Weighing Approach with Analytical Network Process in GIS

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ABSTRACT: *The level and quality of the Web-based Geographical Information Systems is a primary issue and we address this issue in this work. We have used the weighing approach to measure the quality of issue. We have selected the characteristics to study the GIS quality that use the web-based systems. Using the weighing approach, we fix the relative significance of Analytical Network Process to examine the relative use of the issues studied.*

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1. Introduction

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. The overarching goal of a majority of the HCI work has been to propose techniques, methods, and guidelines for designing better and more "usable" artifacts. 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.

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]. A web-based GIS application means a browser supporting an application in order to make its information accessible. Web/based GIS 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 [4], [5].

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 [5-7]. 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 [5].

Today, many various kinds of GIS applications are in everyday use. They significantly vary in available functions. Some of them are commercial solutions; some of them are open-source solutions.

The paper deals with a quality evaluation of a Web-based GIS intranet application providing access to spatial information. WebGIS application developed for the Ministry of Defense was selected as the case study for this work.

An Intranet is an internal information system based on Internet technology, web services, TCP/IP and HTTP communication protocols, and HTML publishing [8]. Intranet resources are available for employed of a company only and number of available respondents for evaluation application is limited. For using these technologies by WebGIS applications all necessary standards were adopted several years ago.

Since all of the usability factors do not have the same importance in the overall usability assessment of the WebGIS applications, the proposed factors have been weighted by adopting ANP (Analytic Network Process) approach [9].

Assessing the quality in use will allow WebGIS application owners to estimate how usable a WebGIS 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 WebGIS applications.

2. Model For Quality in Use in WEBGIS

Usability as a quality characteristics has been defined by different researchers [10-12] and several ISO standards, e.g. ISO/IEC 25010 [13] and ISO/IEC 9241-11 [14].

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 [15].

Many quality models have been proposed to allow software quality evaluation. 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. In fact, each author can propose his own quality model to cover all important issues and to take aim of an evaluation into account [16].

In this work, ISO/IEC 25010 [13] quality model was selected to identify relevant quality characteristics. Since all of these characteristics affect the use of WebGIS applications by final users, they were adapted to the WebGIS application context.

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 [13]. ISO/IEC 25010 is an evolution of the ISO/IEC 9126 [15] 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.

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. The quality in use of a system characterizes the impact that the product (system or software product) has on stakeholders. It is determined by the quality of the software, hardware and operating environment, and the characteristics of the users, tasks and social environment. All these factors contribute to the quality in use of the system. A

Figure 1. Model for quality in use in ISO/IEC 25010 The quality in use model defined by ISO/IEC 25010 is shown in Fig. 1, and a complete definition of the quality characteristics and sub-characteristics can be found in [13]. quality in use model composed of

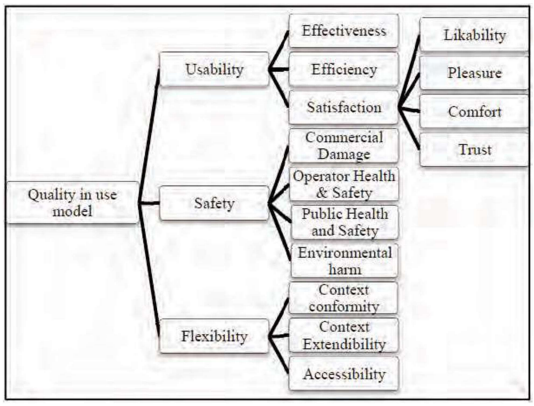

Figure 1. Model for quality in use in ISO/IEC 25010

five characteristics (effectiveness, efficiency, satisfaction, freedom from risk, and context coverage) 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.

After extensive research that we conducted to analyze and compare different software quality models, the ISO/IEC 25010 quality model has been adopted as a basis to focus on usability characteristics of WebGIS applications. 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 WebGIS applications.

In order to define a quality in use model for WebGIS applications, ISO/IEC 25010 quality in use model was adapted.

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

3. The Relative Importance of the Usability Attributes

Although the scope of the product quality model is intended to be software and computer systems, many of the characteristics are also relevant to wider systems and services. These models provide a set of quality characteristics relevant to a wide range of stakeholders, such as: software developers, system integrators, acquirers, owners, maintainers, contractors, quality assurance and control professionals, and users.

The full set of quality characteristic across these models might not be relevant to all types of users. Therefore, for each type of user should be considered the relevance of the quality characteristics in each model before finalizing the set of quality characteristics that will be used. The relative importance of quality characteristics will depend on the highlevel goals and objectives for the project. Therefore, the model should be tailored before use as part of the decomposition of requirements to identify those characteristics and sub characteristics that are most important, and resources allocated between the different types of measure depending on the stakeholder goals and objectives for the product.

The quality models provide a framework for collecting stakeholder needs [13]. Stakeholders include: Primary user (person who interacts with the system to achieve the primary goals), Secondary user (person who provide support, eg. content provider, system manager/administrator, security manager; maintainer, analyzer, porter, and installer), and Indirect user (person who

provide support, eg. content provider, system manager/administrator, security manager; maintainer, analyzer, porter, and installer), and (person who receives output, but does not interact with the system). Each of these types of user has needs for quality in use in particular contexts of use [13].

However, before any usability evaluation can begin, it is necessary to understand the Context of use for the product, i.e. the goals of the user community, and the main user, task and environmental characteristics of the situation in which it will be operated.

Attempts to objectively evaluate quality of information systems are old. Many various methods of usability evaluation have been developed. These methods belong to classical experimental methods; there are qualitative and quantitative methods available. A suitable method must be selected for each evaluation.

User characteristics are also important determinants of usability. The term 'context' includes the characteristics of the users and the work goals they are seeking to achieve, as well as the technical, physical and organizational environments in which they work.

In practice, key issues to be decided are the choice of the evaluation tasks, and identifying the profiles of users for the evaluation, taking into account the availability of suitable users within the resources and timescale of the evaluation.

4. ANP

Since all of the usability factors do not have the same significance in the overall usability assessment of the WebGIS applications, the proposed factors have been weighted by adopting ANP (Analytic Network Process) approach [18].

Literature review was performed to determine the usability factors that are important for the software we analyzed. ANP is applicable when it is difficult to formulate criteria evaluations and it allows quantitative evaluation [17]. As seen above, usability of a system, but also some of their other factors are related to each other. Hence, these interactions go to create a complex model composed of dependence and feedback among the factors. In evaluating software, such a model can be treated with the ANP proposed by [17], [18] in order to determine the relative importance of the usability factors.

ANP has three stages: structuring (design), assessment (comparison), and synthesis (computation).

At the structuring stage, pertinent factors and alternatives, if necessary, are determined. Next, associations between pairs of factors are identified by experts. As a result, a network model, which consists of factors and relations among them, is constructed.

At the assessment stage, a nine-point scale suggested by [17] is used by the decision makers to make pairwise comparisons of the factors in the network. Pair-wise comparisons are made by identifying the less dominant of two elements and using it as the unit of measurement. Users can input their preferences regarding the relative importance of each criterion using a set of linguistic terms.

According to this scale, a value of 1 show that both factors compared have equal influence levels on the affected factor, while a value of 9 shows that one factor has extremely more influence than the other on the affected factor [19].

Then we construct the matrix of pair-wise comparisons where the reciprocal value of the judgment is automatically used for the comparison of the less dominant element with the more dominant one. After we determined the priority weights for each participant, we aggregate the individual judgments using the geometric mean value method. Using these aggregated group judgments, pairwise-comparison matrices are generated.

At the synthesis stage the relative importance of the factors is computed. Importance is viewed as the influence of the factors on a common goal. To synthesize aggregated judgments to compute the relative importance of the factors, the computation of the eigenvector for each pairwise comparison matrix, the generation of a super-matrix and a weighted super-matrix, and the computation of the convergence of the super-matrix (limit matrix) are required. The relative weights (desired priorities) of the factors in the decision network are the values of the limit matrix.

5. Evaluation of Webgis Application

Making the right decision has always been a complex task; therefore we used ANP methodology in our questionnaire to help the respondents to find one that best suits their goal and their understanding of the problem.

Based on the above discussion, this study uses ANP approach in order to identify the most important factors influencing the adoption of WebGIS applications based on consumers' preferences as the research objective.

After the determination of usability factors, the group of experts whose working areas are usability engineering filled in a pairwise relationship matrix separately. Once the hierarchy was established, pairwise comparisons were performed by the participants to assign priorities to each node in each level of the hierarchy. For the higher levels (Fig. 3.), they performed pairwise comparisons among the combinations of usability, flexibility and safety (Level 2) on overall quality in use of WebGIS applications (Level 1).

Of the factors given below which one influences "quality of use" more and how much more?

1=Equally 3=Moderately more 5=Strongly more 7=Very strongly more 9=Extremely more

Factors Influencing the Adoption of Web Portals		
Usability	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Flexibility
Usability	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Safety
Flexibility	⑨⑧⑦⑥⑤④③②①②③④⑤⑥⑦⑧⑨	Safety

Table 1. The relative importance of the quality of use factors for WebGIS applications

For the lower levels, they performed pairwise comparisons among the combinations of effectiveness, efficiency, and satisfaction (Level 3) on usability (Level 2).

In the judgment assessment stage, 30 potential users (22 primary users, 3 person who provide support and 5 indirect users who receives output) filled a pairwise comparison questionnaire. We used paper-and-pencil questionnaire, consisted of series of

Gender (*)	**Female: 4 Male: 26**
Age	Min: 22 Max: 52 Average: 34
Education level (*)	High school: 20
	Undergraduate: 4 MSc: 6
Work experience in full	1-2 years: 2
time position (*)	2-5 years: 9 / >5 years: 19
Computer use (year)	Min: 1 Max: 8 Average: 4
Computer use in a week (h)	Min: 12 Max: 60 Average: 45

Table 2. Demographic Profiles Of Potential Users

questions. An example question from the questionnaire can be seen in Fig. 2. The questionnaire was designed through informal interviews with experts on ANP. Then, using the 1-9 scale, the respondent determines how many times more important the dominant member of the pair is. The respondents express their opinion on a numerical scale, where each number can be associated with the importance level of one factor over the other. The data collected from respondents is a list of pair-wise comparisons concerning the relative importance of each criterion. The respondents judged the relative importance of the affecting factors on the affected factor for all possible pairs. Then, the geometric means of all paired comparison judgments for each question were computed for each group (primary users, secondary users and indirect users) in order to arrive at the aggregated group judgments. By using the ANP methodology, we are able to find the degree of preference of one factor to another with respect to each criterion.

Those respondents who completed the questionnaire were asked for some demographical information for the user statistics. Table 2 presents a summary of the demographic profiles of the respondents.

* # of respondents

Table 3 presents a summary of the relative importance of the factor items of the respondents.

The result of the questionnaire interestingly reveals that Usability had the highest weight (0.5166) among the other criteria.

With respect to Usability, Satisfaction is the most popular choice followed by Effectiveness and Efficiency which are less important ones. With respect to Usability, Satisfaction is the most popular choice followed by Effectiveness and Efficiency which are less important ones.

4. Conclusion

Till now WebGIS quality attribute weighting is considered as a completely subjective task in quantitative WebGIS quality evaluation. This is mostly be done by experts with experiences. Usability, Safety and Flexibility were defined as the main factors in our ANP model. We have proposed an Analytical Network Process (ANP) approach for weighting WebGIS quality attributes in quantitative WebGIS quality evaluation. The present study confirms that an Analytical Network Process (ANP) approach in

Factor	Weight	Factor Items	Weight	Factor Items	Weight
Usability	0.66	Effectiveness	0.35		
		Efficiency	0.28		
		Satisfaction	0.37	Likability	0.27
				Pleasure	0.34
				Comfort	0.22
				Trust	0.07
Safety	0.18	Commercial damage	0.24		
		Operator Health & Safety	0.26		
		Public Health & Safety	0.22		
		Environmental harm	0.18		
Flexibility	0.16	Context conformity	0.43		
		Context Extendibility	0.23		
		Accessibility	0.34		

Table 3. The Importance of the Quality in use Factors for WebGIS Application

WebGIS domain can be used to substitute the experts' weights (weights by direct weighting method without prior ranked attributes).

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