Usability Model for evaluating the usability of Web-based GIS applications

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***Abstract* – This research aims to gain insight into evaluation methodology and to contribute to a higher standard of Web-based GIS applications (WGIS) evaluation in practice. This study proposed a suitable usability model for evaluating the usability of Web-based GIS applications. We explored existing usability standards and published usability models to determining an appropriate model for evaluating the usability of WGIS. The aim of review is that it may help to software developers and users to select the usable system on the basis of various attributes defined in the paper.**

***Keywords* – Web-based GIS, usability, quality of use.**

I. INTRODUCTION

Today, many various kinds of GIS applications are in everyday use. GIS is defined as a set of tools used to collect, store, retrieve, transform and display spatial data from the real world as defined previously [1-3].

Web-based geographic information systems (WGIS) are focused on end-users who have only a very limited knowledge of GIS, if any. This is why Web-based GIS applications should be designed very carefully and with a strong focus on their usability. Today, Web browser is used as a general multi-purpose client application. It provides "well-known" user environment because people are used to use Internet so they know how to work with a web browser. Furthermore, contemporary Web applications can provide adaptive user interface using many various technologies [4]. Because of many positives, including low costs per user, Web-based GIS applications (in general Internet applications) have become the most wide-spread GIS solutions [5]. Next advantage of Web-based GIS applications is their standardization and ability to use web services technology to cascade (mash-up) services into one application [6]. Concerning architecture, Web-based GIS applications are usually based on the n-tier client/server architecture.

A web-based GIS application means a browser supporting an application in order to make its information accessible. WGIS applications have client side and server side architecture over network. Client side is capable to edit and improve performance, user access the GIS functions (information) through any internet browser on computer where people interact with GIS interface [7], [8]. Server side is using web remote in application server and address matching, where server is performing storage and process the data from central database to user query [8-10]. Database side is responsible, and consists of many different databases for different functionalities like store and access the server in order to return the data to the client server. Web browser is used for generating server requests and displays the data results [8].

One of the current goals of the Web engineering research is defining methods for ensuring usability. Usability is one relevant factor of the quality of Web applications. Recently, it has been receiving great attention, being recognized as a fundamental property for the success of Web applications. Defining methods for ensuring usability is therefore one of the current goals of the Web engineering research.

The notion of usability is a key theme in the human-computer interaction (HCI) literature. Determining the degree of usability is a process in which systems are evaluated in order to determine product-success using methods available to the evaluator.

One important success factor is, therefore, the need to warranty the levels of quality of the WGIS as software products [11]. High-quality software products are essential to provide value, and avoid potential negative consequences, for the stakeholders. Assessing the quality in use will allow WGIS application owners to estimate how usable a WGIS application might be and the user's satisfaction.

These studies are certainly important as that would further deepen our understanding on factors that contributes towards the usability of WGIS applications.

In order to evaluate the quality of developed systems, a set of quality characteristics and criteria are required as a basis to describe the system quality. This set of characteristics and the relationship between them is called the Quality Model [12].

II. LITERATURE REVIEW OF USABILITY MODELS

Attempts to objectively evaluate usability of information systems are old. Many usability models have been proposed to allow software usability evaluation. The main purpose of the software product usability model is to specify and assess the level of usability of a product through internal measures of inherent properties of the software, and through external measures of the behavior of the system of which the software is part [12].

This section presents several usability models as the foundation for proposing an appropriate model for web site usability. Usability models are conceptual view and not only

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states the characteristics but also indicates how those characteristics fit together. The selected models are the standard and acceptable model includes Eason Model (1984), Shackel Model (1991), Nielsen Model (1993), ISO 9241-11 (1998), ISO 9126 (2001), QUIM model (2006), ISO 25010 (2010) and 2Q2U (2010).

Eason's Model [13] characterized usability into three sections based on their independency on the platform in which the task is being performed i.e. Task Characteristics, User Characteristics, System Characteristics and User Reaction which is variable dependent. Later, Shackel [14] gave the importance of usability engineering and the relativity of its concept. He gave the four important characteristics of usability namely effectiveness, learnability, flexibility, attitude. Nielsen Model [15] studied and recognized usability as an important attribute to influence the acceptance of a product. He divided acceptability into practical and social acceptance and further on gave five sub attributes of usability namely learnability, efficiency, memorability, errors, and satisfaction. The international organization of standardization gave a model consisting of three basic sub attributes namely effectiveness, efficiency, and satisfaction [16] (ISO 9214-11, 1998). Moving ahead, ISO 9126 [12] laid down the following sub attributes of usability namely understandability, learnability, operability, attractiveness, usability compliance.

Some researchers has combine ISO 9126 and ISO 9241 attributes and develop new model that has effectiveness, efficiency, satisfaction, learnability and security as attributes [17]. Usability standards provided by ISO can be broadly classified into two categories first, product-oriented standards (ISO 9126, 2001; ISO 14598, 2001) and second, process-oriented standards (ISO 9241, 1992/2001; ISO 13407, 1999).

QUIM (Quality in Use Integrated Measurement) [18] is a consolidated model for usability measurement and metrics. It combines various standard and model such as ISO 9241 and ISO 9126 and unified into a single consolidated, hierarchical model. It outlines methods for establishing quality requirements as well as identifying, implementing, analyzing, and validating both process and product quality metrics. This model appropriate for novice users that have little knowledge of usability and can be applied by usability experts and non-experts QUIM model consists of 10 factors and subdivided into 26 criteria or measurable criteria, and finally into specific metrics consists 127 specific metrics. The 10 factors consists Efficiency, Effectiveness, Satisfaction, Learnability, Productivity, Safety, Trustfulness Accessibility, Usefulness and Universality.

ISO has recently developed a new more comprehensive definition of quality in use, which has usability, flexibility and safety as subcharacteristics that can be quantified from the perspectives of different stakeholders, including users, managers and maintainers. It describes a practical method for identifying contextual aspects of usability in software systems, and for helping ensure that usability evaluations reflect the context of use and give data with acceptable validity.

ISO/IEC 25010 is the new standard of software product quality that is awaiting publication, and is a part of the new series of SQuaRE (Software product Quality Requirements and Evaluation) standards [19]. ISO/IEC 25010 is an evolution of the ISO/IEC 9126 and defines a more complete and detailed quality in use model. According to both standards, the quality of a system can be assessed as the extent to which the system satisfies the stated and implied needs of its various stakeholders.

The modelling framework, 2Q2U [20], is designed to flexibly evaluate the external quality for a GIS application for usability and user experience by flexibly combining and relating the concepts of actual usability and actual UX.

Actual Usability, degree to which specified users can achieve specified goals with effectiveness in use, efficiency in use, learnability in use, and accessibility in use in a specified context of use. Actual usability is measured and evaluated in a real operational environment where real users perform actual specified tasks. To this aim, they modelled four characteristics, namely, efficiency in use, effectiveness in use, learnability in use and accessibility in use as shown in Fig. 1. Actual User Experience (UX), degree to which specified users can achieve actual usability, safety, and satisfaction in use in a specified context of use. Actual UX is evaluated not only by measures and indicators of user performance – as in actual usability-, but also by means of satisfaction instruments.

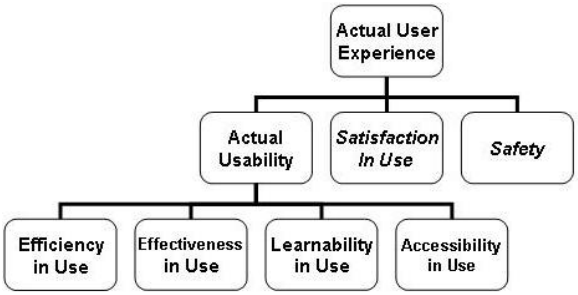

Fig 1. Model composition representing actual usability and actual UX.

2Q2U aligns with the intention of the ISO 25010 standard which encourages tailoring for relative importance of characteristics depending on the situation: "It is not practically possible to measure all …relative importance of quality characteristics will depend on the product and application domain. So the model should be tailored before use…"

In fact, each author can propose his own usability model to cover all important issues and to take aim of an evaluation into account [21].

III. Analysis of Usability Models

During the decades, different literature described various models and attributes of usability. We based our methodology to explore published usability models. This paper, discussed how the usability models and their attributes are evolved.

In this section, a comparison between the availability of the characteristics (called factors or attributes in some usability models) within the eight usability models will be presented. Table 1 presents this comparison, at the end this table you will

find the number of the corresponding characteristics for each usability model.

There are many attributes in each model but there has similarity between the models. From Table 1, 6 attributes are selected based on frequency in each model and other study made by researchers to see the similarity. The attribute that have been selected are effectiveness, efficiency, satisfaction, safety, learnability and flexibility.

TABLE I
A COMPARISON BETWEEN THE USABILITY MODEL

Factors or attributes	Eason	Shackel	Nielsen	ISO 9241-11	ISO 9126	QUIM	ISO 25010	2Q2U
Effectivenes		√		√		√	√	√
Efficiency	√		√	√		√	√	√
Satisfaction			√	√		√	√	√
Safety						√	√	√
Learnability	√	√	√		√	√		√
Flexibility		√				√*	√	√
6	**2**	**3**	**3**	**3**	**1**	**6**	**5**	**6**

*Accessibility

From the 6 characteristics, there are only two characteristics (i.e. „efficiency“ and „learnability“) which are belonging to six usability models. Two characteristic belong to five usability models, that is, the „effectiveness“ and „satisfaction“ characteristics. And, one characteristic (i.e. „safety”) is defined in three usability models and („flexibility”) is defined in four usability models.

IV. DISCUSSION

There are a number of usability models in software engineering literature, each one of these usability models consists of a number of usability characteristics. These usability characteristics could be used to reflect the usability of the software product from the view of that characteristic. Selecting which one of the usability models to use is a real challenge. In this paper, we have discussed and compared the following usability models: Eason Model, Shackel Model, Nielsen Model, ISO 9241-11, ISO 9126, QUIM model, ISO 25010 and 2Q2U.

Based on the discussion of the eight usability models and on the comparison between them, the following comments could be written:

1. The ISO 25010 usability model is the most useful one since it has been built based on an international consensus and agreement from all the country members of the ISO organization.
2. However, based on table 1, it can be concluded that among the usability model, 2Q2U model is more complete than other models and suitable to be used in the WGIS usability because it consolidated model based on previous works and model.

For customizing these characteristics especially for web applications, a wide range of usability guidelines and checklists were studied. It is important to emphasize the fact that the analyzed quality characteristics are those concerning the quality in use and those that are of interest to the end users of WGIS applications.

Since all of these characteristics affect the use of WGIS applications by final users, they were adapted to the WGIS application context. However, other sub-characteristics were not included because they could be considered as not being sufficiently relevant for WGIS application usage.

The 25010 standard categorizes learnability as an internal/external quality subcharacteristic under the operability characteristic. We propose to include learnability in use as a characteristic of usability in use to account for the learning process and the importance of context of use. The satisfaction attribute selectable because to determine whether the web application is usable or not. In addition, more satisfying experiences sometimes lead to better learning performance in the future. Safety is a quality in use characteristic defined by ISO 25010.

Quality in use is the degree to which a product or system can be used by specific users to meet their needs to achieve specific goals in specific contexts of use. A quality in use model composed of four characteristics (Usability in use, Satisfaction in use, Safety in use and Flexibility in use) that relate to the outcome of interaction when a software product is used in a particular context of use. Some of characteristics are further subdivided into sub-characteristics. Each characteristic can be assigned to different activities of stakeholders, for example, the interaction of an operator or the maintenance of a developer.

The characteristics and sub-characteristics of the model are specified below.

1. **Usability** in use: The extent to which a WGIS application can be used by specific users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.

1.1. Effectiveness in use [12, 16, 19]: The degree to which the WGIS application can be used by the users to achieve their specific goals with accuracy and completeness in a specified context of use.

1.2. Efficiency in use [12, 16, 19]: The degree of resources consumed by WGIS application users in relation to the effectiveness reached in a specific context of use.

1.3. Learnability in use [20], degree to which specified users can learn efficiently and effectively while achieving specified goals in a specified context of use.

2. **Satisfaction** in use [12, 16, 19]: the WGIS application users' degree of satisfaction with regard to achieving their pragmatic and hedonic goals in a given context of use.

3. **Safety** in use [15, 16, 19]: The degree, to which the WGIS application does not, under specified conditions, lead to a state in which the personal security of its users is endangered and economic damage is caused.

3.1. Personal Security Risk [19, 22]: the degree of expected impact of harm to the personal security of the portal`s users or clients in the intended contexts of use.

3.2. Economic damage risk [19, 22]: the degree of expected impact of causing economic damage to the web

portal users owing to insecure operations in the intended contexts of use.

4. **Flexibility** in use: the degree to which the quality in use requirements for WGIS application can be achieved in different contexts of use and for as many users as possible.

4.1. Accessibility [19], [23]: the degree of effectiveness, efficiency, safety and satisfaction, when people with the widest range of capabilities use the web portal.

4.2. Personalization [24]: the degree to which the users can modify certain aspects of the portal to suit their specific preferences and needs.

The quality in use model adapted for WGIS application is shown in Fig.2.

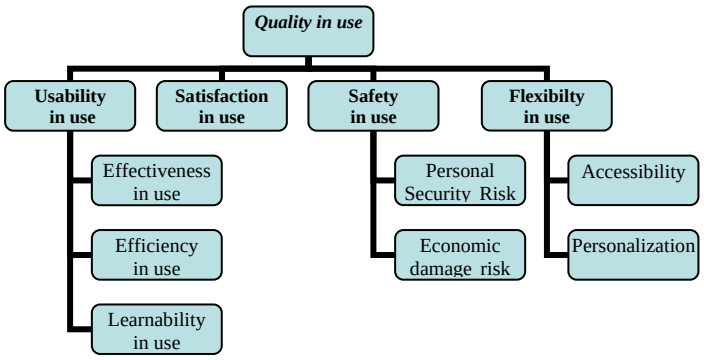

Fig. 2. Quality in use model for WGIS application

V. CONCLUSION

Researchers have not developed yet any model that precisely describes usability definition and all its attributes that takes into account the varying aspects of usability.

This paper provides a detailed analytical comparison of the various attributes, to achieve a more thorough view of the usability strengths and weaknesses. So they can get help in decision making and avoid costly mistakes when choosing WGIS applications. Since different users have different priorities during the usage of system, we consider final usability attributes to decide whether the particular WGIS application being developed is acceptable overall or not by them. Therefore this paper recommends a combination of these attributes into consideration of usability decision making for WGIS.

There are two immediate contributions of this work: comparison and analysis of existing usability model and identification of usability characteristics for WGIS.

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