A Roadmap for Usability and User Experience Measurement during early phases of Web Applications Development

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ABSTRACT

Web usability and User Experience (UX) play a vital role in the success and failure of web applications. However, the usability and UX measurement during the software development life cycle provide many challenges.

Based on a systematic literature review, this thesis discusses the current usability and user experience evaluation and measurement methods and the defined measures as well as their applicability during the software development life cycle. The challenges of using those methods also identified. In order to elaborate more on the challenges, we conducted informal interviews within a software company.

Based on the findings, we defined a usability and user experience measurement and evaluation roadmap for web applications development companies. The roadmap contains a set of usability evaluation and measurement methods as well as measures that we found suitable to be used during the early stages (requirement, design, and development) of web application development lifecycle.

To validate the applicability of the defined roadmap, a case study was performed on a real time market oriented real estate web application. The results and the discussions of the findings as well as the future research directions are presented.

Keywords: Usability; User Experience; Roadmap; Evaluation, Measurement
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Arslan
31st March 2010
Ronneby, Sweden.

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Assad
31st March 2010
Ronneby, Sweden

"WE DEDICAE THIS MASTER THESIS TO OUR BELOVED FRIEND WAQAS KHALID (LATE), WHO IS NOT WITH US ANYMORE"
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<tr>
<td>UEMs</td>
<td>Usability Evaluation Methods</td>
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1 INTRODUCTION:

CHAPTER 1

1.1 Background:

Internet is growing day by day and web applications such as webmail, online resellers, wikis and social networks increasing rapidly on the Internet (Liu 2008). The number of websites is rising and Internet is becoming a global village. World Wide Web contains millions of websites which are developed and deployed in different countries (Liu 2008). Each website has different mission, targets and developed for specific communities (Moreno, Martínez and Ruiz WISE 2007). The websites can be categorized into the sub categories on the basis of the functionalities provided such as; information oriented, business oriented, and service oriented websites (Reynolds 2004).

During the recent years, E-Commerce applications have gained considerable attention. E-Commerce is a way of doing online business; it has the features of buying, selling products and providing services (Ortiz and Granville 2000). In E-Commerce applications buyers and sellers communicate electronically to execute the business online. E-Commerce has two major types, business to business (B2B) and business to consumer (B2C) (Ortiz and Granville 2000). The B2B E-Commerce is a business between the two companies and B2C E-Commerce is a way of selling of products directly to the consumer.

Even though the web applications have been advancing, still the web applications are not mature enough and possess significant risks. The main risks are lack of skilled engineers in web software development and lack of knowledge to create complex and quality web sites, which can be updated quickly and reliably (Barnard and Wesson 2003). Other issues that are associated with immature nature of web software development are reliability, usability, security, availability, scalability, maintainability and time-to-market (Offutt 2002).

Due to the vast range of users, which are multicultural and multilingual, it’s very hard to meet requirements and observations of all the users (Fitzpatrick 2000). The quality of maintaining the web applications is becoming hard task in an ever changing and competitive environment (Fitzpatrick 2000). The important quality attributes of web applications include efficiency, reliability, security and usability.

In a highly competitive environment, the usability of the web applications and the User Experience (UX) play important roles in attracting users to the websites as well as for their sustainability in the market. In the literature, most of the work has been done on developing efficient, high performance and secure web applications, but relatively small amount of research conducted on enhancing the quality of the web applications (Y. Wu and J. Offutt 2002).
ISO 9142-11(ISO 9241-11), defines Usability as “The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”. Nielsen et al. (2001) defines Usability as “efficiency, learn-ability, errors/safety and satisfaction”. Usability is also interconnected with UX.

UX is an important attribute of software products (Hans-Christian Jetter, 2006). UX is related to the repeated tasks, which the user performs like strengths, business constraints, user tasks, security, accessibility and cultural issues (Hassenzahl 2003). These factors play an important role when we talk about web usability and user experience (Hassenzahl 2003). UX can also be defined as a combination of three components, the internal state of the system (needs, expectations, mood, needs etc.), characteristics of the designed system (Usability, Complexity, Functionality etc.) and the context in which the user interact with the system (Hassenzahl and Tractinsky 2006).

For usability and UX measurement, there is no standard set of measures. Different authors have proposed different usability evaluation and UX measurement methods. Generally the usability and user experience are measured at the end of the software development life cycle. Few authors proposed usability evaluation methods on early stages of the software development lifecycle. A three-dimensional web quality model for usability defined by Calero et. al (Calero, Ruiz and Piattini 2005). This study presents a web metric classification, which includes 385 metrics using Web Quality Model (WQM), a three-dimensional web quality model.

The life cycle of typical web applications include; requirements analyses, design, coding, testing and implementation (Lang and Barry 2001). The literature review, which we carried out during this research, shows that the usability is generally evaluated at the end of the software development on testing phase and there are few studies, which discusses the evolution of usability in the life cycle. Gay Saward et al. (2004) performed a study on usability evaluation on the requirements analysis phase by using the information retrieval through user interaction (Saward 2004). Vincenza Carchiolo et al. have done the work on design phase for effective usability and user experience techniques (Carchiolo 2003).

Considering usability and user experience only at the end of the life cycle is very costly, because of different issues like major re-design and re-works. Usability and user experience should be considered from the very beginning of the software development life cycle (Barnum 2008).

This thesis aims to identify the usability and user experience evaluation methods, which are applicable on early phases of the web application development lifecycle. And also identify the metrics from the ISO standards, which can be used to measure the usability and UX on the early phases of web application development lifecycle.

1.2 Aims and Objectives:
This thesis aims to identify the usability and user experience evaluation methods and measures, which are applicable during different phases in the web application development life cycle. And develop a roadmap, which includes different usability and UX evaluation methods, and techniques, which will be applicable on early phases of the web application development.
The aims are achieved on the basis of the following objectives:

- Identify the usability measures in internationally recognized standards, quality models and the literature.
- Review the usability and user experience evaluation methods and their applicability throughout the software development life cycle.
- Identify the challenges of these methods when applied at different phases of the software development life cycle.
- Define a web usability and user experience measurement and evaluation roadmap for web application development companies which can be used at early stages (requirement, design, and development) of the life cycle.
- Perform a case study on a real time market oriented real estate web application to validate the developed roadmap.

1.3 Research Questions:
The research aims to answer the following research questions:

- **RQ1**: What are the different definitions, concepts and terminologies of usability, web usability and user experience in literature?

  This question helps to identify the different concepts of usability, web usability and user experience. The main aim of this research question is to identify the opinions of different authors about usability, web usability and user experience.

- **RQ2**: What are the usability measures in internationally recognized standards, quality models and literature?

  This question identifies the usability measures in different standard and quality models to identify a common set of reliable measures for usability evaluation of web application.

- **RQ3**: What are the Web Usability and UX measurement and evaluation methods that can be used at early phases of software development life cycle?
  - **RQ 3.1**: What are types of usability evaluation methods?
  - **RQ 3.2**: How different UEMs can be categorized on the basis of usability factors?
  - **RQ 3.3**: What is the effectiveness of UEMs during different phases of software development?

  This research question helps to identify the different Usability and UX measurement methods, which can be used to measure Usability and UX at early phases of software development lifecycle. This question is answered conducting a systematic literature review and with the help of case study.

- **RQ4**: What are the challenges faced by web application development companies while measuring and evaluating the usability and user experience?

  This research question helps to identify the challenges, which the web application development companies face while evaluating and measuring the
usability and user experience of the web application. The research question is answered through systematic literature review and conducting a case study.

- **RQ 5**: What type of road map can be developed for combining the usability and UX evaluation methods for measuring usability and UX at early stages of software development lifecycle?

This research question was defined to combine the usability evaluation methods and measures on the early phases of software development lifecycle. This can be come up as a roadmap for measuring the usability and UX on early phases of software development lifecycle.

![Figure 1: Research Methodology](image)

### 1.4 Research Methodology:

There are three types of research methodologies, qualitative, quantitative and mixed (Creswell, 2008). The mixed research methodology has been used in this thesis work. The research is divided into three types, which are: literature review, systematic literature review and case study.

A literature review was performed on the ISO quality measurement standards to identify the measures that are used for measuring the usability and user experience during different phases of the software development lifecycle. And also identify the different definitions, terminologies and concepts of web usability and UX.

A systematic literature review was performed on the web usability and UX evaluation methods and their applicability during the development life cycle. Systematic review also identified the challenges, which the web application development companies faced when using these methods and techniques for evaluating and measuring usability and UX of the web applications.

On the basis of literature review and systematic literature review, a roadmap to measure usability and UX at early stages of software development was defined.
Usability and User Experience Measurement Roadmap for Web Applications

1. Literature Review
   1.1 Identify Usability and UX definitions from different standards and Usability Measurement Methods
   1.2 Identify the definitions of Web Usability and User Experience from Literature
   1.3 Identify the Relationship between Web Usability and UX

2. Systematic Literature Review
   2.1 Identify Different Web Usability and UX Evaluation Methods on early Phases of development Lifecycle
   2.2 Categorize UEMs on the basis of usability factors
   2.3 Identification of UEMs during different phases of life cycle
   2.4 Identify Web Usability and UX challenges

3. Case Study
   3.1 Perform interview to identify the need of a roadmap for Web Usability and UX Measurement
   3.2 Suggestions and recommendations to improve the usability and UX
   3.3 Validate and Test the Usability and UX Measurement Roadmap

Figure 2: Detail Research Methodology
The validation of the developed roadmap was done through a case study. The data was collected through interviews, documentation and through observation. First, we identified the requirements of the roadmap we developed by performing an interview in a company. We applied the roadmap during the development of a real estate online web application. The authors of this thesis participated in the development team and collected data on the applicability of the developed roadmap through observation and informal interviews.

1.5 **Expected Outcomes:**

This research provides the following outcomes:

- Systematic literature review results on usability and user experience measurement and evaluation methods as well as challenges when implementing these methods.
- A roadmap to improve the web usability at the early stages of software development.
- A list of attributes and sub attributes which will be helpful for measuring the usability and user experience of the web product during the early phases of software development lifecycle.
- A discussion on our findings, which will be helpful for measuring the usability and user experience of web applications.
CHAPTER 2

2.1 Usability:

Usability is recognized as one of the most important quality attributes for the software applications. The range of software applications is very much vast, like console based applications, GUI desktop applications, web applications etc. If we just talk about web applications, then usability is perceived as different in different applications. The concept of usability is different in the opinions of different authors. Usability is defined as differently in literature, standards and in usability evaluation methods. In the following sections, the concepts of usability are discussed.

2.1.1 Concepts and Definitions from Literature:

The different definitions of usability are proposed by different authors on the basis of their perceptions of usability. Most of the authors, considered usability as the measurement of some quality attribute and sub attributes. On the basis of literature review, the definitions of usability are provided in the following paragraphs.

According to Shackel and Lee (Lee 1999), usability is measured in the form of five components, which are Effectiveness (Speed), Effectiveness (Errors), Learnability (Retention), Learnability (Time to learn), and attitude. These attributes express usability in the context of speed of a software application, time needed to learn how to use the web site, the retention and attitude of the user and the no of errors in the system.

Nigel Bevan and Macleod (Bevan and Macleod 1994) define usability as the quality requirement of the product which can be measured as user satisfaction and acceptance. This requirement can be met and end users will be happy if the planned objectives are effectively achieved by using appropriate means. Nunnally and Bernstein (Nunnally and Bernstein) explains that it’s possible to measure the usability directly; there are some measures and attributes which inferred to usability indirectly. The defined measures are: User Satisfaction, Perceived effectiveness, and Performance Evaluation.

Nielsen (Nielsen 1993) defined usability in a combination of five quality factors which are: learnability, error/safety, satisfaction, memorability and efficiency. Preece et al. (Preece, Rogers and Sharp 2002) also explained the usability in four components: learnability, flexibility, throughput and attitude. Constantine and Lockwood (Constantine and Lockwood 1999) defined usability as a combination of five components, which are: learnability, system reliability, efficiency, rememberability and user satisfaction. These authors have some commonalities in considering quality attributes for measuring the usability. For example learnability of the system, which includes the easy to aware the functionalities of the system, is one of the most commonly recognized attribute of usability.
The semi-Automated Interface Designer and Evaluator Method (AIDE) (Sears 1997), is an automated web applications evaluation tool, which evaluates the static HTML web page on the basis of some predefined guidelines. These guidelines are related to the placement of specific objects on specific places, style of buttons, layout design, and division of frames. The web page design evaluation in AIDE has been done on the basis of task-independent metrics and task sensitive metrics.

**Task Independent Metrics:** It defines the metrics and guidelines related to design the layout and graphics of the website, and placement of specific objects onto specific places, so that the website is becoming more attractive.

**Task Sensitive Metrics:** It defines the metrics and guidelines related to define the development and execution of the specific task. And also define the interaction of interface with the user tasks.

Macleod and Rengger (Macleod and Rengger, 1993) proposed a model for measuring the usability of the system. This model is called: Diagnostic recorder for Usability Measurement (DRUM). The usability is measured by analyzing the specific user evaluations, which interacts with the system. The measures defined by authors are based on the performance. The author defined some metrics for measuring the usability (see Table 1).

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Task Time – Total Performance</td>
<td>It’s a time needed to complete the task, and calculate the performance time</td>
</tr>
<tr>
<td>Time</td>
<td>on the basis of individual task time.</td>
</tr>
<tr>
<td>Snag, Help and Search times</td>
<td>It’s a time spend to dealing with the problems, time to solve task for</td>
</tr>
<tr>
<td></td>
<td>seeking help on the system and time to search any object.</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>It’s a quality attribute and it’s used to measure the quality and quantity</td>
</tr>
<tr>
<td></td>
<td>of the task output, it’s a measurement of and how the user achieve their</td>
</tr>
<tr>
<td></td>
<td>goals.</td>
</tr>
<tr>
<td>Efficiency</td>
<td>It’s a time to complete the task which relates to the effectiveness, it’s</td>
</tr>
<tr>
<td></td>
<td>also a time to produce the output.</td>
</tr>
<tr>
<td>Relative Efficiency</td>
<td>It’s a measurement of efficiency between how a single user performed the</td>
</tr>
<tr>
<td></td>
<td>task relative to the group of users. And compare with the experts.</td>
</tr>
<tr>
<td>Productive Period</td>
<td>The task time percentage which user not spent on snag, help and search. It's</td>
</tr>
<tr>
<td></td>
<td>a time which user spent to complete the task productively to achieve their</td>
</tr>
<tr>
<td></td>
<td>goal.</td>
</tr>
</tbody>
</table>

Macleod (Macleod et al. 1997) proposed another model for measuring the usability. Metrics for Usability Standards in Computing Model (MUSIC), this model explains some measures which later included into ISO 9241 Standard. MUSIC includes the measures which use to measure performance, efficiency and usability of the product. MUSIC contains a lot of measures so it’s better first to define the specific evaluation objectives. Major factors for implementing MUSIC are time and resources. The compulsory measures for measuring the performance and usability are given in Table 2.
Table 2: Usability Compulsory Metrics in Music Method

<table>
<thead>
<tr>
<th>Compulsory Metrics</th>
<th>Metrics</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness of Task Goal Achievement</td>
<td>Quantity</td>
<td>It represent the proportion of the tasks in the output with which have been attempted.</td>
</tr>
<tr>
<td></td>
<td>Quality</td>
<td>The degree to which the tasks has been achieved.</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>Effectiveness = f (Quantity, Quality)</td>
<td>Effectiveness is measured as a function of quality and quantity of the achieved tasks.</td>
</tr>
<tr>
<td>Task Effectiveness</td>
<td>TES = (Quantity * Quality)/100</td>
<td>It calculate the effectiveness of the tasks in percentage</td>
</tr>
<tr>
<td>Efficiency and Cost of the performed tasks</td>
<td>Efficiency = Output/input User Efficiency = Effectiveness/Task Time Human Efficiency = Effectiveness/Effort Corporate Efficiency = Effectiveness/Total Cost</td>
<td>It’s a ratio of output tasks to input tasks.</td>
</tr>
</tbody>
</table>

Table 3 shows the optional measures of the MUSIC model.

Table 3: Usability Optional Metrics in Music Method

<table>
<thead>
<tr>
<th>Optional Measures</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productive and Unproductive Actions</td>
<td>Productive actions are those which participate in the output of the task, and unproductive just support the task not participate.</td>
</tr>
<tr>
<td>Help Actions</td>
<td>The actions or links which will be available for the help of the users.</td>
</tr>
<tr>
<td>Search Actions</td>
<td>The actions or guidelines for the users to search specific objects on the website</td>
</tr>
<tr>
<td>Snag Actions</td>
<td>The action which does not participate in the output of the task directly and indirectly.</td>
</tr>
<tr>
<td>Productive Time</td>
<td>It’s a remaining which need to complete the task after taking help and knowing the system</td>
</tr>
<tr>
<td>Productive Period</td>
<td>It’s a percentage of time needed to complete the whole task.</td>
</tr>
</tbody>
</table>

There is another sub part of MUSIC, which contains 50 items of user satisfaction questionnaire, called Software Usability and Measurement Inventory (SUMI) (Kirakowski and Corbett 1993). It contains a questionnaire that is previously the part of MUSIC Model. This model provides some measures which is comprised with some questions on user satisfaction. The model is basically composed with five major user satisfaction areas, which are: effectiveness, global satisfaction, efficiency, control, helpfulness and learnability.
Nunally and Bernstein (Nunnally and Bernstein) explain usability in the form of these three observed measures: perceived effectiveness, performance evaluation, and user satisfaction. McCall (McCall, Richards and Walters 1977) explain usability in his quality model in three components: trainability, operability, and effectiveness. It’s a very old quality model, but still it’s a base for the other usability standards and usability evaluation models.

There is another model, Skill Acquisition and Network Model (SANe) (Williams et al. 1997), which explains usability as a quality of the product in interactive devices. The model proposed a user interaction model, which defined device dynamics, user tasks and the defined procedures for performing the tasks. This model is composed of 60 different measures, on which 24 clearly defined the quality goals. These measures are classified in the following quality attributes (see Table 4).

Table 4: Attributes from Skill Acquisition and Network Model (SANe)

<table>
<thead>
<tr>
<th>Measures</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>Efficiency explains the predicted cost to execute the specific task.</td>
</tr>
<tr>
<td>Learning</td>
<td>Explains the familiarity with the system, and how easy the user can perform the task</td>
</tr>
<tr>
<td>Cognitive workload</td>
<td>It explains the load, memory allocation and how to achieve the scalability.</td>
</tr>
<tr>
<td>Effort for Error Correction</td>
<td>It describes the error rate and recovery time.</td>
</tr>
<tr>
<td>Adaptiveness</td>
<td>User acceptance tasks within a specific application domain</td>
</tr>
</tbody>
</table>

2.1.2 Concepts and Definitions from Different Standards:

The different standards developed by the International Organization for Standardization (ISO) define usability differently. The ISO standards, which provide definition for usability, are as follows:

- ISO/IEC 9126-1
- ISO/IEC 9126-4
- ISO/IEC 9241-11
- ISO/IEC 13407

2.1.2.1 ISO/IEC 9126-1: Quality Model:

This standard defines usability as one of the quality attributes among functionality, reliability, usability, efficiency, maintainability, and portability. These attributes are further divided into sub attributes (See Figure 3).

This standard defines usability as: “The competence of the software product to perform specific functions which meet the needs of the users under specific conditions and environment” (ISO/IEC 9126-1).
As usability is the attribute of measuring the quality (See Figure 3), and usability is also divided into sub attributes. The description of sub-attributes is as follows:

Table 5: Usability Measurement Attributes in ISO 9126-1

<table>
<thead>
<tr>
<th>Sub Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understandability</td>
<td>It defines the understandability of the user in context of the specific software product.</td>
</tr>
<tr>
<td>Learnability</td>
<td>It defines about the system is easy to use.</td>
</tr>
<tr>
<td>Operability</td>
<td>It defines about the operation of the system, is that easily operable and how much effort put to perform specific actions.</td>
</tr>
<tr>
<td>Attractiveness</td>
<td>Is the system interface attractive?</td>
</tr>
<tr>
<td>Compliance</td>
<td>Is the system meeting the user specification needs?</td>
</tr>
</tbody>
</table>

These sub-attributes also lie in the scope of usability (See Figure 4).
2.1.2.2 ISO/IEC 9126-4: Quality in Use

This standard defines four major factors about usability: productivity, satisfaction, effectiveness and safety. This standard defines the usability as “a capability of the software product which gives the more functionality to the user to achieve user’s goal with the above mentioned factors”. The standard defines the usability in context of quality in use. The usability of the product enhance on the basis of user interface in context of the environment where it will be use. It shows that the usability is dependent on some circumstances, which show the environment where it will be used. On the other hand, when the quality in use is evaluated, then the design might change on the basis of target users.

The usability evaluation performed on the basis of focus groups (ISO/IEC 9126-4). The testing is based on the user’s common goals, needs and wants. And the design is also evaluated with the color schemes, cultural issues, and target users. The quality in use is testing on the basis of common user goals.

2.1.2.3 ISO/IEC 9241-11: Usability Guidance

According to ISO 9241-11, usability is defined as: “users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”. This standard considered as the usability guidance. This standard provides some guidelines for evaluating the usability in a specific context of use.

ISO 9241-11 provides guidelines for evaluating the usability on different phases of software development lifecycle. It provides some guidelines how can be the usability of specific product is evaluated. The guidance includes the measures for evaluating usability but not include the steps how it will be carried out. ISO 9241-11 provides some usability measurement attributes, which are: effectiveness, efficiency and satisfaction. These attributes have some sub attributes which are specified in the standard.

Table 6: Attributes and Sub Attributes of Usability in ISO 9241-11

<table>
<thead>
<tr>
<th>Effectiveness</th>
<th>Efficiency</th>
<th>Satisfaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completeness</td>
<td>Human Efficiency</td>
<td>Acceptance</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Temporal Efficiency</td>
<td>Comfort</td>
</tr>
<tr>
<td></td>
<td>Financial Efficiency</td>
<td></td>
</tr>
</tbody>
</table>

2.1.2.4 ISO/IEC 13407:

This standard “provides guidance on human centered design activities throughout the life cycle of computer-based interactive systems” (ISO 13407, 1998). The standard performs the human centered design of the software product with satisfaction, effectiveness and performance towards the needs of the users. The design-based evaluation performs in an iterative manner during all the development lifecycle. The four activities for evaluating the human centered design mentioned in the standard are shown in the following figure,

The human centered design evaluation process starts from identifying the needs of the design. Then specify the context of use, which includes, which environment it will use, which kind of users will use the system etc. Then the second step is to specify the user and organizational requirements. Then design the possible design solutions from extracting the user requirements.
Then on last step, the evaluation of design will perform on the basis of requirements. And on this step, it’s also analyzed that how much the design is satisfying the user and organizational requirements. These activities are not bound onto the single phase of software development lifecycle. It can be used on any phase for evaluating the design. The design is evaluated on the basis of the user requirements and perceptions from the system.

2.2 User Experience:

Similar to usability, user experience is also perceived differently by different authors in the software engineering community. Following section describe the different definitions of user experience.

2.2.1 Concepts and Definitions:

Roto defined the user experience as the users’ expectations and feelings from the product (Roto 2006). They proposed some factors which used to analyze the user behavior and feelings of the user. These factors are; user’s perceptions from the product, and the culture issues where the product will be used (Roto and Kaasinen 2008). Jetter and Gerken explained that user experience is not only the combination of the quality attributes which described in ISO quality model standard 9126-1, but it also includes some other factors like usability, reliability, and functionality etc. It’s also including attractiveness, visual design, coolness, fun, stimulation, and the other attributes which will help to be a success of the product (Jetter and Gerken 2006).

Preece et al. (Preece et al. 2002) proposed that user experience contains these attributes: funny, satisfying, helpful, entertaining, motivating, supportive of creativity, aesthetically pleasing, emotionally fulfilling and rewarding. Another
Forlizzi and Battarbee proposed that there are three factors which help to analyzing the user experience (Forlizzi and Battarbee 2004). These factors are:

- User Centered
- Product Centered
- Interaction Centered

Hassanzahl and Tractinsky proposed three major factors for analyzing the user experience (Hassanzahl M) i.e. designed system characteristics, user’s internal state, and the context of interaction. These factors are more clearly defined in Figure 6:

![Figure 6: UX factors](image)

The above figure explains the examples of these three factors for analyzing usability. The designed system characteristics mean the attributes and functionality of the system. This relates to the non functional attributes of the system. The user internal state explains the user’s expectations from the system, which include user perceptions, mood, wants and needs etc. And the third factor explains the context of interaction of the system with the user. This includes the organizational target market, on which country it’s going to be run, which cultural issues effects the system usability etc. These three factors play an important role in increasing the user experience.

Roto (Roto and Kaasinen 2008) also suggested these three attributes for considering the user experience in his research. He performed these attributes on mobile industry for testing user experience of the mobile phones. He proposed three components: system, user and context. These three components have also some attributes which are related to user experience, which are defined in the following Table.

<table>
<thead>
<tr>
<th>System</th>
<th>Context</th>
<th>User</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objects Involved</td>
<td>Social Context</td>
<td>Emotional State</td>
</tr>
<tr>
<td>Products Involved</td>
<td>Task Context</td>
<td>Expectations</td>
</tr>
<tr>
<td>People Involved</td>
<td>Temporal Context</td>
<td>Experiences</td>
</tr>
</tbody>
</table>
These components are further discussed with the examples in the following tables.

Table 8: User Experience Component: System by Virpi 2008

<table>
<thead>
<tr>
<th>User Experience Component: System</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attributes</strong></td>
<td><strong>Examples:</strong></td>
</tr>
<tr>
<td>Objects Involved</td>
<td>Web Browsers, Mobile Devices, and Embedded Systems with user application.</td>
</tr>
<tr>
<td>Product Involved</td>
<td>Internet Service Providers.</td>
</tr>
<tr>
<td>People Involved</td>
<td></td>
</tr>
<tr>
<td>Infrastructure Involved</td>
<td></td>
</tr>
<tr>
<td>Services Involved</td>
<td></td>
</tr>
</tbody>
</table>

Table 9: User Experience Component: Context by Roto 2008

<table>
<thead>
<tr>
<th>User Experience Component: Context</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attributes</strong></td>
<td><strong>Examples:</strong></td>
</tr>
<tr>
<td>Social Context</td>
<td>Expectations, Feelings</td>
</tr>
<tr>
<td>Task Context</td>
<td>The tasks which user performs for achieving the goal.</td>
</tr>
<tr>
<td>Temporal Context</td>
<td>Time to perform specific tasks under some specific restrictions.</td>
</tr>
<tr>
<td>Physical Context</td>
<td>Temperature, Rain, Humidity etc.</td>
</tr>
</tbody>
</table>

Table 10: User Experience Component: User by Roto 2008

<table>
<thead>
<tr>
<th>User Experience Component: User</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attributes</strong></td>
<td><strong>Examples:</strong></td>
</tr>
<tr>
<td>Resources</td>
<td>The resources can be in the form of mental and physical. The physical resources mean, the resources which need to perform the task like hand to keep the mobile. And the mental resources mean the concentration of the user.</td>
</tr>
<tr>
<td>Experiences</td>
<td>The user’s familiarity with the system. More useful tasks which user performs.</td>
</tr>
<tr>
<td>Emotional States</td>
<td>Emotional state depends on the mood of the user. If the mood is good, then the user experience will be good otherwise it may be negative.</td>
</tr>
<tr>
<td>Needs</td>
<td>User want to achieve some functionality</td>
</tr>
</tbody>
</table>

The above tables define the examples of the components, which have been proposed by Virpi. These components are all related to the user behavior. All these components collectively use to analyze the user experience.
2.3 The Relationship between Usability and UX:

The interface is the way of communication between the users and the machines. The interaction between interface and machine is personalized experience of each of the individual user. The communication gives different results depending on how the user observes and interpret the interface. Instinctive interface is not instinct for every user, as easy to use interface is not easy for everyone. The different authors have different opinions on the relationship of Usability and UX, but both the factors have deep influence on each other.

Kang et al. (KANG and Lee 2003) performed the usability test for evaluating the user experience and human behavior. He performed the research on how to observe the behavior of the user while performing the browsing on the webpage and click on different buttons, menus or icons. He selected three electronic devices and performed an experiment for selecting some users to identify the behavior. He concluded that while evaluating the usefulness and interaction, usability is not enough, it can be a part of the user experience. Usability is an important factor but without UX it’s impossible to develop an iterative product enjoyable and useful to users (KANG and Lee 2003).

The other factors which can be used to evaluate the user behavior are: the navigational styles, icons, cultural background, living style, language, philosophy, and habits (KANG and Lee 2003). A Chinese Author Aaron Marcus (Marcus 2003) discussed about the cultural issues, he said that the Chinese population is one-fifth of the world’s population, the Chinese users have a significant effect on the human computer interaction. He discussed about the cultural effects and habits, one student from China pointed out that the universities in United Nations do not have gates and fences while in China and in Korea, there are gates and fences in the universities. It shows the difference in reading habits like top-down and left-right while comparing the Asian and Western Culture. These differences affect the user behavior when we are talking about electronic medium.

Donald Norman (Norman 2002) discussed that the attractive things are work better then the functional, affordable and enjoyable things. He also discussed about the implications of the design, good human centered design handles the stressful situations, bottlenecks, and distractions. But the human centered design is not only dependent on the usability; it’s all dependent on the UX of the product. According to Mahlke (Mahlke 2002), the usefulness is the most important factor for determining the intention of the user on the website. He discussed these four factors for assessing the UX of the web application.

- Usefulness
- Hedonic Quality
- Attractiveness
- Easy to Use
Usefulness has more importance than the hedonic quality, attractiveness, and easy to use. A website is assessed in different quality dimensions. The quality dimensions are visualized in the above figure 7.

"Worldwide, there are more than 750 million people with disabilities. As we move towards a highly connected world, it is critical that the Web be usable by anyone, regardless of individual capabilities and disabilities." Tim Berners-Lee, W3C Director and inventor of the World Wide Web.

Constantinides (Constantinides 2004) defined functionality components of the web application. The two major factors are: Usability and Interactivity. He discussed that these components are closely related to each other, and prove to be a success and failure of the website. These two components are dependent on each other. Interactivity is more enhanced if the UX is efficiently implemented on the website. A web application with high usability has more interactive components which followed the rules of UX. The author also explains that as the technology is rapidly growing, the rich internet applications are becoming more popular, and the essential web experience elements are still limited. He also explains some usability and interactivity factors, the usability factors are:

- Convenience
- Site Navigation Search Process and Information Architecture
- Site accessibility and find ability
- Site speed
- Ordering Payment Mechanism

The interactivity factors are categorized in the following categories:

- Interactivity with the vendor online
- Interactivity with the other web users
Zviran (Zviran et al. 2006) empirically investigated the effect of usability, user centered design or user satisfaction or UX on four type of E-Commerce web sites: customer self service, publish/subscribe, trading and online shopping. The author performed an experiment for finding the relationship between these factors. The research model for relationship is visualized in the above figure 8.

The results from this research calculated through the regression analysis. The findings from this research are: the web sites have hidden, subjective and different factors which can be used to evaluate the user behavior, user satisfaction and usability issues. And they can be be use during different phases of the web application development. The most difficult usability and user experience evaluation is in the online shopping or E-Commerce applications.

Figure 8: The Research Model For Usability and UX (Zviran, Glezer and Avni 2006)

Figure 9: User Centered Design Criteria and their Relationships (Zviran et al. 2006)
The Figure 9 explains the six characteristics which can be used to design the user focused website. These characteristics have strong relationship with Usability and UX, because the appearance of the web page design shows the interaction of the user with the system. The users have not known about the new web site design so it’s good if design is previously showed to the users, and take the feedback of the users for evaluating the Usability and UX.

The different sources have been explored for assessing the relationship between the Usability and UX. As the technology is advancing day by day which change the relationship between the user and technology, the usability professionals need to understand this relationship.

The Usability and UX evaluation is not an easy task, because when we talk about UX, it’s not related to the single user it’s related to the group of users. Which have different behavior in different situations? The Usability and UX has strong relationship with each other, but the nature of the relationship is not known yet. In order to ensure good UX at the end of the life cycle, there is a need to measure usability throughout the development lifecycle and investigate this relationship.
3  Web Usability

CHAPTER 3

3.1 Definitions:

The web industry is focusing more on compatible user interface designs and putting more effort to make web application more usable. For the web designer it is no longer enough to be sensitive toward usability and user experiences issues (Arrue et al. 2007). There should be defined objectives, which are measurable and operational for usability goals. Due to the immense popularity and growth of Internet, it is becoming more and more popular in information sharing and standard way of doing online business. This has increased the emphasis on web usability and user experiences. With the advent of new technology now it is possible to incorporate different type of media e.g. movies, animation, images into web sites.

This has increased the number of usability issues. If these issues are not addressed, by the companies, this would have negative impact on market growth and product quality. Web can be defined as fulfillment of web user needs and expectation along with web application objective in an effective and efficient way. This definition has been adopted from ISO 9141-11 standard

According to Nielsen (Nielsen et al. 2001) there are five key factor in web usability

- Consistent Interface
- Response Time
- Mapping and metaphor
- Interaction styles
- Multimedia and Graphics

Consistent interface means that the placement of navigation elements e.g. buttons and bar should be consistence. Time to response deals with how fast web application responds to user actions. Mapping and metaphors in web usability focus on navigation from one point to another within the application and adoption of specific e.g. payment systems aid in activity of web user within application. The interaction styles focuses on messages of system. These messages are generating during user activity response. The multimedia capabilities are fifth factor in web usability which is added into web design

A usable web site according to Brinck et al. (Brinck, Gergle and Wood 2002a) is the one which is effective, easy to use. A useable website has following characteristics:

- Functionality
- Efficiency
- Learnability
- Memorability
- Error tolerance
• Pleasant feeling

Bedi et. al (Bedi and Banati 2006) has also included following factor in the usability of website.
• Appearance
• Satisfaction
• Feeling
• Trust

According to Nielson (Nielsen et al. 2001), the usability and web design has become an important area of research in human computer interaction (HCI) and also in research related to web. Typically usability has used engineering approach to identity set of principles and common practices that will insure usability as an output of web design (Rasmussen 1996).

There has been great emphasis on indentifying approaches to improve web accessibly. And this is mainly done focusing on download delay, success in searching a web page and gathering information during a web session (Spool 1999).

A web site with high level of usability should fulfill user perceptions and the purpose of user. Consistency and Accessibility to perform task that user intends to do, are part of web usability along with unambiguous interaction, easy to read, content organization, speed and layout. Other than these a better design also consider presentation and interaction (Shneiderman and Plaisant).

Constantinides (Constantinides 2004) has stated that the elements that can enhance the usability of web application are web site conveniences and time load the web page. Other components are Navigation, Information structure and search process, Accessibility, Speed, Process related to payments

User Experience consists of satisfying, enjoyable, funny, entertaining, helpful, motivating, look and feel, supportive or creative, rewarding and emotionally fulfilling experience of user while interacting with system (Preece et al. 2002).

According to McNamara (McNamara and Kirakowski 2006), there are three factors which have a strong relationship for evaluating the Usability and User experience for the web products. These are; Usability (the interaction between the product and the user), Functionality (performance of the product), and Customer Satisfaction (related to the user experience). Although these factors are independent, they are stated to have deep influence on the product and affect the functionality of the product. Here functionality of a software product means what features should be included in the product like product performance, reliability and durability (McNamara and Kirakowski 2006).

For the web applications, there is not a standard set of measures to assess the usability and user experiences. According to recent European Commission’s benchmark studies on quality and usage of public e-services usability is a key property for the users (Arrue et al. 2007). According to this study usability should be one of those properties as it bears on efficiency, effectiveness and user satisfaction. A web quality model was defined by Calero et. al. (Calero et al. 2005). He defined 385 metrics using web quality metrics (WQM), a three-dimensional web quality model. He classifies the usability, maintenance and presentation in 149 metrics.
After performing the literature review, we explored the domain area of the usability and UX, and analyze that how different authors perceive usability and UX. During the literature review we found a lot of usability and UX evaluation methods, which can be used on different phases of the web application development lifecycle. Our thesis was to develop the roadmap, in which we incorporate the different UEMs and UX methods and measures from ISO standard, so we come up with the idea of systematic literature review.

With the help of systematic literature review, we found the evidence that how much UEMs and UX are available in the literature and which methods are implementable on which phase of the web application development lifecycle. The systematic literature answers all of the questions that how much methods are available in literature, which are implementable on early phases of web application development lifecycle, and which are more effective. The next chapter explains the systematic literature review in detail.
4 SYSTEMATIC LITERATURE REVIEW

CHAPTER 4

4.1 Introduction

Usability and User Experience (UX) are important factors in web applications (Nielsen et al. 2001). These two play significant role in the success or failure of web applications. During the development of web applications, they are considered on the later stages of development, mostly during the implementation stage (Barnard and Wesson 2003). To measure the usability and UX for web applications, various methods have been developed.

In this thesis study, we performed a systematic review to identify the usability and user experience measurement and evaluation methods and techniques, and bring into light the implementation challenges for these methods when applied during the early phases of software development life cycle. For performing the systematic review, we used the guidelines defined by Kitchenham (2004).

4.2 Systematic literature review phases:

4.2.1 Planning review:

4.2.1.1 Identify the Need of Systematic review:

The need for performing this systematic review was to analyze how much research has been done on the research review topic, find out the empirical evidence that how much research is fruitful for carrying our research and which areas are still lacking. As Usability and User Experience is a wide field of research therefore preliminary research was conducted. A preliminary search was performed in Compendex database with the following search strings:

(“Usability” OR “User Experience”) AND “Web” AND (“Metrics” OR “Measurement” OR “Attributes” OR “Characteristics” OR “Challenges”)

After performing the search, 7843 research papers have found, some are related with the web usability inspection methods, and some are related to the recommendations and guidelines while implementing these methods. We then re-performed the systematic literature review deciding on the inclusion and exclusion criteria considering our main research questions.

4.2.1.2 Define research questions:

The systematic literature review was performed on the basis of the following research questions. The search strings were extracted from these research questions.

RQ 1: What are the usability and user experience evaluation methods for web applications and their applicability during the development life cycle?

RQ 1.1: What are different types of usability evaluation methods?
RQ 1.2: How different UEMs can be categorized on the basis of usability factors?
RQ 1.3: What is the effectiveness of UEMs during different phases of software development?

Objective:
The purpose of this research question was to find the usability and user experiences evaluation methods for evaluating usability and UX on early stages of web application development lifecycle.

RQ 2: What are the challenges in usability and user experience evaluation during the early phases of web application development lifecycle?
Objective:
This research question was related to the challenges, which the web applications development companies faced while evaluating usability and user experience. And it’s related to the problems, which have been faced while evaluating the usability and user experience during early phases of the web application development lifecycle.

4.2.2 Develop review protocol:
The review protocol is an essential part for performing the systematic literature review to avoid the researchers’ bias. Review protocol has some sub-elements, which are search strategies, the resources which have been searched, the search strings for performing the research, and inclusion and exclusion criteria for selection and rejection of the research papers.

4.2.2.1 Search Strategies:
The search strategies consist of selection of resources and defining search strings. In the following subsection we describe them.

4.2.2.1.1 Resources:
For this systemic review we mainly focused on IEEE and ACM. For the rational, as these are peer reviewed journals and the result from these sources are more credible and trustworthy. Initially we started with Compendex and Inspec but the result set was huge and there was repetition in results. The main sources in Compendex and Inspec were IEEE and ACM. There were also results from source like Springer but very few relevant to our research topic.

As the main focus of the systematic literature review was to find the usability and UX evaluation methods which can implementable on early phases of web application development lifecycle. We handled these papers in our manual search, but nor discussed in the systematic literature review, because they just create the repetition. Regarding conference preceding selection, the conferences that we selected are most relevant to our research area. The main sources for getting the evidence that which usability and UX evaluation methods are available in the literature, these two sources was searched:

- IEEEexplorer
- ACM
For conferences we searched a lot of conferences, the most recent conferences gave the most valuable results, so that’s why we selected the most valuable conference on usability and UX, which are as follows:

- The second COST294-MAUSE International Open Workshop (Hassenzahl, Lai-Chong Law and Hvannberg 2006)
- Human Computer Interaction (HCI) journals and conferences

4.2.2.1.2 Search Strings:
Defining key words is an important step in systematic review it makes the systematic review comprehensive and unbiased. The main source for the keyword identification was recent work related to research area which contains main keywords the main key term are (Usability OR User Experience OR UX) AND (Web OR Internet) AND (measurements OR measures OR metrics OR attributes OR characteristics OR challenges OR issues OR problems) Then all possible related keyword were added in the search. The aim was to cover whole research area.

4.2.2.1.3 Inclusion and exclusion Criteria:
The inclusion and exclusion criteria are the most important part of systematic literature review (Keele 2007). It defines the selection and rejection of papers that are related to the research topic. The last ten years publications has been included, because the most of the search result in preliminary search were from this period. The papers between these periods are selected on the basis of following criteria.
- Papers related to the usability evaluation method(s) of web applications.
- Paper which presented formal web usability evaluation method
- Papers which are related to the web metrics which can be used to measure the usability during the web development lifecycle
- Papers which are related to the challenges, which the web development companies face while usability and user experience evaluation and measurement.

The papers which were excluded from the study:
- Papers which are not published in the last ten years
- Preliminary and introductory studies
- Workshops and books on usability
- Papers not written in English
4.2.2.1.4 Data Extraction Strategy:

The data extraction strategy defines the strategy of extracting the data from the selected research papers (Keele 2007). The data extraction has been performed on the basis of research questions, which are decomposed into the following:

- Which usability evaluation methods and techniques have been reported for evaluating and measuring the usability and user experience of web applications?
- On which phase of development lifecycle (Requirements engineering, designing, development, testing) these methods and techniques have been applied?
- What was the type of evaluation? (Manual/Automatic)
- Was the usability and user experience evaluation method or the technique validated? (Yes/No): If yes:
  - Which type of validation performed? (Case Study, Survey, Experiment)
- Has the validation provided any feedback while applying the usability evaluation method (Yes/No)

The first criterion was used for identifying the usability evaluation methods which has been implemented to evaluate the usability of the web applications. Here, we classified the papers into following types based on the type of the method or techniques them discuss: inspection method, user testing and other. If the method or technique developed for evaluating the usability then it’s marked as an inspection method. If it was used for getting the response from the users and evaluate the user experience, then we marked the paper as ‘user testing’. The ones that did not fall into this category were marked as ‘other’.

In second criterion the papers were classified into the high level phases (Requirements, Design, and Implementation) of the software development life cycle, on the basis of ISO/IEC 12207. The paper was classified into the requirements phase if it takes input from the specification (use cases, scenarios) and measures the usability on the basis of the specification. The paper was classified into the design phase if it takes input from the design documents (Domain Models, User Interaction Model, User Interfaces, and Navigational Methods) and measures the usability on the basis of these design documents. And at last, the papers were classified as implementation if usability measurement is performed at the end for evaluating the application.

In the third criterion the papers were classified as manual if the evaluation was performed manually with measuring the application with metrics, otherwise it’s classified as automatic.

The fourth criterion was related to the validation of the usability evaluation method. If it was validated, then the validation method (Case Study, Survey, Experiment) the author use also noted.

The last criterion was used to classify the papers on the basis of the recommendations and guidelines, which the author mentioned for the designers for evaluating the usability on the design level. And use no when the author is just discuss about the problems.
Another criterion was related to find the challenges which web companies faced while evaluating the usability and UX on early phases of web application development lifecycle. This criterion was used as individually and the results from this criterion were documented in section 4.4.2.2.

4.3 Conducting review:

The conducting review is the execution of the protocol, which had been developed, in 1st phase of the systematic literature review. In conducting review, the defined strings populated into the resources and the results were reviewed. Here, the results were being refined on the basis of inclusion and exclusion criteria, and then the relevant data was extracted from the selected research papers. This phase is discussed below.

4.3.1 Data Extraction:

Data extraction was performed\(^1\) on the basis of the Data Extraction Strategy (See Section 2.1.3.1.). And it was executed on the resources (See Section 2.1.3.1.). The search was performed on the basis of the search strings which have been specified in the search strings section above. Following table shows the results of the search.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Relevant</th>
<th>Selected</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE</td>
<td>423</td>
<td>155</td>
<td>13</td>
</tr>
<tr>
<td>ACM (Total)</td>
<td>380</td>
<td>145</td>
<td>15</td>
</tr>
<tr>
<td>Manual:</td>
<td>84</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>887</strong></td>
<td><strong>218</strong></td>
<td><strong>38</strong></td>
</tr>
</tbody>
</table>

Table 11 summarizes the results of the systematic literature review. The total shows the total number of papers we got after executing the search string (mentioned in Section 4.2.2.1.2.). The relevant shows the number of papers that were relevant to our research questions.

The manual search was conducted for the conference papers. Total 38 (See Table 11.) publications were selected after applying inclusion and exclusion criteria. The selected papers were also checked for redundancy. In case of redundancy latest publications were included in the study.

Table 12 shows the division of the selected publications. The division was performed on the basis of the Data Extraction Strategy. It gives a good idea of how much work has been done in the specific field. The Table 12 shows the division of publications on the basis of method type. The inspection method shows the publications of usability evaluation methods. User testing is related with the user experience. And other is related with any metrics which can be fruitful for measuring Usability and UX.

\(^1\) Data Extraction was conducted on November 14, 2009 and all the results were presented according to that date.
<table>
<thead>
<tr>
<th>Selection Type</th>
<th>Sub-Type</th>
<th>IEEE</th>
<th>ACM E</th>
<th>MAUS E</th>
<th>IE3I C</th>
<th>IWWUA</th>
<th>HCI C</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>Inspection</td>
<td>7</td>
<td>8</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>User Testing</td>
<td>7</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Phase</td>
<td>Requirements</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Design</td>
<td>7</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Implementation</td>
<td>10</td>
<td>9</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>Type</td>
<td>Automatic</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Manual</td>
<td>8</td>
<td>9</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>26</td>
</tr>
<tr>
<td>Validation Type</td>
<td>Survey</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Case Study</td>
<td>10</td>
<td>8</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Experiment</td>
<td>3</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Validation Feedback</td>
<td>Yes</td>
<td>15</td>
<td>11</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

### 4.3.1.1 Analysis of the Results:

The results presented in Table 12 were categorized on the basis of criteria which have been mentioned in the data extraction strategy (See Section 2.1.3.1.).

![Figure 10: Papers categorized by Usability and User Experience Evaluation Type](image)

The results shows that the inspection methods are more implemented (46%) to measure the usability of the web applications, as 39% of user testing methods has been implemented to measure the usability and 15% of the applications are measured from the other methods rather than inspection and user testing. The figure shows the percentage of implementation of methods.

The second criterion was the implementation of the usability measurement methods on the specific phase of the software development lifecycle. The research shows that the least no usability measurement methods have been implemented during the requirements engineering phase (13%), mostly performed during the implementation phase (53%) of the web application. And the percentage is 34% for the design phase, which is close to the implementation percentage.
The third criterion was related to the type of applying the usability measurement method. The type is related to the automatic and manual. Automatic means is there any tool available which measures the usability automatically of the running web application. Manual means the usability measurement is being performed manually with any research method like experiments. Figure 3 shows that the manual implementation of the usability measurement methods is quite more than the automatic.

The fourth criterion was related to the validation methods of usability measurement methods. The Figure 4 shows the statistics related to the implementation of the validation methods. Case study is the most commonly used method (63%). In 26% of the studies, experiments were conducted. And surveys were used only by 9% whereas the rest 2% performed no validation.
The last criterion was related to the feedback from the validation type of the usability measurement methods. Figure 5 show that the 95% of authors in the selected field have shared their experiences, problems, suggestions and recommendations in their publications. And rest of 5% of the studies does not provide any feedback about the implementation of the validation methods.

<table>
<thead>
<tr>
<th>ID</th>
<th>Author</th>
<th>Date</th>
<th>Method Type</th>
<th>Refs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dhawan, S</td>
<td>2008</td>
<td>Inspection Method</td>
<td>IEEE</td>
</tr>
<tr>
<td>2</td>
<td>Desmet</td>
<td>2006</td>
<td>User Testing</td>
<td>IEEE</td>
</tr>
<tr>
<td>3</td>
<td>Panach, JI</td>
<td>2007</td>
<td>Other</td>
<td>IEEE</td>
</tr>
<tr>
<td>4</td>
<td>Abowd et al.</td>
<td>2002</td>
<td>User Testing</td>
<td>IEEE</td>
</tr>
<tr>
<td>5</td>
<td>Alexandra L. Bartell</td>
<td>2005</td>
<td>Other</td>
<td>IEEE</td>
</tr>
<tr>
<td>6</td>
<td>A Anandhan,</td>
<td>2006</td>
<td>Inspection and User Testing</td>
<td>IEEE</td>
</tr>
<tr>
<td>7</td>
<td>A Sutcliffe -</td>
<td>2002</td>
<td>Inspection and User Testing</td>
<td>IEEE</td>
</tr>
<tr>
<td>8</td>
<td>Q Zhou, R DeSantis</td>
<td>2005</td>
<td>Inspection Method</td>
<td>IEEE</td>
</tr>
<tr>
<td>9</td>
<td>J Scholtz -</td>
<td>2001</td>
<td>Inspection Method</td>
<td>IEEE</td>
</tr>
</tbody>
</table>

4.4 Documenting review:

This section shows all the references of the publications, which has been selected in systematic literature review. The publications were categorized with the publication year, topic type and the resource where the papers were published.
4.4.1 Threats consideration:

During the conduct of the systematic literature review, we considered some validity threats. The main threat was not being able to cover all the resources for publication and conferences due to time constraints. The other threats were the selection of the appropriate strings, valid inclusion and exclusion criteria. The quality assessment criteria were also a threat of selecting the appropriate publications.
4.4.2 Result Analysis

4.4.2.1 The usability evaluation methods for web applications

The UEMs which were collected from systematic literature review are shown in Table 14. These UEMs collected from systematic literature reviewing. Table 14 shows the UEMs which can be implementable on the early phases of web application development lifecycle. The main focus of SLR was to identify these methods on different phases of web application development lifecycle.

<table>
<thead>
<tr>
<th>Phase</th>
<th>UEM Type</th>
<th>Description</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before or After Development</td>
<td>Inquiry (Ivory and Hearst 2001a, Whitehead 2006)( Hom, 2005).</td>
<td>These methods capture the requirements of the users by analyzing the likes and dislikes through observation and interviewing.</td>
<td>Field Observation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Focus Groups</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Interviews</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Logging Actual Use</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Proactive Field Study</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Questionnaire</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Scenario Based Inspection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Paper Prototypes</td>
</tr>
<tr>
<td>During Development</td>
<td>Testing (Ivory and Hearst, 2001; Whitehead, 2006; Hom, 2005).</td>
<td>The testing is performed by user itself. The test can be on the actual software or can be on the software prototype. And also analyze that how much the interface is helpful for the user.</td>
<td>Coaching Method</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Performance Measurement</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Question-asking Protocol</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Remote Testing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Retrospective Testing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Teaching Method</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Thinking Aloud Protocol</td>
</tr>
<tr>
<td>During Development</td>
<td>Inspection (Ivory and Hearst, 2001; Whitehead, 2006; Hom, 2005).</td>
<td>The inspection is performed by the usability experts. The inspection is performed during the development phase.</td>
<td>Heuristic Evaluation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cognitive walkthroughs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Guideline Checklist</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Feature Inspection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pluralistic Evaluation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Perspective-based Inspection</td>
</tr>
</tbody>
</table>

The UEMs mentioned in Table 14, were categorized on the basis of the usability factors, these factors were collected from (Mahrin, Carrington and Strooper 2008). After getting the UEMs from the literature using systematic literature review, the effectiveness of the methods has been analyzed on the basis of the following factors:

- Easy to Learn:
- Tool Supported:
- Up-to-date:
- Effectively Supported:
- Complete:
- Effectively Presented:
The categorized UEMs on the basis of the above usability factors are shown in table 15. These methods were also categorized on the basis of the Usability Inspection, Usability Testing and Survey. The phases on which these methods can apply were also mentioned in the table.

This categorization was performed on the basis of the systematic literature review. The green box in this table shows that the identified method is effective at that phase; blue box shows it’s partially effective, and the blank box shows that we did not find any information regarding the applicability from the literature. The UEMs in Table 14 were categorized according to the above factors which are mentioned in Table 15.

Table 15: Categorized UEMs on the basis of Usability Factors

<table>
<thead>
<tr>
<th>Category</th>
<th>UEM</th>
<th>Phase</th>
<th>Easy to learn</th>
<th>Tool-supported</th>
<th>Up-to-date</th>
<th>Effectively supported</th>
<th>Effectively presented</th>
<th>Understandable</th>
<th>Unambiguous</th>
<th>Operable</th>
<th>Navigable</th>
<th>Well Structured</th>
<th>Concise</th>
<th>Tailorable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usability Inspection</td>
<td>Focus Group</td>
<td>RE</td>
<td></td>
<td></td>
<td>RE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coaching Method</td>
<td>DE</td>
<td></td>
<td></td>
<td>RE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Remote Testing</td>
<td>DV</td>
<td></td>
<td></td>
<td>RE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Retrospective Testing</td>
<td>DV</td>
<td></td>
<td></td>
<td>RE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Teaching Method</td>
<td>DV</td>
<td></td>
<td></td>
<td>RE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heuristic Evaluation</td>
<td>DV</td>
<td></td>
<td></td>
<td>RE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cognitive walkthroughs</td>
<td>DV</td>
<td></td>
<td></td>
<td>RE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Planaristic walkthroughs</td>
<td>DV</td>
<td></td>
<td></td>
<td>RE</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Feature inspection</td>
<td>DV</td>
<td></td>
<td></td>
<td>RE</td>
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<td>Guideline checklist</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Perspective-based inspection</td>
<td>DV</td>
<td></td>
<td></td>
<td>RE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Scenario based inspection</td>
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<td></td>
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</tr>
<tr>
<td>Usability Testing</td>
<td>Proactive Field Study</td>
<td>RE</td>
<td></td>
<td></td>
<td>RE</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Question asking protocol</td>
<td>DV</td>
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<td></td>
<td>RE</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Think aloud protocol</td>
<td>DE</td>
<td></td>
<td></td>
<td>RE</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Performance measurement</td>
<td>DE</td>
<td></td>
<td></td>
<td>RE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Logging Actual Use</td>
<td>RE</td>
<td></td>
<td></td>
<td>RE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Field observation</td>
<td>RE</td>
<td></td>
<td></td>
<td>RE</td>
<td></td>
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<tr>
<td>Inquiry</td>
<td>Questionnaire</td>
<td>RE</td>
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<td>RE</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Interview</td>
<td>RE</td>
<td></td>
<td></td>
<td>RE</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

During systematic review result analysis we look into the effectiveness of different UEMs during different phases of software development. The effectiveness of the UEMs which are mentioned in Table 14, were analyzed on the basis of the effective and partial effective. The effectiveness of these methods was found on the basis of the systematic literature review. The Table 16 shows the most effective applicable UEMs on the basis of the systematic literature review, and the effectiveness were
calculated as by dividing the most effective factors divided by total no of factors analyzed. Table 16 shows the effectiveness, which provides a summary of Table 15.

<table>
<thead>
<tr>
<th>UEMs</th>
<th>Phase</th>
<th>Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus Group</td>
<td>RE</td>
<td>5 5/13</td>
</tr>
<tr>
<td>Heuristic Evaluation</td>
<td>DE</td>
<td>4 4/13</td>
</tr>
<tr>
<td>Cognitive Walkthrough</td>
<td>DV</td>
<td>5 5/13</td>
</tr>
<tr>
<td>Scenario based Analysis</td>
<td>RE</td>
<td>5 5/13</td>
</tr>
<tr>
<td>Question asking protocol</td>
<td>DV</td>
<td>5 5/13</td>
</tr>
<tr>
<td>Paper prototypes</td>
<td>RE</td>
<td>4 4/13</td>
</tr>
</tbody>
</table>

The collected UX evaluation methods of different phases are mentioned in Table 17. These methods are also categorized after performing the systematic literature review. UX evaluation methods are mainly implemented during testing and implementation phase. The main methods for UX evaluation are Emotion based evaluation approach, Questionnaire Approach for UX evaluation, Sum of factor approach, Narration and Storytelling, UX measurement in Software Engineering.

<table>
<thead>
<tr>
<th>UX Methods</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emotion Based Evaluation Approach (Desmet 2003)</td>
<td>Testing and Implementation</td>
</tr>
<tr>
<td>Questionnaire Approach for UX Evaluation (Hassenzahl 2004)</td>
<td>Testing and Implementation</td>
</tr>
<tr>
<td>Sum of factor approach (Geven, Schrammel and Tscheligi 2006)</td>
<td>Testing and Implementation</td>
</tr>
<tr>
<td>Narration and Storytelling (Geven et al. 2006)</td>
<td>Testing and Implementation</td>
</tr>
<tr>
<td>Cultural probe method (Gaver, Dunne and Pacenti 1999)</td>
<td>Testing and Implementation</td>
</tr>
<tr>
<td>UX measurement in Software Engineering (Doerr and Kerkow 2006)</td>
<td>All Software Engineering Phases</td>
</tr>
</tbody>
</table>

The second main research question for performing the systematic literature review was to find the challenges, which the web application development companies face during the evaluation of usability and UX. The next section explains the identified challenges.

4.4.2.2 **Usability and UX Challenges:**

The systematic literature review also helped us to identify the major challenges and issues, which are related with web usability and UX. The emergence of Internet and World Wide Web has affected businesses, commerce, education and communication immensely. Now the world is rapidly adopting new means of communication, which is Internet and web. Ecommerce is expanding rapidly and world get closer and closer day by day. The accessibility and ease to use are main factor in the success of Internet application. (Liu 2008)
Web development is different from traditional software development. The main concern in web application development is usability and user experience. The web development is usually carried out in ad-hoc manner and there are not well standardized practices which are specifically designed of such application. This ad-hoc approach works fine for small web application but as the complexity and sophistication grows; it requires systematic approach for development.

Due to lack of discipline process, web development encounters many challenges. A web site that is unable to satisfy user needs and expectation will result into a failure. A web usability and user experience is not easy to achieve (Hornbæk 2006). The systematic literature review shows that there are many challenges for organization to make web site usable and easy to use. During the literature review main challenges in web usability are identified as;

- Ad hoc development approach
- Subjective and objective usability measures
- Learnability measures
- Usability over time measures
- Extending, validating and standardization of satisfaction measures
- Relationship between usability measures

**Ad hoc development approach:** The web development activities are usually carried out in an ad hoc manner. In this approach the process are not well defined which make it very difficult measure or assess the usability and user experiences. Usability is tested at later stages or before delivery time. And during testing the main focus is on functionality rather than usability.

**Subjective and objective usability measures:** Subjective usability measures concern the perception or understanding of user toward the interface or output. The objective measures are not dependent on user’s perception. The objective measures are easy to measure where as the subjective measures are hard to measure. In the research the difference between usability and performance is very clear but very hard to define exactly (Muckler and Seven 1992).

Another reason to consider both subjective and objective measures of usability is that both these can lead to different results regarding the usability of web interface. Tractisky and Meyer (Tractinsky and Meyer 2001) found differences in subjective experiences duration between interfaces when objective time was fixed. In the field of psychologists have recognized and quantified the difference between subjective and objective measure long time ago.

The challenges to measure usability are to develop subjective measures for aspects of quality-in-use, which are usually measured by objective measures and vice versa. During our research we suggested web organization has to pay special attention while selection measures of usability.

**Learnability measures:** Measuring Learnability is also a challenge for an organization during the development of the product (Hornbæk 2006). Learnability measures are based on user interaction with system. Different methodologies are followed to measure these attributes of usability. E.g. Wulf and Golombek (Wulf and Golombek 2001) used questionnaire to gather user feedback after using the application.
This challenge is most relevant to research addressing systems that user should be able to quickly learn and learning curve of system is less. Companies should put more emphasis on measures of Learnability e.g. measuring time required to reach certain level of proficiency and there is need to develop easy to adopt method to measure Learnability during web application development.

**Usability over time measures:** The research (Hornbæk 2006) shows that user usually spend very less time interacting with system which is under investigation. This short interaction doesn’t yield accurate estimation of usability of system. The research also show that how usability enhanced by spending more time interacting with system.

**Extending, validating and standardization of satisfaction measures:** The non-standardization of measure of satisfaction is also a challenge. Almost every measure of satisfaction is acquired by questionnaires (Hornbæk 2006). The problem with such questionnaire is that they are prepared for individual understands of the questions, and these questionnaires do not dig deep into usability issue rather they provide general information which make too hard to relate with specific part of user interface.

The second challenge with this measure is the validation of satisfaction measure. User satisfaction is measured by rating scale for usefulness of the product or services, satisfaction with functions or features, number of time user expresses frustration or anger, user versus technological control of tasks and perception that the technology supports tasks as needed by user (Nielsen et al. 2001). As understanding satisfaction of each individual varies that make it very hard to generalize the satisfaction results and also the validation of these results is very hard.

**Relationship between usability measures:** It also very important to understand the relationship between different usability measures, it helps to mitigate the problems that arise during usability measure measurement.

According to Karat et. al (Vergo et al. 2001) the relationship with mouse movement and satisfaction measures in web application context intended to provide entertaining access to multimedia. Relationship suggested that few mouse clicks results in more user interaction with system and better web experiences.

### 4.4.3 Draw conclusions:

The systematic literature review results show that there are a number of usability measurement and evaluation methods, which can be used to measure usability during the early phases of software development lifecycle. For evaluating the usability of the software product, it is very important to select the appropriate UEM method (Fitzpatrick 1999, Ssemugabi and de Villiers 2007). For proper UEM selection, it’s also important to consider time, efficiency, ease of application, cost effectiveness and expertise evaluation (Parlangeli, Marchigiani and Bagnara 1999, Gray and Salzman 1998).

Moreover, the selection of proper UEM at specific phase of software development lifecycle is a big issue. The variations in different usability measurement methods make it difficult to measure usability during early phases of software development lifecycle (Ssemugabi and de Villiers 2007). The proper UEM
selection is also dependent on the type of software development lifecycle. This study aims to provide the proper UEMs selection on early phases of web application development lifecycle.

Web applications development is different from other types of software development lifecycle (San Murugesan, Hansen and Ginige 2001). The main differences are:

- Web based system consists different combination of web pages i.e. static and dynamic web pages.
- The main focus of the web-based systems is on interfaces, multimedia pictures and on presentation.
- The development focus in web-based system is on contents presentation.
- The web-based system is used diverse user with different ages, skills and capabilities.
- The development time is very short in web development that make hard for formal planning and testing in contrast with traditional software development.

The web companies face difficulties of measuring usability of their market oriented products, because most of developers don’t apply the particular methods for measuring usability, and they do not consider the user experience while measuring usability (Ssemugabi and de Villiers 2007). There are few clear guidelines of how different usability measures, criteria and standards are related to each other, and how they apply on a particular application (Seffah et al. 2006).

The companies usually measure usability on an ad-hoc basis and employ those usability measurement methods that they know. These choices are optimal for all web applications in competitive environment. This effort will not be fruitful for the usability of the product, and it may be wasted because of wrong choice. The other motivations for measuring usability are (Seffah et al. 2006):

- Subjective applications needs strong complements for measuring usability, and needs expert based measurement.
- Reduce the cost of measuring usability on early phases for selecting the measures on the right time.
- Need a strong communication between developers and usability experts.
- Need a method which provides strong metrics and usability background to those developers which have not strong software engineering background.
- Need an economic usability measurement method which help to produce easy to use software product in limited resources.

In the next chapter, we provide a roadmap, which includes a number of usability evaluation methods and measures that can be used at early phases of the web application development life cycle, and which defines a complete process when and how to measure usability throughout web application software development. The selection of UEMs on proper phase of web application development lifecycle was based on the systematic literature review.
This chapter presents the roadmap we developed to measure usability and user experience for the market oriented web applications. This roadmap was designed on the basis of the systematic literature review (See Chapter 4.).

Figure 15: A Roadmap for Usability and UX Measurement during early phases of software development lifecycle.
The web application development lifecycle consists of different phases (Requirement Analysis, Design, Development, Testing, and Implementation) and every phase has its own requirements and functionalities for measuring Usability and UX. Usually the usability is measured at the end of the software development lifecycle on the implementation phase (Liu 2008).

In this roadmap, the different usability measurement methods and guidelines are associated with the software development lifecycle phases. This roadmap measures the usability on first three phases of the development lifecycle (See Figure 15). The usability measurement and UX measurement on early of phases of web application development reduce the cost and effort of the product (Liu 2008). The quality of the web product analyzed through the better Usability and UX of the product, and it can ensure through by selecting the proper UEM method on specific phase of software development (Liu 2008).

The figure 15 defines roadmap for measuring Usability and UX on early phases of web application development lifecycle. These phases provide the combination of UEMs and the Measures, which helps to measure usability. The UEMs and UX evaluation methods which have been incorporated in the roadmap are supported by systematic literature review (See Chapter 4). The following sections explain the UEMs which can be incorporate on these phases and evaluates the usability.

5.1 Software Requirement Analysis:

Software requirement analysis is the first part of the development lifecycle and also the first part of measuring usability. Requirements analysis is recognized as a most critical part of software development lifecycle, it’s a process of analyzing the system globally, specify the requirements and elaborate the environment where the system will use (Dardenne, Fickas and van Lamsweerde 1991).

At this phase, in addition to all other requirements, Usability and UX requirements are also set. Every software product have different usability requirements, the usability requirements are depends on different factors which are: cost of the product, user requirements, complexity of the product, no of clicks, the technology in which the system is developed (Hu and Chang 2006, Mahrin et al. 2008). So it’s better to define the usability requirements in requirements analysis phase, so that the clear goal for measuring the Usability and UX is available.

There are some UEMs which are associated (See Figure 16) with the different sub-phases of the software requirements analysis phase. The main focus is on defining the usability and UX measures and usability evaluation techniques, the rest of the requirements analysis phase is not discussed in this roadmap. The requirements are specified on the basis of the user needs and goals, and Usability and UX is achieved through achieving the user goals. The following steps define the requirement analysis phase of roadmap.
Figure 16: Usability Measure at Requirement Phase

Figure 16 shows the first part of the roadmap, the UEMs which are associated on this part are mentioned in Table 15, and Table 16 shows the effectiveness of these methods on requirements analysis phase.

5.1.1 Elicit Requirements:
As this roadmap was designed for the market oriented web products, so the focus group was defined for extracting and formulating the software requirement. Elicitation is a process of extracting, formulating and dividing the requirements into a functional points which can be implement as a complete user action (van der Merwe and Kotzé 2007). It defines the preliminary architecture of the specification of the system and elaborates the environment and expressed the requirements in a representation language. The main methods for eliciting the usability requirements from the users are: Interviews and Questionnaires (Goguen and Linde 1993).

5.1.1.1 Focus Groups:
According to ISO/IEC 9126-4, the focus group is best to evaluate the usability requirements of the software product. And also on the basis of the systematic literature review, the focus group is best method to get the usability requirements of the software web product. So, focus group was selected to specify the software requirements and usability requirements.
Focus group recognized as a research method in 1950’s (Templeton 1994). It’s kind of open group interview or discussion of the practitioners. It’s a planned discussion which has some goal of the discussion, specific practitioners, and the members which has interest in the research. Focus groups typically contain 3-12 members moderated by one member, which define the goal and arrange the time and place (Langford and McDonagh 2003). Focus groups follow the predefined structure of discussion defined by moderator. The members selected may be the users of the product, developers, designers, requirements analysts, and usability experts.

The main focus of this discussion is to share the ideas between different users and gets the rich information from different participants. Focus groups mainly provide the qualitative research which produce: fast, insightful information getting, inexpensive and rich information (Widdows 1991). Currently the method is used in different areas like political campaigning, System Usability and UX evaluation and in different business areas (Widdows 1991, Baker 1991, Edmunds 2000, Morgan 1997, Neter and Waksberg 1964, Stewart, Shamdasani and Rook 2006, Rubin and Chisnell 2008).

The focus group can also perform research through electronic media, but it’s not more useful (Lindvall et al. 2002). The guidelines and the procedures for performing the focus group research are explained in (Templeton 1994, Langford and McDonagh 2003, Morgan et al., Krueger and Casey 2008, Nielsen and SunSoft 1997).

Following are the steps for performing the focus group research (Kontio, Lehtola and Bragge 2004).

- Defining the research problem
- Planning the event
- Participants selection
- Conducting the open ended session of focus group
- Report Writing and Data Analysis

5.1.1.2 Usability Requirements:

By defining the usability requirements in the beginning of the project is to ensure that the end product will meet the needs of the users and satisfying the experiences of the users (Bachmann 2004). As the requirements serve as the roadmap of the project, but often the usability and UX is not associated with the roadmap. Usability requirements are the expected behavior of the user reaction to the system (Bachmann 2004). Usability requirements should be defined explicitly early in the requirements phase so that it will help further in the roadmap. The benefits for defining the usability requirements in requirements engineering phase are:

- It provides the roadmap and common way to achieve the user needs on early phases of the development lifecycle.
- It supports usability testing
- Serve as way to achieve user needs.

The usability requirements differ from products to products. The different authors defined different criteria for measuring the usability and user experience (Bachmann 2004). It depends on the cost which will be put on the product for measuring usability. But for common software products the usability requirements are:
The following attributes have been included in this roadmap on the basis of literature review and systematic literature review. These attributes were selected from the ISO 9126 standards. Because most of the literature which we found are using these attributes for measuring usability.

- **Understandability**
  ISO 9126 Definition: Whatever user can understand how to select a software product that is suitable for their intended user and how it can be used for particular tasks.

- **Learn-ability**
  ISO 9126 Definition: “The capability of the software product to enable the user to learn its application.

- **Efficiency**
  ISO 9126 Definition: “The capability of software product to provide appropriate performance, relative to the amount of resources used, under stated conditions”

- **Effectiveness**
  ISO 9126 Definition: “The capability of software product to enable users to achieve specified tasks with accuracy and completeness in specified context of use.”

- **Operability**
  ISO 9126 Definition: “The capability of assessing whether user can operate and control the software.”

- **Attractiveness**
  ISO 9126 Definition: “The capability of assessing the appearance of the software, and will be influenced by factors such as screen design and color.”

- **Usability Compliance**
  ISO 9126 Definition: “External usability compliance metric should be able to assess adherence to standards, conventions, style guides or regulations relating to usability.”

These usability requirements are measured on design and development of the software product. The measures are defined in proceeding sections which are used to measure these usability requirements.

### 5.1.2 Requirements Specification:

As the roadmap have some dependencies, because the usability requirements are defined in the requirements specification. The requirement specification modified iteratively because this roadmap was developed for the market oriented iterative products.
5.1.2.1 Paper Prototypes:

Paper prototypes are highly effective, low cost, and highly used form of testing and evaluating the usability of the software product (Grady 2000). Paper prototypes were incorporated into the roadmap for formulating the sketches of the web application. This technique was selected because of its effectiveness (See Chapter 2).

They are very helpful because they work on the early stages of the software development lifecycle (Grady 2000). Often the developer develops the web sites by using rich components not keeping in mind the needs of the users. And as a result the usability testing is very delayed and completed at the end of the software development. It increases the overhead of the development budget. And the customer may not accept the product due to complex structure, difficult contents etc. The significant redesign of the web site is not possible in some situation due to less time and less budget. The example paper prototype is shown in figure 17.

These are the benefits of using the paper prototypes (Grady 2000):

- Less cost and less resources required, in terms of materials and team required to create the prototypes.
- Significant criticism from the users, which help to improve the flaws and deficiencies in the system design.
- The designers are willing to change the significant changes in the design, but it needs less time and less effort
- Improved Usability and UX.

5.1.2.2 Scenario Based Analysis:

Scenario based analysis is very popular among software engineers for analyzing and validating the requirements (Letier et al. 2005). The main purpose of performing the scenario based analysis to perform the usability analysis on early phases, and it’s
also very cost effective on early stages (Letier et al. 2005). A scenario defines the sequence of interaction between the user and the component. And here we define the process of interaction, and it’s a good way to define an easy process for the user interaction. This analysis is performed iteratively with the requirements elicitation and specification.

Scenarios are a cheap kind of prototypes; it’s developed to reduce the complexity of the system. The use cases, which have been, developed in requirements specification, here we analysis the sequence of interaction and refine the sequence to give the easiness to the user. The scenarios are validated with the paper prototypes, which discussed in the above section.

5.1.2.3 Refined Paper Prototypes:
Here the prototype is refined according to the comments, which has been received from the focus groups for evaluating the paper prototypes on the basis of scenario based analysis. The whole requirements engineering phase of the method is iterative, if there is a need to be change then it can be change, until the good usable and high user experience paper prototypes are achieved.
5.2 Software Designing:

Design is the creative process of figuring out how to implement all of the customer's requirements; the resulting plan is called the design. The early design decision address the system's architecture, explaining how to decompose the system into units, how the units relate to one another, and describing any externally visible properties of the units. Later design decision helps how to implement individual modules (Rost 2005).

Figure 18: Usability Evaluation during design phase

One method for system architecture is call Hofmiester method (Hofmeister, Nord and Soni 2000). It defines the software architecture in conceptual view, module view and execution view. This method starts by the global analysis of different factors that affect the system. These factors are product factors, technological factors and organizational factors.

Software prototyping is software development methodology in which prototypes are created before the actual development of the system. The prototypes are partial functional software development. It simulates only a few aspects of features of the complete software (Pfleeger 2009).
The main purpose of a prototype is to allow software user to evaluate different aspect of software. The main advantage of prototyping is to reduce time and cost. Prototyping also improve the user involvement in software development, this will be helpful for satisfying the user's needs and requirements.

In the traditional software development models most of the time is spend on refinement of different intermediate artifacts and the actual user interfaces are developed at final stages of software development. The main challenge with this approach is that user interface testing cannot be carried out at early stage of software development. It also difficult of user to be part of design process by showing them software specification documents because these documents contains technical terminologies therefore it is hard for user to understand such documents (Nielsen 1993).

The prototype saves time and money. During prototype development either we can reduce the features or we can reduce functionality of the features. Figure 19 shows types of prototypes.

![Figure 19: Prototype Design](image)

**5.2.1 Prototypes types**

**Vertical prototyping:** In vertical prototyping numbers of software features are reduced. Such prototype only contains few selected features but in depth functionality. During the testing of such system actual user can perform tasks in realistic environment which helps to evaluate the usability of software.

**Horizontal prototyping:** In horizontal prototyping the system's level of functionality is reduced. The result of this approach is a fully feature complete user interface but without any functionality. In horizontal prototype the testing is carried out on complete interface but user cannot perform real tasks on system without functionality.

**5.2.2 Usability testing methods**

Usability testing methods are used to ensure that a website is satisfy user needs or not by identifying usability issues. For usability evaluation and for the identification of usability issues, it is necessary to select a suitable testing technique.
A number of usability evaluation techniques can be applied on the design phase of software development lifecycle (See Chapter 4). The UEMs are again listed in table 15.

Every testing technique has different requirements; by applying different testing techniques different usability problems could be identified. That is why many usability professionals often suggests using different testing techniques (Ivory and Hearst 2001b). To choose which testing technique to employ depends on the strengths and weaknesses of that technique, also its applicability with regards to the researcher’s objectives. For our proposed roadmap we have selected heuristic evaluation to evaluate the usability. This technique has been selected on the basis of the factor like time required, number of users, number of evaluator and equipment required (Holzinger 2005). Table 18 shows the different factors of each testing techniques. The systematic review helped us to identify the suitable techniques for our proposed framework

Table 18: Usability Evaluation Techniques on Design Phase

<table>
<thead>
<tr>
<th></th>
<th>Heuristic Evaluation</th>
<th>Feature Inspection</th>
<th>Guideline Checklist</th>
<th>Thinking Aloud</th>
<th>Coaching Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time needed</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>User required</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3+</td>
<td>30+</td>
</tr>
<tr>
<td>Required evaluators</td>
<td>3+</td>
<td>3+</td>
<td>1-2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Equipment needed</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Required Expertise</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

5.2.3 Heuristic evaluation

“Heuristic evaluation is a systematic inspection of a user interface to examine if the design is in compliance with recognized usability” (Blandford et al. 2004). The heuristic evaluation technique was designed by Nielsen, Nielsen and Molich defined ten basic rules known as heuristics for heuristic evaluation (Nielsen and Mack 1994). A group of professionals follow these rules ‘heuristics’ defined in (Nielsen 2005) to identity usability problems in the system (Dix et al. 2004).

Desurivre observed that by using heuristic evaluation usability professionals not only discover problems in systems interface but also recommend the improvements in the system (Heather and J. C 1993) (Kan Peng, K. Ramaiah and Foo 2004). According to Nielson heuristic evaluation gives better results when performed on operational systems. Nielsen also described that usability professionals give better results than non professions in a study conducted on heuristic evaluation (Nielsen 1992).

The main drawback of heuristic evaluation is that it requires an expert evaluator; another drawback is that several experts are required. According to J.Hom, Heuristic Evaluation can be applied on different stages of development like: design, code, deployment and test (Hom 2009). Usually four usability experts
required for usability evaluation also Heuristic Evaluation covers only two usability issues that is effectiveness and efficiency but not satisfaction (Hom 2009).

The ten heuristic were proposed by the Nielsen, which are widely used for conducting the heuristic evaluation. The ten Nielsen heuristics are described in the following table.

Table 19: Ten Heuristics of Nielsen

<table>
<thead>
<tr>
<th>Heuristics</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>User control and freedom</td>
<td>The system has the functionality to undo and redo functionalities, as the user performed the wrong task so he/she must have the way to exist from the undesired state.</td>
</tr>
<tr>
<td>Error Prevention</td>
<td>Use the options for confirmation, user must commit the action. So that user prevents the errors and problems.</td>
</tr>
<tr>
<td>Visibility of the System Status</td>
<td>The user must know always about the status from the systems feedback. The user must know whether it is logged in or not.</td>
</tr>
<tr>
<td>Recognition rather than recall</td>
<td>Make the options and actions more clear, so that user doesn’t need to memorize and recall anything. It’s not a good practice that user remembers different options at different levels of the application.</td>
</tr>
<tr>
<td>Aesthetic and minimalistic design</td>
<td>The system provide only the relevant information, the irrelevant information reduce the visibility and usability of the product.</td>
</tr>
<tr>
<td>Help and documentation</td>
<td>The system must have the relevant documentation and help manuals, so that the user can learn anything about the system.</td>
</tr>
<tr>
<td>Flexibility and efficiency of use</td>
<td>The system has the ability that accommodates the inexperience and experience users. The users can tailor the last actions which they perform.</td>
</tr>
<tr>
<td>Help users recognize, diagnose and recover from problems</td>
<td>Errors messages should be clear and understandable. The problem is clearly defined and should suggest a possible solution.</td>
</tr>
<tr>
<td>Match between system and real world</td>
<td>The system must have mapping of the real world of the system. And system must the logical behavior rather than oriented.</td>
</tr>
<tr>
<td>Consistency and standards</td>
<td>The terminologies and words which can be used in the system follow the standards and must be consistent in the whole system. The terminologies used must be logical.</td>
</tr>
</tbody>
</table>

On the basis of results of systematic literature review, we found out that heuristic evaluation method was best suitable evaluation method during the design phase of software development (See Chapter 4), the other methods can be used to evaluate usability, but it depends on the cost, time and usability requirements of the product.

5.2.4 Usability Measures:
This ISO standard was developed by International Electrical technical Commission (IEC) for Software Engineering – Product Quality to provide a comprehensive specification and evaluation model for the quality of software
products. After performing the detailed literature review and systematic literature review, it has been analyzed that most of the measures are extracted from the ISO 9126 Standard. There were criticisms of the first version of ISO/IEC 9126 suggesting it was not comprehensive, was difficult to understand, and arbitrary with respect to the selection of characteristics and sub-characteristics some of which were unverified and perhaps unverifiable.

However, the standard was substantially revised in 2001 and 2002, therefore we used an approved international standard as our starting point. And it’s very good to incorporate the measures on this phase with UEMs. Organizations may be persuaded to adopt ISO/IEC 9126 because it is an international standard addressing an extremely important concern i.e. the quality of software. It is therefore important that use of ISO/IEC 9126 be properly tested and evaluated. Furthermore, it is surprising that, unlike SPICE, ISO/IEC 9126 has not been subject to a formal evaluation as part of its production process. The measures extracted from ISO/IEC 9126 standard are mentioned in Appendix A. The measures used at this phase were related to Understandability, Learnability, and Attractiveness.

5.3 The Development Phase

During the development phase, the software development team develops the components either from scratch or by composition (Pfleeger 2009). In the implementation phase the architecture document from the design phase and the requirement document from the analysis phase are used to develop exactly what has been requested, though there is still room for innovation and flexibility.

For example, a component may be narrowly designed for this particular system, or the component may be made more general to satisfy a reusability guideline. The architecture document should give guidance. Sometimes, this guidance is found in the requirement document. The implementation phase deals with issues of quality, performance, baselines, libraries, and debugging (Rost 2005).

Figure 20: Usability Evaluation during development
Prototypes are very valuable for performing usability in early development phases. Prototypes help the involvement of users in development process. With the help of prototype users can understand system in much better way (Pfleeger 2009).

The prototyping techniques help to perform usability testing and require little effort while implementation. The prototypes are used to test by using usability evaluation techniques. The most common techniques for prototyping are.

**Paper mock-ups:** At the start of the design process, the designer creates paper prototypes for the user usually with pencil drawings or printouts of screen designs. The designer will act as the computer, showing the user the next element when a transition between graphical elements occurs (Preece et al. 2002).

**“Wizard of Oz” technique:** A human expert acts as the system and answers the user’s requests, without the user’s knowledge. The user interacts normally with the screen, but instead of using software, a developer sits at another computer (network-connected to the user’s computer) answering the queries. The user gets the impression of working with a real software system, and this method is cheaper than implementing a real software prototype (Preece et al. 2002).

**Scenarios, storyboards, and snapshots:** A scenario describes a fictional story of a user interacting with the system in a particular situation; snapshots are visual images that capture the interaction occurring in a scenario; and storyboards are sequences of snapshots that focus on the main actions in a possible situation. They make the design team think about the appropriateness of the design for a real context of use, and they help make the process user-centric (Preece et al. 2002).

**Remote Testing:** Usability testing during the implementation phase is through the analysis of typical end users interacting with system. Recently the concept of "virtual" usability engineering which involve remote testing, has emerged (Nielsen 1993).

In remote testing all human-computer interaction is recorded on video and also audio-recording all subject as they interact with system prototypes. This techniques is known as think aloud while interacting with the system. The majority of usability problems and challenges can be identified and summarized by the data collected during remote testing (Nielsen 1993). During this process subjects are verbalized their thoughts while performing a task. The complete audio and video recording of the interaction can be analyzed using coding and classification of user problems (Kushniruk, Patel and Cimino 1997). The resulting information is from this evaluation summarized and presented to designer, allowing iterative changes to the system.

The development is an important phase of the software development lifecycle. Because the software is developed in this phase, and at the end we have a complete running software product. The software is developed on the basis of the software requirements and usability requirements which we have been discussed in the previous sections. In this phase, the usability requirements are verified on the basis of the usability requirements through appropriate UEMs. The appropriate UEMs which can be used on the development phase are mentioned in chapter 4.
5.3.1 Cognitive Walkthrough:

Cognitive walkthrough is a usability evaluation method in which the evaluators examine the step-by-step task of the user (Holzinger 2005). The method is focus on the Learnability of the software product, and it evaluates that the user needs how much time to learn the system.

Cognitive walkthrough is an exploratory learning method, which can be used where no helping material and documentation is provided. This method can be used on the early stages of software development phase, but the best phase is coding phase (Holzinger 2005). The no of experts of 1-4 can be used to evaluate the usability of the product; these experts can be the software developers.

This method is very popular in a software engineering community because it can be used where you don’t have usability experts (Allendoerfer et al. 2005). Cognitive walkthrough session is performed on the basis of the success and failure stories which called the action sequences. These action sequences must be prepared and handover to the evaluators before starting the cognitive walkthrough session.

The action sequences helped in two ways: this provides feedback for improving the design of the product, and it’s also providing the possible sequences to reach the destination efficiently. Sometime the user feels that he/she is on the wrong way, but that way also leads to the right path due to the different intention of the designer (Allendoerfer et al. 2005).

It is analyzed that the more details provided to the evaluators can affect the problems identification in cognitive walkthrough session. The more information provided helps to identify more problems. Its better if the evaluators create their own action sequences (Wharton et al. 1994). To perform the cognitive walkthrough session, the evaluators must know the following (Wharton et al. 1994):

- Running prototype of the system
- User tasks
- Action Sequences list

On the basis of the results of the systematic review, cognitive walkthrough has been included in our usability evaluation roadmap on development phase due to the fact that we identified this technique as one of the most effective ones after our systematic literature review. (Please see Table 15 for the effectiveness of the methods that can be used in the development phase of web application development lifecycle).

5.3.2 Usability Metrics at Development Phase

Following usability measures has been included in the roadmap at development phase; the selection was based on literature review: Understandability, Learn ability, Efficiency, Effectiveness, Operability, Attractiveness, and Usability Compliance.

Appendix A shows the usability metrics, which have been collected from different literatures and ISO standards. These can be used to measure the Usability during the development phase of software.

2 Action sequences describes the user perform the task (Allendoerfer et al. 2005)
6  CASE STUDY

CHAPTER 6

We conducted a case study in order to validate the roadmap and the effectiveness of the Usability and UX methods and techniques that are included in the roadmap to be implemented during early phases of the web application development lifecycle.

6.1 Introduction of Case Study:

Software engineering consists of software development, execution, and maintenances of software and related artifacts (Jedlitschka and Pfahl 2005). The main focus of research in software engineering is at investigating how this development, operation, and maintenance are conducted by software engineers and other stakeholders under different conditions. Individuals and organizations are involved in software development and social and political questions are significant for this development. That is, it consists of different discipline and case studies are conducted in these disciplines. This means that many research questions in software engineering are suitable for case study research (Runeson and Höst 2009).

Case study is defined as studying phenomena in their context. Case studies provide an approach that does not require strict boundary in study object and its context, the key is to understand relationship between both (Shull, Singer and Sjøberg 2007).

There are five major steps while conducting a case study (Runeson and Höst 2009)

1. Design of Case study.
2. Data collection preparation
3. Evidence collection.
4. Data Analysis
5. Reporting

6.1.1 Structure of Case Study:

The case study was organized in a Company X, and performed on the market oriented software product of the company. The case study structured with defining the design and plan of performing the case study, defined the research questions, and defined the methods, protocol, then analysis and interpretation of the results. The following sections explain the structure in more details.
6.1.2 Design and Planning:

6.1.2.1 Objective:

We had two objectives in this case study:

- To validate the web usability and UX evaluation methods and the measures, which has been incorporated in the roadmap by evaluating their usability during specific phases of web application development lifecycle?
- To validate the roadmap itself by evaluating its usefulness in improving the usability and UX of the Web applications.

The first objective was achieved by performing interviews in the company after the implementation of usability and UX evaluation methods and the measures incorporated in the roadmap during the case project.

The second objective was achieved by implementing the roadmap and checking the results whether it improves the usability and UX.

6.1.2.2 The Case:

The case study was performed in the Company X on the real time market oriented product MyPlejs which is related to search the apartments for short term and long term in Stockholm. We performed a holistic case study (Runeson and Höst 2009), where we put the case in one context, as our context is to measure the usability on early stages of software development lifecycle.

Figure 21: Holistic Case Study (Runeson and Höst 2009)

6.1.2.2.1 Case Organization:

Company X has branches in Gothenburg and Stockholm in Sweden. They started a new department for developing web products in Stockholm in early 2009. The company provides the services like web design, web applications development, logo design, E-Commerce market oriented products and office automation. The company has big product which is related to the searching for apartments for short and long term in Stockholm. The company is product based, and has skilled developers, designers and project manager.

6.1.2.2.2 Case Product:

The product named as MyPlejs was selected for performing the case study. MyPlejs is related with the apartments searching in the Stockholm. It provides the following services:
- Search for an apartment for bed and breakfast, it is short term contract with the landlord may be for 2-3 nights.
- Search for an apartment for long term, which is 6-12 month contract with the landlord.
- Landlords upload the apartments on the website for searching tenants for their apartments.

![Figure 22: Screen Shot of MyPlejs](image)

The beta version of this product was launched; it’s deployed for beta testing. We were in the development team of the product, and we had developed some modules of this product. The product was developed with high motive of enhancing the usability and UX during the development of the product. And the thesis study is also related to the measurement of usability and UX on early stages of the web application development lifecycle. The figure 22 shows the screen shot of the web product.

### 6.1.2.3 Research Questions:

The following research question answered while performing the case study:
- Are the web usability and UX evaluation methods and the measures are effective, which has been incorporated in the roadmap usable during specific phases of web application development lifecycle?
- Is the roadmap effective in improving the usability and UX of the Web applications by incorporating different Usability and UX evaluation methods and techniques from the early phases of the life cycle?
6.1.2.4 Methods:

There are three types of methods used to perform the case study (Runeson and Höst 2009), which are:

- Direct Method i.e. Interviews
- Indirect Method i.e. Observations
- Independent i.e. Documentation Analysis

As we were in the development team of product, we used all three methods for collecting the data.

6.1.3 Case Study Protocol:

The case study protocol serves as guideline for design decisions and also defines the field procedures. Case study protocol helps to collect data in systematic manner. It also helps to make research concrete during the planning phase that may help to select data sources to use.

Our case study protocol contained the following contents, which helped us for executing the case study:

- The research questions for performing the case study, which has been described in the section 6.1.2.3.
- The data collection methods which were used for collecting the data for executing the case study, which has been described in the 6.1.2.4.
- The objectives which we wanted to achieve from the case study are described in the 6.1.2.1.
- The interview structures and details, and what were the purpose of specific meetings, which has been described in section 6.1.4.1.
- The interview questions which has been asked while performing the interviews which are mentioned in Appendix C.
- The documentation of the case product which helped to perform the usability and UX evaluation methods and measures.

The case study has been conducted while working within the company as software developers and also with the help of meetings and observations. The purpose of working in company was author’s background and experience in web application development. Second reason was to understand the challenges in actual working environment in web development organization and to collect the evidence for research validation.

6.1.4 Data Collection:

Data collection is an important part of any case study. Several sources can be used in case study to collect data and several data sources also helps to insure the validity of collected data. For our case study we used three different sources to collect data which are: interviews, observations and documentation.

6.1.4.1 Interviews:

The main source of information in this case study was interviews. The interviews were conducted within the case organization. The interview questions (See Appendix C) were based on systematic literature review results and on the formulated research questions. We used both open end and closed end questions
during the interview. The interview conducted in semi structure manner i.e. questions were planned but additional question were added during the interview.

Interviews were divided into four sessions and were conducted during the different phases of software development lifecycle i.e. Requirement phase, design phase and development phase. The participants selected for performing the interviews were: 3 developers, 1 project manager and 1 usability expert.

The first meeting was related to the introduction of the current system which the company was using. In this meeting, first the authors introduce themselves and discuss the purpose of the performing the case study, as the thesis study was performed according to the requirements of the company, so this meeting were more predefined goals. The process which company needed to improve the Usability and UX measurement was the main agenda of the meeting. In second meeting, the different measures and measurement methods discussed, for measuring Usability and UX on requirements analysis phase, the discussed process is described in section 5.2.1. This process includes usability measurement methods, which had been defined on the basis of interviews and literature review.

In the third meeting, the Usability and UX measures and measurement method which can be used to measure the usability on software design phase. The measures selected in interview were defined in section 8.3.5. And the fourth and last meeting was performed to finalize the measures which can be used to measure the Usability
and UX on development phase. These measures were selected by calculating the measures on the market oriented product and by evaluating the results. The selected measures for measuring the usability of the market oriented product MyPlejs were defined in the section 8.3.5.

6.1.4.2 Observations:
As the authors were the part of the software development team, we could have made observations and collect data which were relevant to the case study. This also helped to gain deep understanding of the actual challenges faced in an organization. Moreover the authors also analyzed that how the web companies overcome these challenges in a limited time frame.

6.1.4.3 Documentation:
The third source of information used was software project documents. There were minutes of meetings, project management plan, software requirement specification, software detail design, and organizational charts and company’s database.

6.1.4.4 Analyses and Interpretation:
The defined roadmap for measuring Usability and UX had been discussed in the interviews and then validated by implementing it during the case product development life cycle.

The case study was performed on the basis of the two objectives, which are described Section 6.1.2.1. As the roadmap has three parts which are associated with the early phases of web application development lifecycle, when conducting the case study, continuous feedback about the usability and usefulness of them were get about the methods and the measures which are associated with the roadmap during the interviews. After the product is developed, whether the final product improved with respect to usability and user experience by using the roadmap is assessed.

For validating the first part of roadmap, a focus group (3 developers, 1 project manager, and 1 usability expert) was formed to use the usability and UX measurement in the requirements engineering phase of the roadmap. As this roadmap was designed for measuring the Usability and UX of market oriented web products, so the focus group was the main source for providing the requirements of the products.

When the authors start performing the case study, the product MyPlejs was in a development phase and the design was not finalized. As this product was developed in an iterative software process model, the requirements were changing day by day. Before performing the case study, the scale for evaluating the usability requirements has been defined, as the usability attributes was measured between 0-1. The required usability scale was defined by 0.7; it’s finalized by performing the interview with the company.

The authors discussed the different UEMs and UX methods which are more effective on the web application requirements phase (see Table 15).
The authors started collecting data while implementing the requirements part of the roadmap working with the focus group along with the requirements which the company had defined for MyPlejs. On the basis of the requirements and perceptions of the focus group the authors designed the paper prototypes. The figure 24 shows the paper prototype of the product.

The Usability testing on paper prototyping was performed in two days. Each day, three users evaluated the paper prototypes. The users were selected so that they did not know anything about the product and no one told about the practical use of the product before performing the test. And the test was performed on the basis of some scenarios that have been designed in the form of flowcharts. On the basis of the scenarios the users analyzed the paper prototypes of the product. The scenarios are described in Appendix B. The users gave some comments and the comments had been documented. After performing the 30 min test of each user on paper prototype, the authors discussed the comments with the focus group. The paper prototypes were refined according to the comments of the users. The users rated the paper prototypes on the basis of the scenarios. A rating scale between 1-5 was used. The rating scale was defined according to the following:

- 5: Highly Usable
- 4: Very Usable
- 3: Useable
- 2: Low Usable
- 1: Not Usable

The following figure shows the ratings of each user on paper prototypes.
After implementing the usability and UX measurement in the requirements engineering phase of the roadmap, an interview was made with the focus group. The results from the paper prototypes and the feedback from the users show that paper prototypes are very helpful in understanding the flow of the application. They stated that although other methods (See Table 14) can also be used during the requirements phase, the paper prototypes were very helpful in visualization of the web application. And with the visualization, the users have much clearer idea of the product. But it’s very hard to generate the project documentation of paper prototypes and collaborate with the larger teams.

The feedback from the focus group shows that, the paper prototypes is a good source for implementing the design of the product on early phase like requirements engineering. The feedback from the users shows, it gives the global view of the web product; it’s also a very good source for implementing the software architecture of the web product. It has been analyzed that, for evaluating the paper prototypes, there should be some scenarios which help to analyze the flow of the web product. And the roadmap provides the good combination of UEMs on requirements phase, because at the end of the requirement engineering phase the paper prototypes is a good artifact to design the web product.

In the design phase of the roadmap, the authors executed the same procedure which they followed in the requirements phase. First they had discussed the different UEMs and UX methods on design phase with the company by presenting the table 15. And analyze that which methods are suitable for the company and for the product. On design phase there was also some measures which were extracted from the ISO standards, mentioned in Appendix A. After discussing with the company, the authors finalized the best suitable methods and the measures for design phase.

On the basis of the UEMs and UX methods and the measures, the following usability attributes were measured for checking the effectiveness of the selected methods:
- Understandability
- Learnability
• Attractiveness
• Usability Compliance
• User Experience

The measurement was performed on the basis of the data which has been collected from Company X for the product MyPlejs. First, the heuristic evaluation was performed on the basis of the ten heuristic principles which have been described in section 5.2.2.3. The heuristic evaluation performed by 4 experts which has knowledge of performing these heuristics.

Each expert performed the evaluation individually. They looked at the designed user interfaces of the product, on the basis of the scenarios which has been described in Appendix B. The requirements specification was also provided to the experts, so that they had clear mindset. They experts went through the interface twice and evaluated them on the basis of scenarios.

Every expert documented their findings on the report. All the documented reports were then collected and compared. The moderator wrote a summarized report on the basis of the reports collected from the experts. The report helped a lot for evaluating the usability of the software web product, because it has all summarized evaluations of the tasks of the web product, which helps to improve the quality of the web product.

And then secondly, the usability attributes was measured on the basis of the metrics identified from the ISO standards. These measured usability attributes at design phase are visualized in the following graph.

![Usability And UX at Software Design Phase](image)

Figure 26: Usability and UX at Design Phase

The design phase of the roadmap provides some metrics and evaluation method for evaluating the usability and UX which has been shown in Figure 26. Here the design phase of the roadmap the UEMs (See Table 14) other than heuristic evaluation can also be used on the basis of conditions of application of UEMs. But as Table 16 shows that heuristic evaluation was found to be more effective than the other UEMs on design phase, so that’s why its selected for design phase. The
feedback from the evaluators was also very good for heuristic evaluation. Table 26 shows the effectiveness of the selected UEMs and UX methods and measures, which has been selected for the design phase of roadmap.

The results from heuristic evaluation were on the basis of the Nielsen Heuristics (See Table 20). And also the other measures for evaluating the usability incorporated on this phase which results have been shown in figure 26. And the figure 26 shows that the usability and UX is very good at design phase. And this is also connected with the first phase of the roadmap in which the paper prototypes was created.

For validating the third and last part of the roadmap, we performed the same procedure which they followed during the design phase. First we discussed in the company all possible UEMs and UX methods which can be implementable in this phase. And on the basis of the effectiveness of the UEMs and UX methods they selected the cognitive walkthrough method. The measures were also discussed with the company and the selected measures on development phase are mentioned in Appendix A.

The cognitive walkthrough method (See Section5.3.1) was used to measure the usability of the web product at development phase. The four experts (3 developers and 1 usability expert) evaluated the web product at development phase of the roadmap. As cognitive walkthrough is an exploratory method, so they explore the different features of the product, and validate with the different scenarios (See Appendix B) of the product.

The validation of the usability requirements with the scenarios at design and development phase of the roadmap, also ensure the required usability and UX at design and development phase. Because at each phase of the roadmap, the validation was performed on the basis of scenarios.

The understandability and Learnability again measured on the development phase because there were some measures which couldn’t be applied on the software design phase. The measures are described in Appendix A. The measurement is visualized in figure 27.
At the end of the development phase of roadmap, the required usability is ensuring the usability requirements (See Section 5.1.1.2) which were defined in the requirements analysis phase of the roadmap. The required usability was ensured with the required usability scale which was defined in the beginning of this section. All the attributes have reached 0.7, which shows that the required usability is achieved after implementing the roadmap. Table 27 shows the effectiveness of the UEMs and UX evaluation methods and measures which has been selected for development part of the roadmap.

The required usability scale can also be defined more than this; it depends on the resources which the company used to ensure the usability. And it can also be improved through more users and usability experts. It’s also effects according through the size of the company and the size of the product of which the usability is measured.

As these attributes (See figure 27) usually measured on the development phase, but in the roadmap there are some UEMs which can help to improve usability and UX before the development phase. This helps to reduce the overhead to enhance the quality of the web product. And the UEMs at different phases of roadmap make a comprehensive way of evaluating the UEM and UX, its helps a lot to ensure the required usability and UX which has been defined for the product.

On the basis of comments and feedback of the experts which evaluates the usability at different phases of roadmap, this roadmap provide the systematic way to evaluating the usability and UX. In a traditional way of evaluating usability UX, in which it’s evaluate at the end of development phase, the changing in the design enhance the cost of the product. So, with the help of this roadmap, the risks can be minimized with the help of different UEMs and measures which incorporated on different phases.

### 6.1.5 Discussions of the Results

The above graphs shows the measured usability and UX on requirements, design and development phase. Based on the feedback received during the case study, the
authors come up with some suggestions and recommendations while applying measures on the product, which are as follows:

- Usability and UX are very much interlinked with the web application development lifecycle. So it’s better to measure on early phases.
- This roadmap requires more users to perform the test, and the focus group must include members of software development team and the users which will use the product.
- For testing the paper prototypes, the scenarios must be defined in a simpler way. It’s a good way to visualize them with the figures.
- For measuring the UX, the test must be performed by more users. From the case study and the feedback from company shows that, the more users perform the test to evaluate the design, the more the product will meet the needs of the users.
- As usability is not tied with the one phase of software development lifecycle, so the measurement on early phases increases the chances of quality product.
- On requirement analysis phase, it’s better to define the usability requirements. As these requirements are different in different web applications, like in any application may be understandability is much important than the attractiveness. Before measuring the usability, the clear goals for measurement could be define.
- As UX was measured on design and development phases, from the case study it has been analyzed that, the more users according to the target market of the product perform the test.
This chapter presents the main discussions of this thesis.

The systematic review revealed that the major challenges that are faced during usability and UX evaluation. These challenges are Ad hoc development, subjective and objectivities usability measures and short development time. (Section 4.4.2.2)

The roadmap which developed after thorough systematic review and by conducting case study helped us to identify the need of such road. This roadmap provide a guideline for Web Development Companies and with the help this roadmap they can enhance web usability and UX, this will also reduce the development cost of a software product (section 5)

The case study and systematic review helped us to identify most suitable UEM to achieve good results, it’s important for the web companies to pay more attention on the selection of UEM. The efficiency is not only related with the proper selection, it’s also includes the proper implementation of the UEM, which includes the artifacts, and the proper selection of resources.

For creating the paper prototypes of the web application, it’s important to put the specific colors for the specific links, so that the evaluator easily navigates on the links. The drop down menus seems to be challenge and difficult to manage, so it’s better to manage it through accordion. Such it’s easy to expose the back side of the option. When you click on the menu, just pull down the accordion. Don’t create another paper if the change is little; just to put the change with fluid. By showing the no of pages to the evaluator, must create the switch board on which all the links shown, so that the evaluator have a good idea and navigation of the pages.

On the basis of feedback from company and literature review we concluded that heuristic evaluation is a very effective way of measuring the usability. For implementation of heuristic evaluation, it’s necessary to provide all the resources to the evaluators and provide the information, which needs for evaluation. For getting the best results from heuristic evaluation, its better that evaluators have enough experience to perform the heuristic evaluation. The moderator must summarize the evaluations of the different experts for avoiding the duplications of the records.

For performing the cognitive walkthrough, there should be predefined goals. These goals can be related to the user action or system action like to check the spelling of the web page. The evaluator performs the action in this way, which leads to the destination of the action. The scenarios or stories with a clear goal should be defined before performing cognitive walkthrough.
One of the observations during the case study conduct was that it is very hard to change the mindset of the developers and evaluators who are used to measure the usability and UX at the end of the implementation phase. The proposed roadmap of UEM and UX is one solution which can help developer and evaluator solve this problem. According to the feedback form company investing little more time on the product, the quality product can be developing and user will be happy with the product.

The complete, clear and unambiguous requirements lead to the selection of the appropriate UEMs on the proper phases of development lifecycle. And for selection of UEMs, you have also clear usability requirements; it helps to put the UEMs on specific phase accordingly.

We identified a need for the software organizations to train the software developers how to elicitate the usability requirements. We observed that developers don’t know much about the usability, and they don’t have knowledge of the UEMs. The software developers and project managers require improving their knowledge on usability requirements elicitation and measurement for producing a user focused quality product.

The usability evaluators should be involved in the whole software development lifecycle, so that they feel their responsibility in the team. The evaluator’s involvement in the requirements elicitation process is important for the usability evaluation point of view. And it’s also very important to reduce the communication gap between the team members and the evaluators.

As the web companies developed the software product on ad-hoc basis (See Section 4.3.2), it’s necessary to form a well defined process of developing a high quality product. And in this case, the usability is tested at the end of the implementation, which increases the overhead and delivery time of the product. But with the help of proposed roadmap this overhead cost can be reduced and they can measure usability during early stages of software development.

The subjective and objective measures both lead to the different results while measuring the usability of the web interface (See Section 4.3.2). It has been analyzed that the selection of these measures is important, objectives measures can be generalized for the different web applications, but the subjective measures can be different according to the nature of the web application. And subjective measures should be defined according to specific product.

The purpose of this roadmap is to ensure the usability on early phases of development lifecycle, so it’s necessary for the proper selection of the UEMs for the specific phase. The selection also includes the different factors which have been discussed in systematic literature review (See Chapter 4). It can be possible that the one best method could not be apply in any situation, so the best way is to implement the proper method on the proper situation. This roadmap helps to measures the usability and UX in web applications especially in real estate applications.
CHAPTER 8

8 VALIDITY THREATS

Validation is an important part of any type of research whether qualitative or quantitative. The validation improves the credibility and accuracy of research. There has been different validity threats in every type of research (Internal, external, construct, conclusion). (Wohlin et al. 2000)

The following validity threats were considered during this thesis

8.1 Internal validity

One validity threat for the systematic review was the “research bias”, i.e. publication can be selected on the basis of researcher expectations. In order to avoid this bias, both authors were involved in every step of the systematic review execution. A data extraction of the same pilot articles to ensure the same level of understanding. The same procedure was performed to gain a common understanding of the study quality assessment data. Another threat was inadequate conduct of the systematic review. It means that the evidence that has been gathering during the systematic review execution is not sufficient to analysis and to make decision on the basis of systematic review. This threat was mitigated by following the well-defined review protocol.

Another potential threat was the data extraction procedure. In this thesis the main focus was identify usability and UX evaluation methods, which are clearly mentioned in literature. e.g. in results and we avoided to interpret author’s writing.

Other internal validity threat which was related with this research work, references biasness, to mitigate this threat our main focus was to select peer review research work IEEE and ACM.

8.2 External validity

An external validity threat is related with result generalization (Wohlin et al. 2000). The results of this study are valid only for this industrial context. More case studies should be conducted to evaluate the roadmap in other web development organizations.

An external threat to our research was publication bias in the systematic review. This was because of short time and limit resources. This is a threat to generalize the findings of our research work.
8.3 Construct Validity

Construct validity deals with theory and observation. The major threat is evaluation apprehension, which means there is tendency for subjects to perform well during evaluation (Wohlin et al. 2000). The main aim of constriction validity main threat is evaluation concern, i.e. there is tendency for subjects to perform well during evaluation. But generally subjects are afraid of being evaluated. To mitigate this threat organizations and participants names were kept anonymous.

8.4 Conclusion Validity

The conclusion validity is deals with the reliability of research results. (Wohlin et al. 2000). One such threat was the reliability of extracted data from the systematic literature review. The data extraction forms were tested during the systematic review to overcome this threat.

Another major threat was the case study was conducted in one company; we might not be able to generalize our analysis and findings. This threat could be mitigated if we have more time and resource and by using other type of validation method e.g. survey or experiment in addition to case study.

For threats related to industrial data collections: questionnaire were prepared and discussed with project manager before conducting initial meeting. This questionnaire was designed on the basis of literature review and brainstorming of authors and main purpose was to get knowledge about industry and meeting participant background.
CHAPTER 9

The goal of this study was to investigate the usability and UX measurement for web applications and the applicability of UEMs at early stages of software development life cycle. The systematic literature review revealed that due to tight schedule, the main focus is on meeting the functional requirements of the software product. The less importance is given to the non-functional requirements of the software product. The usability evaluation on last phase increase the cost of the development and it’s very hard to fulfill the requirements of the customers.

The literature review also showed that there are different usability evaluation methods proposed by different researchers but there is not specific Usability and UX measurement roadmap which can be applied during early stages of web application development lifecycle. The literature review also revealed the major challenges in usability and UX measurement. These challenges are ad-hoc software development approach, short time frame, subjective and objective measures, scattered market and cultural issues. This research also showed that there is very close relationship between usability and user experience. The ultimate goal of the thesis study is to improve the Usability and UX of the market oriented web product.

On the basis of literature review and systemic literature review usability and UX evaluation methods were proposed on early phases of web application development lifecycle. The interview results showed that there is a real need of such roadmap which helps the industry to reduce the software cost. And also help industry to satisfy customer needs.

A case study was conducted in a web application development company to validate the applicability of the roadmap we defined. The case was a market oriented web application product. The case study helped to apply the proposed roadmap on specific case. The case study helped to identify the current practices in industry and provide future improvement and suggestion to the organization.

This roadmap will help to identify usability and user experience measures and evaluation techniques during the early phases of web application development lifecycle. The main advantage of this roadmap is that it provides measures from different standards and also provides different measurement methods on different phases which incorporate with software development lifecycle. This mixture makes it more comprehensive for measuring Usability and UX.

Web applications are become integral part of our daily life and the main objective of web development industry to provide user with usable and reliable web products that meets their specific requirement and enhances their user experience. The result of case study shows the importance of usability for web products, but in most cases it is measured at later stages of software development.
In order to conclude we would like to say that usability and user experience are very important non functional requirements which should not be neglected during the requirement engineering, design and development phase. Research to investigate more empirical evidences and insight of industrial practices are a must in order to provide clarity to different perspectives of usability and user experience.

9.1 Research Questions Revisited:

This thesis study was performed on the basis of the five research questions; this section defines that how these questions are answered and where answered in the thesis.

- **RQ1: What are the different definitions, concepts and terminologies of usability, web usability and user experience in literature?**

  Different definitions, concepts and terminologies were identified in thesis study about usability, web usability and user experience. These concepts and terminologies were identifies from literature and international recognized standards. These identified definitions and concepts are explained in chapter 2 and 3.

- **RQ2: What are the usability measures in internationally recognized standards, quality models and literature?**

  This question helps to identify the different measures about usability from literature; these measures are defined in Appendix A.

- **RQ3: What are the Web Usability and UX measurement and evaluation methods that can be used at early phases of software development life cycle?**
  
  - **RQ 3.1:** What are types of usability evaluation methods?
  - **RQ 3.2:** How different UEMs can be categorized on the basis of usability factors?
  - **RQ 3.3:** What is the effectiveness of UEMs during different phases of software development?

  This research question was defined for identifying the different usability and user experience measurement and evaluation methods. This question was answered with the systematic literature review in chapter 4.

- **RQ4: What are the challenges faced by web application development companies while measuring and evaluating the usability and user experience?**

  This research question was defined for identifying the challenges from the literature and from the web application development company. The challenges which identified from the systematic literature review are mentioned in section 4.4.2. These challenges were also compared with the challenges which the web application company faced, discussed in chapter 7.
• **RQ 5: How can the web usability and UX evaluation methods for measuring usability and UX at early stages of web application development lifecycle can be incorporated into a Roadmap?**

  This research question was helped to identify the different web usability and UX evaluation methods and usability measures which can be incorporate in the web application development lifecycle. This research question was answered in chapter 5.

### 9.2 Future Work

The aim of this thesis was to investigate Usability and UX measurement and evaluation methods for web applications. Therefore scope of the study was limited to providing results of the investigation. But during this study we identified the following aspects which required attention and would assert the findings of this study in a better way.

• **Validation of the roadmap with the other types of web applications compares, validate and improve the roadmap according to the results.**

  First and the foremost future work related to this study would be validating the usability and UX roadmap with other type of web applications and then evaluates the effectiveness of this roadmap.

• **Analyze the usability and UX evaluation roadmap for agile environment.**

  This roadmap was developed on the basis of the iterative software development lifecycle. It can be enhanced by analyzing the adoption of this roadmap in agile environment.

• **Find the relationship between the different usability and UX evaluation methods and measures from ISO standard of quality.**

  Another possible future extension of this work can be the relationship between different usability and UX evaluation methods and measures and analyze the tradeoff between these evaluation methods and measures. Studies regarding the customer perspective on usability and user experience also seem to be important from the usability evaluation perspective. Because this would help software developer improving their understanding regarding what the customer expects and fulfill their needs.
10 REFERENCES

CHAPTER 10


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Whitehead, C. 2006. Evaluating web page and web site usability. 789. ACM.


## CHAPTER 11

### Appendix A: Usability Measures at Software Design and Development

<table>
<thead>
<tr>
<th>Metric Name</th>
<th>Description</th>
<th>Measurement Formula</th>
<th>Interpretation</th>
</tr>
</thead>
</table>
| Completeness of Description  | What proportion of functions (or types of function) is described in the product description? | X = A/B  
A = Number of functions (or types of functions) described in the product description  
B = Total number of functions (or types of functions) | 0 <= X <= 1  
The closer to 1 the more complete. |
| Demonstration Capability     | What proportion of functions requiring demonstration has demonstration capability? | X = A/B  
A = Number of functions demonstrated and confirmed in review  
B = Total number of functions requiring demonstration capability | 0 <= X <= 1  
The closer to 1 the more capable. |
| Demonstration Accessibility  | What proportion of demonstrations/tutorials can the user access whenever user actually needs to do during operation? | X = A / B  
A = Number of cases in which user successfully sees demonstration when user attempts to see demonstration  
B = Number of cases in which user attempts to see demonstration during observation period | 0 <= X <= 1  
The closer to 1 the better. |
| Demonstration Effectiveness  | What proportion of functions can the user operate successfully | X = A / B  
A = Number of functions operated successfully  
B = Number of demonstrations/tutorials | 0 <= X <= 1  
The closer to 1 the better. |
<table>
<thead>
<tr>
<th>Metric</th>
<th>Definition</th>
<th>Formula</th>
<th>Range</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evident functions (ISO/IEC 9126-2, 2003)</td>
<td>What proportion of the product functions is evident to the user?</td>
<td>$X = \frac{A}{B}$</td>
<td>$0 \leq X \leq 1$</td>
<td>The closer to 1, the better.</td>
</tr>
<tr>
<td>What proportion of the product functions is evident to the user?</td>
<td>$A = $ Number of functions (or types of functions) evident to the user</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B = $ Total number of functions (or types of functions)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Function Understandability (ISO/IEC 9126-2, 2003)</td>
<td>What proportion of the product functions will the user be able to understand correctly?</td>
<td>$X = \frac{A}{B}$</td>
<td>$0 \leq X \leq 1$</td>
<td>The closer to 1, the better.</td>
</tr>
<tr>
<td>What proportion of the product functions will the user be able to understand correctly?</td>
<td>$A = $ Number of user interface functions whose purpose is understood by the user</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B = $ Number of user interface functions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understandable input and output (ISO/IEC 9126-2, 2003)</td>
<td>Can users understand what is required as input data and what is provided as output by software system?</td>
<td>$X = \frac{A}{B}$</td>
<td>$0 \leq X \leq 1$</td>
<td>The closer to 1, the better.</td>
</tr>
<tr>
<td>Can users understand what is required as input data and what is provided as output by software system?</td>
<td>$A = $ Number of input and output data items which user successfully understands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B = $ Number of input and output data items available from the interface</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learnability</td>
<td>What proportion of functions is described in the user documentation and/or help facility?</td>
<td>$X = \frac{A}{B}$</td>
<td>$0 \leq X \leq 1$</td>
<td>The closer to 1, the more complete.</td>
</tr>
<tr>
<td>What proportion of functions is described in the user documentation and/or help facility?</td>
<td>$A = $ Number of functions described</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B = $ Total number of functions provided</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of function learning (ISO/IEC 9126-2, 2003)</td>
<td>How long does the user take to learn to use a function?</td>
<td>$T = $ Mean time taken to learn to use a function correctly</td>
<td>$0 &lt; T$</td>
<td>The shorter is the better.</td>
</tr>
<tr>
<td>How long does the user take to learn to use a function?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of learning to perform a task in use (ISO/IEC 9126-2, 2003)</td>
<td>How long does the user take to learn how to perform the specified task efficiently?</td>
<td>$T = $ Sum of user operation time until user achieved to perform the specified task within a short time</td>
<td>$0 &lt; T$</td>
<td>The shorter is the better.</td>
</tr>
<tr>
<td>How long does the user take to learn how to perform the specified task efficiently?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effectiveness of the user documentation</td>
<td>What proportion of tasks is described in the user documentation and/or help facility?</td>
<td>$X = \frac{A}{B}$</td>
<td>$0 \leq X \leq 1$</td>
<td>The closer to 1, the more complete.</td>
</tr>
<tr>
<td>What proportion of tasks is described in the user documentation and/or help facility?</td>
<td>$A = $ Number of tasks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B = $ Total of number of tasks provided</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Term</td>
<td>Calculation</td>
<td>Max Value</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>-----------</td>
<td>------------------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>and/or help system (ISO/IEC 9126-2, 2003)</strong></td>
<td>tasks can be completed correctly after using the user documentation and/or help system?</td>
<td>1.0</td>
<td>1.0 is the better.</td>
<td></td>
</tr>
<tr>
<td><strong>Effectiveness of the user documentation and/or help systems in use (ISO/IEC 9126-2, 2003)</strong></td>
<td>What proportion of functions can be used correctly after reading the documentation or using help systems?</td>
<td>X = A / B</td>
<td>0&lt;=X&lt;=1 The closer to 1.0 is the better.</td>
<td></td>
</tr>
<tr>
<td><strong>Help accessibility (ISO/IEC 9126-2, 2003)</strong></td>
<td>What proportion of the help topics can the user locate?</td>
<td>X = A / B</td>
<td>0&lt;=X&lt;=1 The closer to 1.0 is the better.</td>
<td></td>
</tr>
<tr>
<td><strong>Help frequency (ISO/IEC 9126-2, 2003)</strong></td>
<td>How frequently does a user have to access help to learn operation to complete his/her work task?</td>
<td>X = A</td>
<td>0&lt;= X The closer to 0 is the better.</td>
<td></td>
</tr>
<tr>
<td><strong>Attractiveness</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Attractive Interaction (ISO/IEC 9126-3, 2003)</strong></td>
<td>How attractive is the interface to the user?</td>
<td>X=A/B</td>
<td>Assessment Classification</td>
<td></td>
</tr>
<tr>
<td><strong>User Interface appearance customizability (ISO/IEC 9126-3, 2003)</strong></td>
<td>Does user interface is flexible to customize according to user needs?</td>
<td>X=A/B</td>
<td>0 &lt;= X &lt;= 1 The closer to 1, the better</td>
<td></td>
</tr>
<tr>
<td>Metric</td>
<td>Description</td>
<td>Formula</td>
<td>Interpretation</td>
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<tr>
<td><strong>Efficiency:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>- Time Behavior Metrics: Response Time</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Response Time</strong> (ISO/IEC 9123-2)</td>
<td>What is the time taken to complete a specified task?</td>
<td>$T = (\text{time of gaining the result}) - (\text{time of command entry finished})$</td>
<td>$0 &lt; T$ The sooner is the better.</td>
<td></td>
</tr>
<tr>
<td><strong>Response time</strong> (Mean time to response) (ISO/IEC 9123-2)</td>
<td>What is the average wait time the user experiences after issuing a request until the request is completed within a specified system load in terms of concurrent tasks and system utilization?</td>
<td>$X = T_{\text{mean}} / T_{\text{Xmean}}$ [ T_{\text{mean}} = \frac{\sum (T_i)}{N}, \text{for } i=1 \text{ to } N ] [ N = \text{number of evaluations (sampled shots)} ] [ T_i = \text{response time for i-th evaluation (shot)} ]</td>
<td>$0 \leq X$ The nearer to 1.0 and less than 1.0 is the better.</td>
<td></td>
</tr>
<tr>
<td><strong>Response time</strong> (Worst case response time ratio) (ISO/IEC 9123-2)</td>
<td>What is the absolute limit on time required in fulfilling a function? In the worst case, can user still get response within the specified time limit? In the worst case, can user still get reply from the software within a time short enough to be tolerable for user?</td>
<td>$X = \frac{T_{\text{max}}}{R_{\text{max}}}$ [ T_{\text{max}} = \text{MAX}(T_i) \text{ (for i=1 to N)} ] [ R_{\text{max}} = \text{required maximum response time} ] [ \text{MAX}(T_i) = \text{maximum response time among evaluations} ] [ N = \text{number of evaluations (sampled shots)} ] [ T_i = \text{response time for i-th evaluation (shot)} ]</td>
<td>$0 \leq X$ The nearer to 1.0 and less than 1.0 is the better.</td>
<td></td>
</tr>
<tr>
<td><strong>- Time Behavior Metrics: Throughput</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Throughput</strong> (ISO/IEC 9123-2)</td>
<td>How many tasks can be successfully performed over a given period of time?</td>
<td>$X = \frac{A}{T}$ [ A = \text{number of completed tasks} ] [ T = \text{observation time period} ]</td>
<td>$0 &lt; X$ The larger is the better.</td>
<td></td>
</tr>
<tr>
<td><strong>Throughput</strong> (Mean amount of throughput) (ISO/IEC 9123-2)</td>
<td>What is the average number of concurrent tasks the system can handle over a set</td>
<td>$X = \frac{X_{\text{mean}}}{R_{\text{mean}}}$ [ X_{\text{mean}} = \frac{\Sigma (X_i)}{N} ] [ R_{\text{mean}} = \text{required mean throughput} ] [ X_i = \frac{A_i}{T_i} ] [ A_i = \text{number of concurrent tasks observed} ]</td>
<td>$0 &lt; X$ The larger is the better.</td>
<td></td>
</tr>
<tr>
<td>Measure</td>
<td>Description</td>
<td>Formula</td>
<td>Constraint</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>Throughput (Worst case throughput ratio)</td>
<td>What is the absolute limit on the system in terms of the number and handling of concurrent tasks as throughput?</td>
<td>$X = \frac{X_{\text{max}}}{R_{\text{max}}}$ where $X_{\text{max}} = \text{MAX}(X_i)$ for $i = 1 \text{ to } N$ and $R_{\text{max}}$ is the required maximum throughput.</td>
<td>$0 &lt; X$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$X_i = \frac{A_i}{T_i}$ for $i = 1 \text{ to } N$ where $A_i$ is the number of concurrent tasks observed over set period of time for $i$-th evaluation and $T_i$ is the set period of time for $i$-th evaluation.</td>
<td>The larger is the better.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$N = \text{number of evaluations}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>User Efficiency (MUSiC)</td>
<td>How user achieve each task efficiently.</td>
<td>User Efficiency = Task Effectiveness/Task Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human Efficiency (MUSiC)</td>
<td>How much effort user needs to achieve the task efficiently.</td>
<td>Human Efficiency = Task Effectiveness/Task Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corporate Efficiency (MUSiC)</td>
<td>How much resources which need to achieve the task efficiency.</td>
<td>Corporate Efficiency = Effectiveness/Total Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turnaround Time (ISO/IEC 9123-2)</td>
<td>What is the wait time the user experiences after issuing an instruction to start a group of related tasks and their completion?</td>
<td>$T = \text{Time between user’s finishing getting output results and user’s finishing request}$</td>
<td>$0 &lt; T$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The shorter the better.</td>
<td></td>
</tr>
<tr>
<td>Waiting Time (ISO/IEC 9123-2)</td>
<td>What proportion of the time do users spend waiting for the system to respond?</td>
<td>$X = \frac{T_a}{T_b}$ where $T_a = \text{total time spent waiting}$ and $T_b = \text{task time}$</td>
<td>$0 \leq X$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The smaller the better.</td>
<td></td>
</tr>
<tr>
<td>Efficiency Compliance (ISO/IEC 9123-2)</td>
<td>How compliant is the efficiency of the product to applicable</td>
<td>$X = 1 - \frac{A}{B}$ where $A$ is the ratio of satisfied compliance items relating to efficiency.</td>
<td>$0 \leq X \leq 1$</td>
<td></td>
</tr>
<tr>
<td>Regulations, standards and conventions?</td>
<td>A= Number of efficiency compliance items specified that have not been implemented during testing</td>
<td>B= Total number of efficiency compliance items specified</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Effectiveness:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Computational Accuracy (ISO/IEC 9123)</strong></td>
<td>How completely the requirements of the user are implemented. X = A/B A= Number of functions in which specific accuracy requirements had been implemented, as confirmed in evaluation B= Number of functions for which specific accuracy requirements need to be implemented</td>
</tr>
<tr>
<td><strong>Input validity Checking (ISO/IEC 9126-2)</strong></td>
<td>Check the validation of the user's input X=A/B A= Number of input items which check for data validation B= Number of input items which could check for data validation.</td>
</tr>
<tr>
<td><strong>Task Completion (ISO/IEC 9126-4)</strong></td>
<td>Measure the tasks of the user which has been completed by user efficiently. X=A/B A= Number of Tasks Completed B= Total number of tasks attempted</td>
</tr>
<tr>
<td><strong>Effectiveness</strong></td>
<td>Measure the effectiveness of the website in terms of accuracy and completeness E = 50% Cgt + 50% Agt Agt=Accuracy Cgt=Completeness</td>
</tr>
<tr>
<td><strong>Operability</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Input validity Checking (ISO/IEC 9126-3, 2003)</strong></td>
<td>What proportion of input items provides check for valid data? X=A/B A=Number of input items which check for valid data B=Number of input items which could check for valid data 0 &lt;= X &lt;= 1 The closer to 1, the better.</td>
</tr>
<tr>
<td><strong>User operation Cancellability (ISO/IEC 9126-3, 2003)</strong></td>
<td>What proportion of functions can be cancelled prior to completion? X=A/B A=Number of implemented functions which can be cancelled by the user B= Number of functions 0 &lt;= X &lt;= 1 The closer to 1, the better Cancellability</td>
</tr>
<tr>
<td>Requirement</td>
<td>Formula</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>User operation undoability</td>
<td>( X = \frac{A}{B} )</td>
</tr>
<tr>
<td>Customizability</td>
<td>( X = \frac{A}{B} )</td>
</tr>
<tr>
<td>Physical accessibility</td>
<td>( X = \frac{A}{B} )</td>
</tr>
<tr>
<td>Operation status monitoring</td>
<td>( X = \frac{A}{B} )</td>
</tr>
<tr>
<td>Operational consistency</td>
<td>( X = 1 - \frac{A}{B} )</td>
</tr>
<tr>
<td>Message clarity</td>
<td>( X = \frac{A}{B} )</td>
</tr>
<tr>
<td>Interface element clarity</td>
<td>( X = \frac{A}{B} )</td>
</tr>
<tr>
<td>Operational error</td>
<td>( X = \frac{A}{B} )</td>
</tr>
<tr>
<td>recoverability (ISO/IEC 9126-3, 2003)</td>
<td>tolerate user error?</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td><strong>Usability compliance</strong></td>
<td></td>
</tr>
</tbody>
</table>
| Usability Compliance (ISO/IEC 9126-3, 2003) | How compliant is the product to applicable regulations, standards and conventions for usability? | $X = \frac{A}{B}$  
A = Number of correctly implemented items related to usability compliance confirmed in evaluation  
B = Total number of compliance items | $0 \leq X \leq 1$  
The closer to 1, the more Compliant |
APPENDIX B: SCENARIOS

CHAPTER 11

Project: myprejs

Concept model - Overview

2009-10-12

Get convinced

List objects

Guide tour

Get involved

Create application

Create object

Select object to book

Be involved

Apply for objects

Invite tenant

Mark availability

Receive bookings

Prepare for guest

Prepares payment

Pay rest of fee

Be informed

Gas balance

List all booking on my objects

List all bookings

See payments

See payments

Colors

Content types

Paid services
Project: myplejs

Status and favorites on dashboard

Please read here how the tenant and the landlord interact in the dashboard by setting status.

Flow chart

Dashboard

Landlord

Tenant

Views

Favorite (tags)

Has his own

Shows potential objects to

Affects only the tenants

Sets

Status

(voting API)

Pending (default)

Apply

Ignore

Status table

App_ID

Obj_ID

Tenant status

Landlord status

Tenant

Apply

Pending

Ignore

2009-10-15

Status in table affect both tenants and landlords

Nine (9) status combinations

Is set to 'pending' also by landlord?

Yes

No

Does combination application/object exist in table?

Yes

No

DELETE row

UPDATE row

INSERT row

One row per combination of App_ID and Obj_ID
13 Appendix C: Interview Questions

CHAPTER 13

This section presents the questions for the interviews that were conducted at company.

The interview questions are designed for usability and in the industrial setting. The questions intend to cover the usability and UX definition, measures, evaluation methods, challenges

1. What are main products of your company developed?
2. What is typical size of project team?
3. What are different roles (Developer, Designer, and Coder) in a project team?
4. How would you describe your usability evaluation process?
5. How many employees do you have in your organization?
6. How do you involve User in Usability Evaluation process?
7. At what stage of software development do you measure usability of software product?
8. How many people are involved in usability evaluation process?
9. How do you define usability and UX?
10. What methods or techniques do you used usability of web applications?
11. Do usability engineers have any type of formal training/course for usability evaluation/Testing?
12. How many Usability Inspection Methods are you familiar with?
   a:- Heuristic evaluation
   b:- Cognitive Walkthroughs
   c:- Perspective Based Usability Inspections
   d:- Pluralistic Walkthroughs
   e:- Feature Inspection
13. Which inspection method(s) do you use for usability evaluation?
   a:- Heuristic evaluation
   b:- Cognitive Walkthroughs
   c:- Perspective Based Usability Inspections
d: Pluralistic Walkthroughs
e: Feature Inspection

14. During which phase of software development do you evaluate the Usability?
   a: Analysis
   b: Design (Prototyping)
   c: Coding
   d: Testing
   e: Deployment

15. On the average how much of total time do you spend on Usability evaluation during software development life cycle?
   a: 10-20%
   b: 20-30%
   c: 30-40%
   d: If Other (Please Specify)

16. What are the challenges you face while performing Usability Evaluation Methods?

17. Do you think there is need of usability and UX roadmap which can be used at early stages of software development?

18. Which are the Usability attribute(s) you consider more while usability evaluation application? (5= Very Important, 4= Important, 3= Moderately Important, 2= Of Little Importance, 1= Unimportant)
   a. Functionality
   b. Context of Use
   c. Attractiveness
   d. Effectiveness
   e. Satisfaction
   f. Memorability
   g. Understandability
   h. Helpfulness
   i. Flexibility
   j. Efficiency
   k. Learn-ability
   l. Errors/ Safety
   m. Operability
   n. Load Time