdrawn set of standards that defined a quality in use model, External quality model, and Internal quality model. The three models attempted to define quality models from different stakeholder perspectives and allow both top-down and
bottom-up evaluation of software system. ISO/IEC 25010 contains all of the characteristics of ISO 9126 and adds two new characteristics (ISO/IEC 25010, 2011).

According to (ISO/IEC 25010, 2011) the model composed of two quality models, the quality in use model and the product quality model. The models contain five, eight factors respectively with some of the factors further divided into sub-factors, and the quality models can serve as a framework that endeavors to cover all factors of quality from all of the stakeholder perspectives for the system in question.

2.4.4.1. Quality in Use Model

(ISO/IEC 25010, 2011) described quality in use as the degree to which a product of system can be used by specific end-users to achieve their needs. The model is much concerned with the end user perspective, which allows for a quality measurement from a bottom-up perspective.

Figure 2.7 shows the quality in use model broken down by characteristic and including the sub-characteristics.

![Fig 2.7: quality in use model (ISO/IEC 25010, 2011)]
2.4.4.2. Product Quality Model

The product quality model focuses on the software product and the computer the software resides on in contrast to the quality in use model, which targets the humancomputer system. The product quality model is comprised of 8 characteristics with their respective sub-characteristics (ISO/IEC 25010, 2011).

Figure 3 shows the characteristics and subcharacteristics of the product quality model.

According to (ISO/IEC 25010, 2011) the product quality characteristics influence quality in use characteristics and can be used as predictive measures for quality in use metrics for differing stakeholders. For example, functional stability influences quality in use from the primary user’s perspective and maintainability influences quality in use for maintenance tasks. The product quality model focuses on the target computer system that includes the
target software product and the quality in use model focuses on the whole system that includes the target computer system and software product.

2.4.5. Multi Criteria Based Fuzzy Model for Website Evaluation

(Neha Chaudhary & O.P. Sangwan, 2015) stated that the evaluation of web application has significant role to gain competitive advantage in the market and to improve overall quality of software. In this paper, the authors have considered usability and structural complexity as a metrics for the evaluation of web application.
In this paper the authors have proposed a web application evaluation framework using fuzzy logic. They have identified five attributes and they are used for the evaluation of any web application. During this research a tool is developed in php.net to collect value of few parameters. For user satisfaction the authors have conducted survey with students. The authors have provided the students questionnaires and ask for their feedback on the basis of their feedback usability is computed. Finally, the authors have proposed a fuzzy model and evaluate that with different web applications.

Fig 2.10: Web Evaluation Framework (Neha Chaudhary & O.P. Sangwan, 2015)

2.4.6. UNSCALE: Multi-criteria Usability Evaluation Framework for Library Websites in a Fuzzy Environment

(Kokila et al., 2018) states that the assessment of web usability is a viable and an appropriate tool to ensure the quality of services provided by the websites and hence has attracted the focus of website owners. This paper presents library website usability evaluation framework called UNSCALE, which is developed around the blending of fuzzy AHP and extensive evaluation technique. The use of this fuzzy extensive evaluation technique to assess the web usability not only produces an overall website usability score, but will additionally mirror scores related to each of the evaluation dimensions. Hence it will facilitate the website owners to gather information regarding the improvement requirements to upgrade the usability status.
2.5. Related Works

Web application quality is one of the major issues while designing a web-based application, as quality is directly related to parameters that directly deal with the design of any system. Today web technology has become a promising technology to design and build complex web-based applications. Modern web applications are full-fledged, complex software systems. Now that most of us rely on web-based systems and applications, so reliability, performance and maintainability are the key issues. Several methodologies have been defined to support the disciplined development of web applications, but these methodologies are not feasible mainly due to short time-to-market and resource constraints. As a consequence, existing web applications often lack in design quality. Also companies increasingly invest and rely on web services; the importance of metrics for those services continues to grow. This means that software faults in web applications have potentially disastrous consequences. Most of the efforts on web applications have been on making them more usable and reliable, but relatively little work has been done to ensure their quality.
(Kelemework, W & Ali, A, 2017) developed and evaluated the applicability of the USE (Usefulness (Usability), Satisfaction, Ease of use, and Ease of learning) model for Ethiopian Universities’ website context. The researchers evaluated the model using PLS-SEM method with PLS-Algorithm. The researchers study uses three university web sites to test the model. The researchers have found that usability is influenced by the proposed usability factors. The authors have found that usability is influenced by user satisfaction, ease of use, and ease of learning by 53.1%, 20.1%, and 6.1% and also user satisfaction is the major factor that have a big influence on web site usability and the USE model is convenient to study web site usability.

Figure: 2.12: USE (Usefulness (Usability), Satisfaction, Ease of use, and Ease of learning) model (Kelemework, W & Ali, A, 2017)

(Anusha & N. Rama, 2016) constructed a new website quality and usability evaluation framework after a detailed study of various related software and website quality models. They used ISO 9126-1 model as a base model for the construction of the framework and the model was validated by applying it on a case study online shopping website. The
authors used structural equation modeling with pls-algorithm to determine the subjective measures with the highest and lowest contributing factors for website quality and usability. The authors conducted a survey with 200 respondents to validate the proposed model. The authors work has identified the important quality factors of the case study website Flipkart that makes it usable and successful.

Fig 2.13. The proposed website quality and usability evaluation framework (Anusha & N. Rama, 2016)

(Nur Sukinah Aziz & Adzhar Kamaludin, 2014) has investigated the connection among the attributes for website usability. Most of the hypotheses are supported in this study. However, the attribute of effectiveness and the path between accessibility and perceived
usefulness were not significant. This may be explained by assuming that the users feel that there are not relevant to them to use the website based on the answer in questionnaire. User satisfaction is also found to be significant in affecting user’s intention to use. The research paper analyzes the attributes that give some influence to the website usability.

Fig 2.14. Research model (Nur Sukinah Aziz & Adzhar Kamaludin, 2014)

2.6. Limitations of Existing Web Evaluation Methods

In order to propose a new academic web application quality evaluation framework effectively, some limitation has to be considered based on the existing web application evaluation models and frameworks. Most of the quality models listed and explained in the existing models share common drawbacks that using these models for quality
evaluation of web application does not seem to be reasonable. Some of the problems can be summarized as listed below:

- Most of the existing frameworks introduce general high level attributes lacking justification that describe which factors to determine for evaluating a particular software in a specific domain.
- Lack of basic principle for deciding which specific quality characteristic relate to which high level quality criteria.
- It does not show clearly how the sub characteristics are composed for the overall assessment of the web application and the method that should be used to measure the general quality assessment.
- Anusha (2014) clearly states that a web application evaluation method should evaluate a web application quality based on its specific domains such as e-health, education, agriculture, etc. The author states that it is important to create a comprehensive web application evaluation method that is applicable to the specific domain.
- One of the major drawbacks of the ISO 9126 model according to (Djouab, R, 2012) is its generality; due to this, the model does not describe the business manager needs, the traceability of the software and the consistence of the data are not represented in the model and the model also does not include measurements methods (Rachida, 2016).

2.7. Summary

Evaluating quality of a product requires having a good evaluation framework that consists of essential quality characteristics and evaluation methods. The existing software quality models and web application quality models as discussed in the previous section, in one way or another consist of similar characteristics, although some of the models focus on a particular property of a product and while few others present some very broad and high level quality characteristics that are vague and difficult to measure.
Table 2.1: Common high level quality characteristics of software & web application Quality models

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<tr>
<th>High level quality characteristics</th>
<th>web Quality models</th>
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<td>W-QEM I</td>
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<td>Functionality</td>
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<td>Efficiency</td>
<td>✓</td>
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<td>Usability</td>
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<td>Performance</td>
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<td>Reliability</td>
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<td>Portability</td>
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<td>Content</td>
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<td>Feasibility</td>
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<td>Maintainability</td>
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<td>Modifiability</td>
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<td>Testability</td>
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<td>Understandability</td>
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<td>Integrity</td>
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<td>Flexibility</td>
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<td>Navigation</td>
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<td>Presentation</td>
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CHAPTER THREE
RESEARCH METHODOLOGY

3.1. Overview

In this section, the methodologies used in the research thesis are presented. The basic research processes include problem discovery, problem definition, research method selection, sample design, data collection, data encoding, data processing and analysis, result interpretation and reporting. The research design adopted, the target population, description of the sample and sampling techniques, instruments, and data collection instruments and data analysis procedures are discussed.

3.2 Research Design and Approach

To fulfill the aims of this research, design science research methodology was adopted as research methodology because design science, as conceptualized by (Simon, H, 1996), supports a pragmatic research paradigm that calls for the creation of innovative artifacts to solve real-world problems and its ultimate aim is to solve a problem by creating an artifact. Thus, DSR combines a focus on the information technology artifact with a high priority on relevance in the application domain. Design science research methodology is used to define the stages of this research and it includes six steps: problem identification and motivation, definition of the objectives for a solution, design and development, demonstration, evaluation, and communication (Pefferset al.,2008). The final output of a design science research can be categorized as; constructs models, methods, instantiations and better theories.

The design science research paradigm is highly relevant to Information technology and Information System research because it directly addresses two of the key issues of the discipline which are the central, though controversial, role of the IT artifact in IS research((Weber, R., 1997);(Orlikowski, W & C. Iacono, 2001)) and the perceived lack of professional relevance of IS research (Hirschheim, R & H. Klein, 2003).
The research activities of DSR within the Information System discipline are described via a conceptual framework for understanding information systems research and a clear set of guidelines are presented for conducting good design science research (see Table 3.1). A detailed discussion of each of the 7 guidelines is presented in the 2004 *MISQ* paper (Hevner et al., 2004).

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Description</th>
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<tbody>
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<td>Guideline 1: Design as an Artifact</td>
<td>Design science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation</td>
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<tr>
<td>Guideline 2: Problem relevance</td>
<td>The objective of design science research is to develop technology-based solutions to important and relevant business problems</td>
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<tr>
<td>Guideline 3: Design evaluation</td>
<td>The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods</td>
</tr>
<tr>
<td>Guideline 4: Research contributions</td>
<td>Effective design science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies</td>
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<tr>
<td>Guideline 5: Research rigor</td>
<td>Design science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact</td>
</tr>
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<td>Guideline 6: Design as a search process</td>
<td>The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment</td>
</tr>
<tr>
<td>Guideline 7: Communication of research</td>
<td>Design science research must be presented effectively to both technology-oriented and management-oriented audiences</td>
</tr>
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Fig 3.1: Design science research guidelines (A. Hevner, S. March, J. Park, & S. Ram, 2004)

In this research thesis different previous Literatures have been reviewed to understand the state of the problem (problem identification), the objectives of a solution have identified(Objectives), the design of web application framework have explicated(Design), the use of the framework was demonstrated in academic web applications
We designed a questionnaire to gather the data for the study based on the research parameters obtained. The questionnaires were designed to collect information from student users. The questionnaire had open and closed ended items. The proposed data collection instrument for this research was a design Likert scale that allowed the researcher to assign numbers 1-5 to collect both qualitative and quantitative data about quality of web application from the sample population. The respondents for the questionnaire were current BSC students at Bahir Dar University. The rationale behind using students for the case study is because of the fact that the new framework proposed focuses on the perspectives of student users. In a typical usability study, a minimum of 30 participants is required as cited in many usability analyses related works. To conduct the evaluation case study, samples of 400 students studying in the university were chosen. It was conducted to assess the quality requirements that the users expect from the web app and to evaluate the framework. Evaluating the quality of the web app from student user perspective helps to recommend web application quality improvement efforts.

The developed web application quality evaluation framework integrates the best factors for web applications quality from usability perspective but it is commonly intended for web applications, which provide educational services. Data was gathered on different usability quality sub-factors, it is analyzed using pls-Algorithm, and finally a design of a framework is developed for use in evaluating web applications. The scope of application of the developed quality evaluation framework includes evaluation of academic web applications from student perspectives.

According to (Burns, S., & Groove, T, 2005), quantitative research is conducted to describe, examine and determine relationships among the variables. This study adopted descriptive design which was the most suitable design because it is more accurate in collecting information on different aspects of web application quality factors from student users and the design was used in collecting quantitative responses from the respondents.
in order to evaluate the extent to which some quality aspects of an academic web application were relevant.

This research thesis work seeks to produce a framework, model and better theory. Many scientists have presented various design science research models (Hevner et al., 2004), (J. Nunamaker & M. Chen, 1990), (Peffers et al., 2008). This paper adapted the model presented in (Peffers et al., 2008) as seen in fig. 1, below.

![Diagram of Design Science Research Methodology](image)

**Fig 3.2. Design science research (K. Peffers et al, 2008)**

Design science research methodology is used to define the stages of this research and it includes six steps: problem identification and motivation, definition of the objectives for
a solution, design and development, demonstration, evaluation, and communication (K. Peffers et al, 2008).

3.2.1 Problem identification and motivation

Evaluating quality of a web application in general requires a set of quality factors that describe what is expected from the sites characteristics and the set of the characteristics and the relationship between them form a quality evaluation model. In order to be able to evaluate the quality of web application, it is necessary to study which quality factors to take into account while evaluating the quality of a web application. In addition, the diverse nature of web applications and very short time to-market makes it difficult to measure these existing quality frameworks.

(Dittrich, 2016) stated that studying the social and cultural practices that could influence software development and use can benefit the effort towards improving usability as method is practice pattern so this work developed a comprehensive academic web applications evaluation framework that fits the context of Ethiopia as Ethiopia is a multi-ethnic society, Cultural diversity and heterogeneity is another constraint to usability evaluation.

According to(José et al., 2014), general models for assessing web quality are difficult to apply to specific cases due to their generic nature and the need of organizations and the software industry for specific quality models capable of doing specialized evaluation on individual components. Therefore, this work developed a usability based web applications quality evaluation framework, which is originated from the basic models of (ISO/IEC 25010, 2011) and (ISO/IEC IS 9126-1, 2001). The thesis work reviewed existing quality evaluation models and frameworks and developed a web application evaluation framework that fits the context of developing countries.

3.2.2. Define the objectives for a solution
The general objective of the research thesis conducted is to develop a usability based quality evaluation framework for web applications that provide academic services. The web application evaluation framework provides a mechanism for evaluating the quality of academic applications with respect to their usability. The framework is validated using BiT web application that provides educational services in Ethiopia. To achieve the above stated objective, data were gathered from 400 Bahir Dar university students using questionnaire. From different data collection method, questionnaire survey was used because of its lower cost and time. Questions were prepared for each usability sub factors using (ISO/IEC IS 9126-1, 2001) and (ISO/IEC 25010, 2011) as a base model.

3.2.3. Design and development

The artifact is the web application evaluation framework that improves the quality of academic web applications from usability perspective. The researcher selects best usability sub factors from (ISO/IEC IS 9126-1, 2001) and (ISO/IEC 25010, 2011) models.

3.2.4. Demonstration

Using the quality factors in the proposed framework, a small survey was conducted on the case study web application to test the designed evaluation framework and at the same time to evaluate the quality of the web application from current students’ perspective. The questionnaire was developed and administered to current Bachelor students of the university. The questionnaire enabled to explore the opinions of the students in using the Bahir Dar university E-Library web application and assess the effectiveness of the evaluation framework designed.

3.2.5. Evaluation

Using the quality factors in the proposed framework, a small survey was conducted on the case study web application to test the designed evaluation framework and at the same time to evaluate the quality of the web application from current students’ perspective.
The questionnaire was developed and administered to current Bachelor students of the university. The questionnaire enabled to explore the opinions of the students in using the bahir dar university E-Library web application and assess the effectiveness of the evaluation framework designed.

The aim of conducting the case study was to show how effective the proposed evaluation framework is good in evaluating the case study academic web application, an emphasis was given to the questions designed to address the new quality factors. The high-level quality factors and their sub quality factors in the new quality evaluation Framework and their subsequent questions designed to address the properties of each factor is proposed. We designed a questionnaire to be used to gather data for the study based on the research parameters. The questionnaires designed were used to solicit information on the sample population. The questionnaire allowed measuring of a set of requirements that contribute to the quality of a web application given a set of predefined parameters. The questionnaires were chosen because they collect a lot of information over a very short period of time, are cost effective and the data collected are easy to analyze.

3.2.5.1. Structural Equation Modeling

According to (Chin W.W, 1998), SEM is used to describe a large number of models used to evaluate the validity of substantive theories with empirical data. In IS research the PLS model is being used for research in recent years, because of its ability to model latent constructs under non-normality with small to medium sample size and the major goal is to determine if a theoretical model is consistent with the data collected to reflect the theory or not so the consistency of the model is evaluated through model-data fit.

3.2.6. Communication

According to Nguyen (2020) the usefulness of scientific knowledge is limited if that knowledge is not communicated to other people. This research thesis submitted to the faculty as partial fulfillment of MSc degree in Software Engineering and defended. The contributions of this effort will be disseminated in peer reviewed scholarly publications.
and university weekly seminars. The findings and recommendations of the developed framework is also placed in the university research repository so that other researchers, practitioners may use the best practices those recommended by the study for their future use. Further, the framework was used to evaluate the academic web applications in a subsequent case study to improve their applications quality from usability perspective.

CHAPTER FOUR
FRAMEWORK DESIGN AND DEVELOPMENT

4.1. Overview
The artifact is the usability based academic web application quality evaluation framework that improves the usability of academic organizations web applications from the users point of view. In order to design the new evaluation framework, a careful study on key quality factors for web applications, previous related works in academic web application evaluation and the quality factors in the reviewed web application models was made to identify necessary high-level quality characteristics, sub characteristics and criteria. The framework is proposed by using (ISO/IEC IS 9126-1, 2001) as a base model. The high-level quality factor in the proposed framework is usability that is part of the (ISO/IEC IS 9126-1, 2001) quality model. The Framework first outlines necessary high quality characteristics, which are further classified into sub characteristics and criteria. According to (Philip et al., 2012), One of the first steps in evaluation is to define non-functional requirements, usually, by means of quality models. Quality models categorize product or system-in-use quality into characteristics that are further subdivided into sub-characteristics and quality attributes.

According to (ISO/IEC IS 9126-1, 2001), a quality model is the set of factors, and the relationships between them that provides the basis for specifying quality requirements and evaluation.

4.2. Quality factors

The success of a web application is determined by several factors. There is no one element that determines the success of a web application, rather the success of a web application is ultimately based on the characteristics and tasks of the web application parts working together to create a web application that can be found, interact with users and provide user satisfaction. There are several research works on web application success, each highlighting different factors necessary to build a successful web application. (J.Cox & B.G.Dale, 2002), claim that the following factors highly influence the success of a web application: clarity of web application purpose, design, accessibility and speed, content, customer service and customer relationship.
The developed quality evaluation framework considered the following quality characteristics and sub-characteristics. It includes usability as a quality factor and sub-quality factors consists of learnability, User Interface aesthetics, Attractiveness, Understandability and operability.

![Diagram of Quality Factors]

**Fig 4.1. The study Framework Quality Factors**

### 4.2.1. Usability

(ISO 9241-11, 2018) described usability as the extent to which a product can be used by users to accomplish specific goals with different criteria’s such as effectiveness, efficiency, and satisfaction, in a specified context of use. For conventional or traditional software applications, usability may be a nice to have, but for web applications, it is critical due to the shifts in user expectations. There has been little focus to evaluate software usability from an end-user perspective using quantitative methods. In this research thesis, we propose a framework for web application usability evaluation from an end-user viewpoint.
This work developed a tailored web applications quality evaluation framework, which is originated from the basic models of (ISO/IEC IS 9126-1, 2001) with specifically focusing on usability perspective of web applications in academic domains. According to (Rachida D & Moncef B, 2016) the (ISO/IEC IS 9126-1, 2001) model is used as a base model because ISO 9126 is suitable to be used in the evaluation of e-learning.

Based on the sub characteristics of usability in the (ISO/IEC 25010, 2011), (ISO/IEC IS 9126-1, 2001), the reviewed web application models, and other related works, the following sub characteristics are considered for this framework.

**4.2.2. Sub-Quality factors**

According to (Rachida D & Moncef B, 2016) from the listed limitations of (ISO/IEC IS 9126-1, 2001) it is possible to modify or add new usability quality sub-characteristics to the model of ISO 9126.

**4.3. Quality criteria for the new framework**

<table>
<thead>
<tr>
<th>Quality Criteria</th>
<th>Sub Characteristics</th>
<th>Criteria</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usability</td>
<td>Understandability</td>
<td>-The must help users to understand how to move around the web application -Terms used in the site are understandable -Information organization in the web application is understandable</td>
<td>-To help users understand the structure of the web application easily and make use of the web application, the overall organization of the web application should be presented in different methods (site maps, alphabetical indexes or table of contents, image maps) -Label terms used must be simple</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-----------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Learnability</td>
<td>- Ease of learning how to use the web application</td>
<td>- Learning how to use the web application should be easy for users</td>
<td></td>
</tr>
<tr>
<td>Operability</td>
<td>- Ease of use of the web application</td>
<td>- Operating the web application should not be a nightmare for users. The web application should be easy to handle that would make users feel in control while using it</td>
<td></td>
</tr>
<tr>
<td>Attractiveness</td>
<td>The capability of the software product to be attractive to the user.</td>
<td>The capability of the software product to be attractive to the user.</td>
<td></td>
</tr>
<tr>
<td>User Interface</td>
<td>- Consistent text layout, page layout, font size and font color</td>
<td>Spacing of characters, font size used, colors used for labels, fonts, backgrounds, positions of navigation elements must be visually consistent</td>
<td></td>
</tr>
<tr>
<td>Asthetics</td>
<td></td>
<td>- Users prefer consistent alignments for page elements like text boxes, rows, columns, paragraphs</td>
<td></td>
</tr>
</tbody>
</table>
To facilitate finding information, pages should not be over crowded with items of information.

Each of the attributes are described by different indicators. There are 21 indicators that describe the latent variables (independent and dependent). Respondents are requested to rate each indicator using five point Likert scale (Strongly disagree, Disagree, Neutral, Agree, strongly agree). The indicators for each considered attributes or latent variables are indicated below.

**Usability**

1. Academic web app developed ensures easiness of users to find way to information from the homepage(Usab1)
2. Sites developed ensure users accurately predict which section of the web app contains the information that he/she is looking for(Usab2)
3. The homepage content of the web app developed makes user want to explore the site further(Usab3)
4. Is the web app well suited for first time visitors? (Usab4)
5. How do you rate the overall structure of the web app? Are they straight forward? (Usab5)

**Learnability**

1. I think the overall structure of the web app is straightforward(Learn1)
2. I think it is easy to learn how to use the web app(Learn2)
3. I quickly became skillful with it(Learn3)
4. I learned to use it quickly(Learn4)

**Understandability**

1. Terminologies used in the web app are understandable(Understand1)
2. Organization of information in the web app is easy to understand(Understand2)
Operability

1. It is easy to find information I need on the web app (Oper3)
2. It is easy to use the web app (Oper4)
3. It is easy to operate different tasks (Oper5)

User interface design Aesthetics

1. This web application interface design is attractive (UI1)
2. I am comfortable with the colors used at this web application (UI2)
3. This web application contains no feature that irritates me such as scrolling or blinking text and looping animations (UI3)
4. This web application has a consistent feel and look (UI4)
5. This web application does not contain too many Web advertisements (UI5)

Attractiveness

1. This web application is attractive (Attr4)
2. I am attracted by the services that the web application provides (Attr5)
Fig 4.2. The study Framework
CHAPTER FIVE
DEMONSTRATION, EVALUATION AND DISCUSSION

5.1. Evaluation techniques for Empirical Analysis

5.2.1 Structural Equation Modeling (SEM)

According to (Urbach, N., & Ahlemann, F., 2010) structural equation models describe the relationships between several of these latent variables. Different algorithms such as pls algorithm and software’s such as SMARTPLS are available.

5.2.2 Estimation of Model Parameters in SEM

the researchers distinguished two techniques used for estimating the parameters in Structured Equation Modelling, (CBSEM) and the variance-based (Henseler et al., 2009).

Table 5.1: Comparison between CBSEM and PLS(Henseler et al., 2009)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>CBSEM</th>
<th>PLS-PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Parameters oriented</td>
<td>Prediction oriented</td>
</tr>
<tr>
<td>Approaches</td>
<td>Covariance</td>
<td>Variance</td>
</tr>
<tr>
<td>Assumptions</td>
<td>Typically, Multivariate normal</td>
<td>Predictor specification</td>
</tr>
<tr>
<td></td>
<td>distribution and independent</td>
<td>(non-parametric)</td>
</tr>
<tr>
<td></td>
<td>observations (parametric)</td>
<td></td>
</tr>
<tr>
<td>Parameter estimates</td>
<td>Consistent</td>
<td>Consistent as indicators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and sample size increase</td>
</tr>
<tr>
<td>Latent variables (LVs)</td>
<td>Indeterminate</td>
<td>Explicitly estimated</td>
</tr>
<tr>
<td>Scores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epistemic relationship between LVs and its indicators</td>
<td>Typically, only for reflective Mode</td>
<td>Both reflective and formative mode</td>
</tr>
<tr>
<td>-----------------------------------------------------</td>
<td>-------------------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Implications</td>
<td>Optimal parameters</td>
<td>Optimal prediction accuracy</td>
</tr>
<tr>
<td>Model complexity</td>
<td>Small to moderate model complexity (e.g. less than 100 indicators)</td>
<td>Large complexity (e.g. 100 constructs and 1000 indicators)</td>
</tr>
<tr>
<td>Sample size</td>
<td>Ideally based on analysis of a specific model. Minimum sample size recommendation ranges from 200 to 800</td>
<td>Power analysis based on the portion of the model with the largest predictors. Minimal recommendation ranges from 30 to 100.</td>
</tr>
</tbody>
</table>

5.2.3.1. The PLS-SEM Algorithm

According to (Mateos-Aparicio,2011) model estimation in PLS-SEM uses a three-stage approach that belongs to the family of least squares algorithms
5.3 Evaluation Results and Discussion

5.3.1 Path coefficients for the inner model

The path from understandability to usability has a coefficient of positive .093. The path from learnability to usability has a coefficient of positive .553. The path from user interface aesthetics to usability has a coefficient of positive .187. The path from attractiveness to usability has a coefficient of positive .255. The path from operability to usability has a coefficient of positive .196.
Figure: 5.2: Path coefficients
Path coefficients are always standardized path coefficients. Given standardization, path weights therefore vary from -1 to +1. Weights closest to absolute 1 reflect the strongest paths. Weights closest to 0 reflect the weakest paths. Above,

- The path weight of positive .553 shows that learnability has a positive effect on usability.
- Understandability at the path weight of positive .093 shows that it has positive effect. Learnability at the path weight of positive .553 shows that it has a positive effect.
- User interface aesthetics at a path weight of positive .187 shows that it has a positive effect.
- attractiveness at a path weight of positive .255 shows that it has a positive effect.
- operability at a path weight of positive .196 shows that it has a positive effect.
Figure 5.4: R square

For the endogenous variable usability, the R-square value is 0.729, meaning that about 72% of the variance in usability is explained by the model.

5.3.3 Outer model measurement loadings and weights

5.3.3.1 Loadings

According to (Hair et al., 2014: 103) a loading of 0.70 is the level at which about half the variance in the indicator is explained by its factor.
5.3.3.2 Weights

Outer model “weights,” in contrast to loadings, do not vary from 0 to plus or minus 1. Weights vary from 0 to an absolute maximum lower than 1.

<table>
<thead>
<tr>
<th></th>
<th>Attractiveness</th>
<th>Learnability</th>
<th>Operability</th>
<th>Understandability</th>
<th>Usability</th>
<th>User Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attr4</td>
<td>0.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Attr5</td>
<td>0.994</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learn1</td>
<td></td>
<td>-0.270</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Learn2</td>
<td></td>
<td>0.850</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Learn3</td>
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<td>0.684</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learn4</td>
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<td>-0.130</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oper3</td>
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<td></td>
<td>-0.872</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oper4</td>
<td></td>
<td></td>
<td>-0.336</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oper5</td>
<td></td>
<td></td>
<td>0.182</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UI1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.886</td>
<td></td>
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<tr>
<td>UI2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.808</td>
<td></td>
</tr>
<tr>
<td>UI3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.798</td>
<td></td>
</tr>
<tr>
<td>UI4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.369</td>
<td></td>
</tr>
<tr>
<td>UI5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.067</td>
<td></td>
</tr>
<tr>
<td>Understand1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.880</td>
<td></td>
</tr>
<tr>
<td>Understand2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.620</td>
<td></td>
</tr>
<tr>
<td>Usab1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.277</td>
</tr>
<tr>
<td>Usab2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.703</td>
</tr>
<tr>
<td>Usab3</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>-0.507</td>
</tr>
<tr>
<td>Usab4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.629</td>
</tr>
<tr>
<td>Usab5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.588</td>
</tr>
</tbody>
</table>

Figure:5.5: Loadings
5.3.4 Assessing model fit

According to (Chin W.W, 1998), SEM is used to describe a large number of models used to evaluate the validity of substantive theories with empirical data. In IS research the PLS model is being used for research in recent years, because of its ability to model
latent constructs under non-normality with small to medium sample size and the major goal is to determine if a theoretical model is consistent with the data collected to reflect the theory or not so the consistency of the model is evaluated through model-data fit.

In Fig 4.2, arrows go from the factors (learnability, understandability, user interface aesthetics, attractiveness, operability and usability) to the indicator variables, determines the values of the measured and representative indicator variables. The model fit of themodel can be done using Composite Reliability (sometimes called construct reliability) and Average variance extracted so the result found is presented below.

5.3.4.1 Measurement fit for reflective models

5.3.4.1.1 Composite reliability

Composite reliability (sometimes called construct reliability) is a test of convergent validity in a reflective model. The result of composite reliability is depicted as follows in Fig 5.7. (Chin, 1998; Höck & Ringle, 2006) stated that Composite reliability should be equal to or greater than 0.6 however very high composite reliability or construct reliability (> .90) indicate that the multiple indicators are minor wording variants of each other rather than being truly representative measures of the construct the factor represents. Based on this, the result indicates that understandability and user interface aesthetics indicators explain the latent variables well.
5.3.4.1.2 Average variance extracted (AVE)

(Chin, 1998; Höck & Ringle, 2006: 15) stated that in an adequate model, Average variance extracted should be greater than .5 as well as greater than the cross-loadings, which means factors should explain at least half the variance of their respective indicators. AVE below .50 means error variance exceeds explained variance based on this Fig 5.8 shows Average variance extracted is better for the understandability latent variable.
5.4. Web Application Quality Evaluation Tool

It was found that some items on the questionnaire describing the various subcharacteristics were found significant and thus contributed to the overall academic web application quality and those that were found not significant will be discarded in the development of the proposed model.

5.4.1. Academic web application Quality Evaluation Tool

The tool is implemented using JSP. 40 student participants (10 for each web application) were chosen randomly from Bahir Dar Institute of Technology. The students were tasked to use the proposed framework for evaluating 4 web applications which are BDU Digital Library (E-library), BDU SIMS, BDU Human resource management system and BDU property management systems. They were asked to use the web applications for about 10 minutes to answer 6 related questions.
Evaluation Results

Based on Your Evaluation, the following are the results.

**UNDERSTANDABILITY RESULTS**
terminologies used in the web app are understandable: 3.0
organization of information in the web app is easy to understand: 3.0

Total: 6.0/8.0

**USABILITY RESULTS**
the Academic web app developed ensures easiness of users to find way to information from the homepage: 3.0
the Site developed ensure users accurately predict which section of the web app contains the information that you are looking for: 3.0
the homepage content of the web app developed makes a user want to explore the site further: 3.0
how do you rate the overall structure of the web app Are they straight forward: 3.0
is the web app well suited for first time visitors: 3.0

Total: 15.0/20.0

**OPERABILITY RESULTS**
it is easy to find information I need on the web app: 3.0
it is easy to use and operate the web app: 3.0
It is to operate: 3.0

Total: 9.0/12.0

**LEARNABILITY RESULTS**
i think it is easy to learn how to use the web app: 3.0
i quickly became skillful with it: 3.0
i learned to use it quickly: 3.0
i think the overall structure of the web app is straightforward: 3.0

Total: 12.0/16.0
### Figure 5.9: Evaluation of Results.

#### Table 5.2: User satisfaction evaluation

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>No</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>∑</td>
<td>%</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>∑</td>
<td>%</td>
</tr>
<tr>
<td>Ease to use</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>40</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Efficient in performing evaluation</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>10</td>
<td>37</td>
<td>92.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>7.5</td>
</tr>
<tr>
<td>Interactive</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>10</td>
<td>29</td>
<td>72.5</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>11</td>
<td>27.5</td>
</tr>
<tr>
<td>Well organized content</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>10</td>
<td>37</td>
<td>92.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>7.5</td>
</tr>
<tr>
<td>Ease to move around the web application</td>
<td>10</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>35</td>
<td>87.5</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>12.5</td>
</tr>
<tr>
<td>Attractive user interface design</td>
<td>3</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>25</td>
<td>62.5</td>
<td>7</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>15</td>
<td>37.5</td>
</tr>
<tr>
<td>Ease to read and</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>32</td>
<td>80.0</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>20.0</td>
</tr>
</tbody>
</table>
The assessment of usability factors in regards to academic web applications quality is an important area of research. Much work needs to be conducted to create a framework for evaluating academic web applications to increase the acceptance level of those applications by the users. Therefore, some of the contributions that the research thesis provides are:

1. Developing a framework for evaluating the quality of web applications from usability perspective.
2. Identifying the most important web application usability quality sub-factors.
3. This research thesis proposed and evaluated a web application evaluation framework that fits the context of Ethiopia.

<table>
<thead>
<tr>
<th>Comprehensible Content</th>
<th>Score 1</th>
<th>Score 2</th>
<th>Score 3</th>
<th>Score 4</th>
<th>Score 5</th>
<th>Score 6</th>
<th>Score 7</th>
<th>Score 8</th>
<th>Score 9</th>
<th>Score 10</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear and easy to understand report</td>
<td>10</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>38</td>
<td>95.0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Feel in control when using the app</td>
<td>10</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>37</td>
<td>92.5</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Gain better understanding about usability after using the framework</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>33</td>
<td>82.5</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>7</td>
</tr>
</tbody>
</table>

### 5.5. Contribution of the Study

The assessment of usability factors in regards to academic web applications quality is an important area of research. Much work needs to be conducted to create a framework for evaluating academic web applications to increase the acceptance level of those applications by the users. Therefore, some of the contributions that the research thesis provides are:

1. Developing a framework for evaluating the quality of web applications from usability perspective.
2. Identifying the most important web application usability quality sub-factors.
3. This research thesis proposed and evaluated a web application evaluation framework that fits the context of Ethiopia.
CHAPTER SIX
CONCLUSIONS AND FUTURE WORK
6.1. Conclusions

It is important to have a framework that instructs web developers and administrators in the development of a quality academic web application. The framework will help to improve the services offered to thousands of students who use Bahir Dar university e-library web application. The new framework will be able to help organizations to improve their web application that meets the user’s requirements based on the quality attributes considered such as operability, learnability, user interface aesthetics, understandability, and attractiveness. The developed framework should be adopted in order to improve the quality of academic web application.

Path coefficients are always standardized path weights therefore vary from -1 to +1 where weights closest to absolute 1 reflect the strongest paths and Weights closest to 0 reflect the weakest paths. As we can observe from the path coefficients, above, the path weight of positive .553 shows that learnability have a positive effect on usability, understandability at the path weight of positive .093 shows that it has positive effect on usability, learnability at the path weight of positive .553 shows that it has a positive effect on usability, user interface aesthetics at a path weight of positive .187 shows that it has a positive effect on usability, attractiveness at a path weight of positive .255 shows that it has a positive effect on usability, operability at a path weight of positive .196 shows that it has a positive effect on usability, the R-square value is 0.729, meaning that about 73% of the variance in usability is explained by the model.

User satisfaction evaluation was conducted on the framework tool it was found that participants were satisfied with proposed framework where mean value for positive feedback is 85.75%. even if this is a good result, the user interface design can be improved.
6.2. Recommendations

From this thesis research work, it can be noted that evaluating the quality of an academic web application is not a one task. However, quality evaluation of an academic web application is very essential since it assist the educational organization to know whether their sites meet user’s requirement or not. So development of future web application evaluation framework research’s should consider all participating stakeholders such as developers, staff members and others.
References


S. B. Shum, & C. McKnight. (1997). World Wide Web Usability Introduction to This Special Issue. *International Journal of Human-Computer Studies, 47*(1), 1-4.


Dear Respondent:

The student at **Bahir Dar Institute of Technology** pursuing a Master of Science in Software Engineering. As a requirement for the degree program, he is conducting a study on a framework for evaluating quality of academic Web Applications, which will culminate in the development of a framework for determining quality in academic Web Applications.

The questionnaire is designed to collect data on the adopted Web Application quality characteristics. Please take a few minutes to answer the questions below. Kindly respond to all the items in the questionnaire. Your response will be strictly confidential and anonymity will be ensured.

Put a tick (✓) alongside the option that is applicable to you or fill in the spaces provided. **DONOT** indicate your name on this questionnaire. The data will be processed objectively, so answer the questions truthfully.

Thank you for your time and cooperation

Sincerely yours
Samuel Ashagrre
Mobile … +251932213479

E-mail…SamuelAshu1994 @gmail.com

Questionnaire Survey for MSc Thesis on a Framework for Evaluating Web Applications quality based on usability
PART ONE: General Information

Direction: Please provide the required information on the space provided

1. Gender
   - [ ] Male
   - [ ] Female

2. Faculty?
   [ ]

3. How long do you visit the WebApplication?
   - [ ] daily
   - [ ] weekly
   - [ ] monthly
   - [ ] yearly
PART TWO: Web Application Quality

Kindly rate the following attributes of a Web Application in terms of the Usability parameters and questionnaires.

Put a tick (✔) alongside the option that is applicable to you in the spaces provided.

Rate the statement using the 1-5 point Likert scale provided where (5 = strongly agree, 4=agree, 3=neutral, 2=disagree, 1=strongly disagree).

Usability

<table>
<thead>
<tr>
<th>Statements</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic web app developed ensures easiness of users to find way to</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>information from the homepage?</td>
<td></td>
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<tr>
<td>Sites developed ensure users accurately predict which section of the</td>
<td></td>
<td></td>
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<tr>
<td>web app contains the information that he/she is looking for?</td>
<td></td>
<td></td>
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<tr>
<td>The homepage content of the web app developed makes a user want to</td>
<td></td>
<td></td>
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<tr>
<td>explore the site further?</td>
<td></td>
<td></td>
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<tr>
<td>Is the web app well suited for first time visitors?</td>
<td></td>
<td></td>
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<tr>
<td>How do you rate the overall structure of the web app? Are they</td>
<td></td>
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<td></td>
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<tr>
<td>straight forward?</td>
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</tr>
</tbody>
</table>
# Learnability

<table>
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<tr>
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<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>I think the overall structure of the web app is straightforward</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>I think it is easy to learn how to use the web app?</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>I quickly became skillful with it</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>I learned to use it quickly</td>
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</tbody>
</table>

# Understandability

<table>
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<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminologies used in the web app are understandable</td>
<td></td>
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<tr>
<td>Organization of information in the web app is easy to understand</td>
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</tbody>
</table>

# Operability

<table>
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<tr>
<th>Statements</th>
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<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is easy to find information I need on the web app</td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>
It is easy to use the web app

**User interface design Aesthetics**

<table>
<thead>
<tr>
<th>Statements</th>
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<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>This web application interface design is attractive</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>I am comfortable with the colors used at this web application</td>
<td></td>
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<tr>
<td>This web application contains no feature that irritates me such as scrolling or blinking text and looping animations.</td>
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<tr>
<td>This web application has a consistent feel and look.</td>
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<tr>
<td>This web application does not contain too many Web advertisements</td>
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</tr>
<tr>
<td>The design of the web application makes sense and it is easy to learn how to use it</td>
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</tr>
</tbody>
</table>

**Attractiveness**

<table>
<thead>
<tr>
<th>Statements</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>This web application is attractive</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>I am attracted by the services that the web application provides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>