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USABILITY EVALUATION OF WEB SERVICES BY STRUCTURAL EQUATION MODELING

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ABSTRACT
This paper is aimed at determining of the effect of subjective measures of web service usability on its objective measures. Using these results by appropriate design of web system its usability can be improved. A checklist combining the dimensions of web service usability and web service quality is proposed. For determining the subjective measures with the highest and lowest contribution to web service usability the structural equation modeling employed. A case study with 179 students using a student information system was carried out. By exploratory and confirmatory factor analysis the checklist was empirically verified and validated. Structural equation modeling was employed to evaluate the usability of the student information system. Data analysis revealed that the objective measures of web service usability have a strong and positive effect on its subjective measures. The most significant checklist dimensions affecting on web service usability were determined. For example the contribution of assurance was found to be highly influential on web service usability. Also the user navigation within the system can be neglected because of its low impact on web service usability. In contrary to previous studies this case study found a strong similarity between web service quality and web service usability. These results could be used for designing web services with better usability.

Keywords: web service usability, structural equation modeling.

1. INTRODUCTION

Recently the web services especially in e-commerce are gaining increasing importance. The customers would like to buy goods by fast and convenient web sites. But most of e-commerce web sites are not usable and can not satisfy their customers [4]. Usability presents ‘‘the capability to be used by humans easily and effectively’’; ‘‘quality in use’’; ‘‘the effectiveness, efficiency, and satisfaction with which specified users can achieve goals in particular environments’’ [6]; how easy it is to find, understand and use the information displayed on a website [8]. Usability refers to 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 user (ISO 9241-11). The development of good quality websites requires sophisticated methods for usability design and evaluation integrating human-computer interaction, cognitive psychology, and software engineering [5], [6], [9], [10], [13], [15].

Structural equation modeling (SEM) is a statistical technique that is able to examine causal variables. The parameters in the SEM model are connection strengths or path coefficients between different variables, which reflect the effective connectivity. Parameters are estimated by minimizing the difference between the observed covariances and those implied by a structural or path model [11]. The main goal of SEM is to express the pattern of a series of inter-related dependent relationships simultaneously between a set of latent (unobserved) constructs, each measured by one or more manifest (observed) variables. So SEM seems to be preferable to conventional statistical methods in complex analysis of usability. SEM is a strong modeling technique for effectively dealing with multicollinearity (if many variables are highly correlated) which is one of the benefits of SEM which makes it stronger than factor analysis and multiple regression in usability evaluation.

For measuring the quality of web-based services the web-based SERVQUAL instrument with 28 checklist questions in 6 dimensions is used [9]. It is based on SERVQUAL [14] using a 5-point distance semantic scale or 7 point Likert scale. But there is missing a quantitative model for evaluation of quality. The usability and quality are affecting each other [3]. WebQual [2] evaluate the user perceptions of the quality of e-commerce web sites trying to include usability dimensions in the assessment process. But some usability dimensions and items seem confusing and overlapping with quality dimensions. Therefore there is a need of a comprehensive quantitative evaluation approach which can handle both quality and usability evaluation techniques.

So in this study, we try to present a modified checklist based on SERVQUAL enhanced by usability dimensions, measuring web service usability and web service quality.

2. DESCRIPTION OF SEM-BASED APPROACH

Based on SERVQUAL [14], on web-based SERVQUAL [9], on usability heuristics [12] and on standard ISO 9241-10 [7] we developed a checklist with 2 objective and 8 subjective dimensions (cf. Table 1). By pretests with students using the student information systems of Fatih University some questions were changed or deleted.

Table 1. Checklist dimensions

Nr	Dimension	Number of checklist items
	Objective dimensions	
1.	effectiveness	1
2.	efficiency	1
	Subjective dimensions	
3.	satisfaction	1
4.	Reliability	5
5.	Integration of communication	3
6.	Navigation	3
7.	Controllability	2
8.	Assurance	4
9.	Responsiveness	4
10.	Quality of information	3

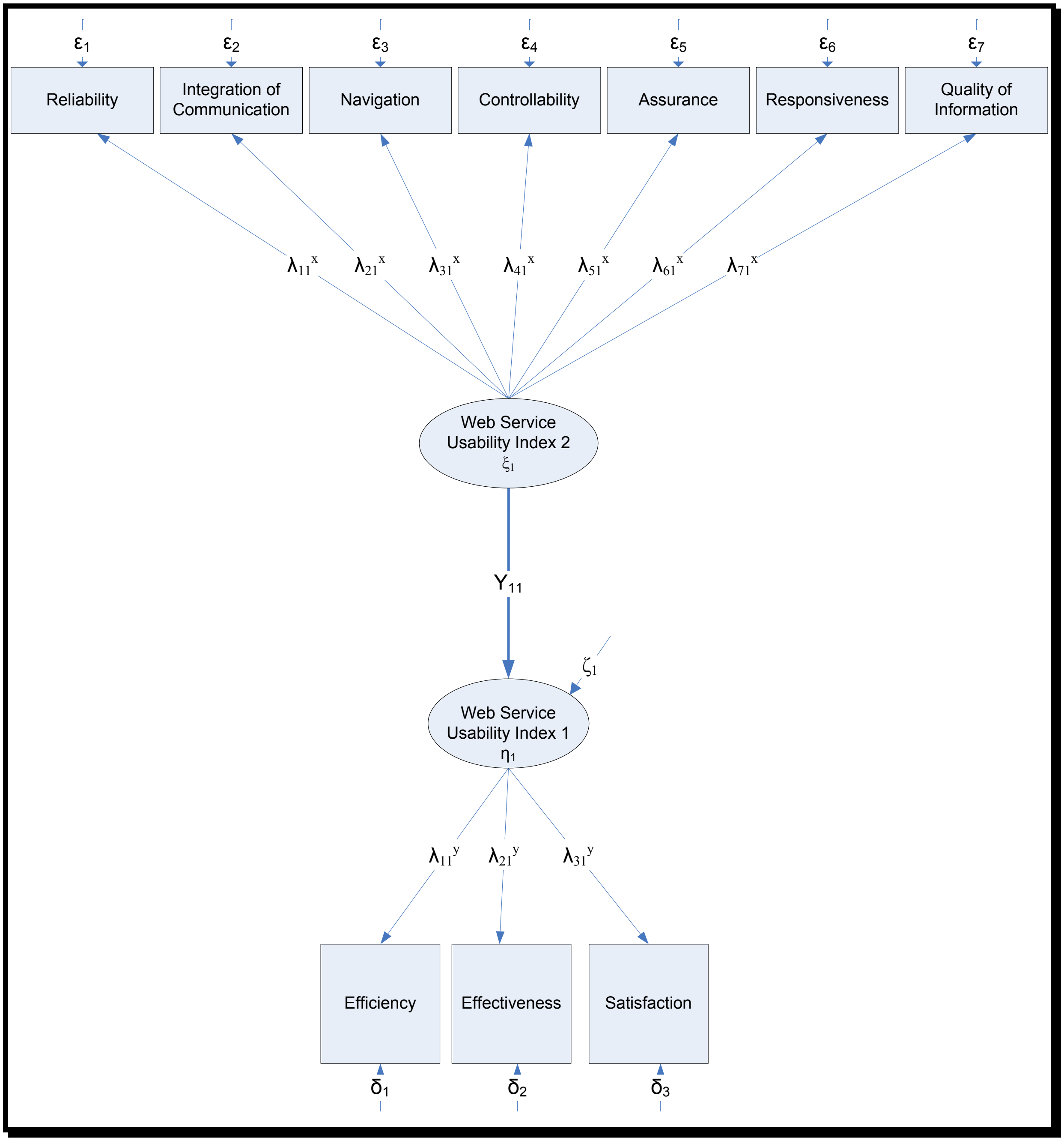
To increase the meaningfulness and strategic influence of usability data, there is a need to represent the entire construct of usability as a single dependent variable (usability index) without sacrificing precision [15]. The usability index is a measure, expressed as a percentage, of how closely the features of a web site match generally accepted usability guidelines [8]. According to the standard ISO 9241-10 usability is defined 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 user. We propose to aggregate these first 3 dimensions (mostly objective) to a quantitative Web Service Usability Index 1 ($WSUI_1$) and to aggregate the subjective dimensions of usability: reliability, integration of communication, navigation, controllability, assurance, responsiveness, and quality of information to a quantitative Web Service Usability Index 2 ($WSUI_2$). The aim of SEM-based approach is to measure the structural relationship between $WSUI_1$ and $WSUI_2$.

Depending on factor analysis, the weights for each subdimension of checklist dimensions can be found. For example the subdimensions of *reliability* dimension are checklist questions 3 to 7. By taking factor analysis scores into account, an aggregation of each dimension can be calculated in the similar way. In SEM-based approach, these aggregated dimensions will be assumed to be the observed (measured) variables for the latent (unobserved) construct Web Service Usability Index 2.

Similarly efficiency, effectiveness, and satisfaction are the observed (measured) variables for the latent (unobserved) construct Web Service Usability Index 1.

The approach aims to prove the validity of the checklist for evaluation of web service usability by considering both objective and subjective measures of usability evaluation and to determine the most and least critical dimensions for web service usability.

Figure 1. SEM-based approach



3. CASE STUDY

The checklist was experimentally studied by testing and evaluating the web service provided by student information system of Fatih University. 179 undergraduate students were selected from five different departments. 40 % of the students were male and 60 % female. All tests were carried out in the computer laboratories of Fatih University by allocating one computer to each participant. The participants received checklists containing the aim of the survey and they have to proceed. They were asked to perform three tasks using their personal accounts in Fatih University student information system.

A data gathered was analyzed as follows:

1. Exploratory factor analysis (EFA) with varimax rotation for determining the underlying dimensions of Web Service Usability Index 2.

2. Confirmatory factor analysis (CFA) for determining if the extracted dimensions in step 1 fit good to the data.
3. Measuring the direct and indirect impact of Web Service Usability Index 2 on Web Service Usability Index 1 by structural equation modeling.

EFA was undertaken to produce a set of parsimonious distinct non-overlapping dimensions of Web Service Quality for university student information system from all checklist items. The factor analysis produced 7 factors which explained 59.18 % of the observed variance. Cronbach's alphas for the underlying factors range from 0.69 through 0.75 with suggesting satisfactory level of construct reliability.

The chi square value (323 with 227 degrees of freedom) has a statistical significance level of 0.0001 that is not above the minimum level of 0.05. Although the chi-square value in the model is not above the minimum level of 0.05, it has been argued that the chi-square measure of fit should not be regarded as the best indicator of the model fit. Particularly, when there is a data departure from normality. Therefore, one needs to test X2/df, GFI, AGFI, TLI, and CFI values for judging the adequacy of the model. Statistics are given in Table 4.

The value of $\chi 2$ statistic is 323, with $\chi 2/df$ ratio value 1.42. As this ratio is within the range of 0-3, where lower values indicate better fit, the results show that our model indicates a good fit in line with this criterion. In addition, both the goodness-of-fit (GFI) and adjusted goodness-of-fit (AGFI) indices for Web Service Usability Index 2 construct are highly satisfactory, as they are very close to a value of 1.0, which denotes a perfect fit. The results attest the construct validity for the measurement model of Web Service Usability Index 2.

The final step in the analysis was to test the structural equation model as specified in Figure 3. The hypothesized structural equation model was tested using AMOS software package [1]. For Web Service Usability Index 2, the indicator variables were the respective dimensions (factors) as determined by the exploratory and confirmatory factor analyses. Model fit determines the degree to which the structural equation model fits the sample data.

The goodness-of-fit indices for the path model [Satorra-Bentler $\chi 2$ = 36.149 with df = 32; GFI = 0.962; AGFI = 0.934; NFI = 0.902; CFI = 0.987; RMSEA = 0.027] are well within the generally accepted limits, indicating a good fit to the data.

Figure 3 shows the model results related to the direct structural relationship between Web Service Usability Index 1 (WSUI1) and Web Service Usability Index 2 (WSUI2) as indicated in the following equation:

$$\eta_1 (WSUI_1) = \gamma_{11}\, \xi_1 (WSUI_2) + \zeta_1 = 0.91\, \xi_1 (WSUI_2) + 0.735$$

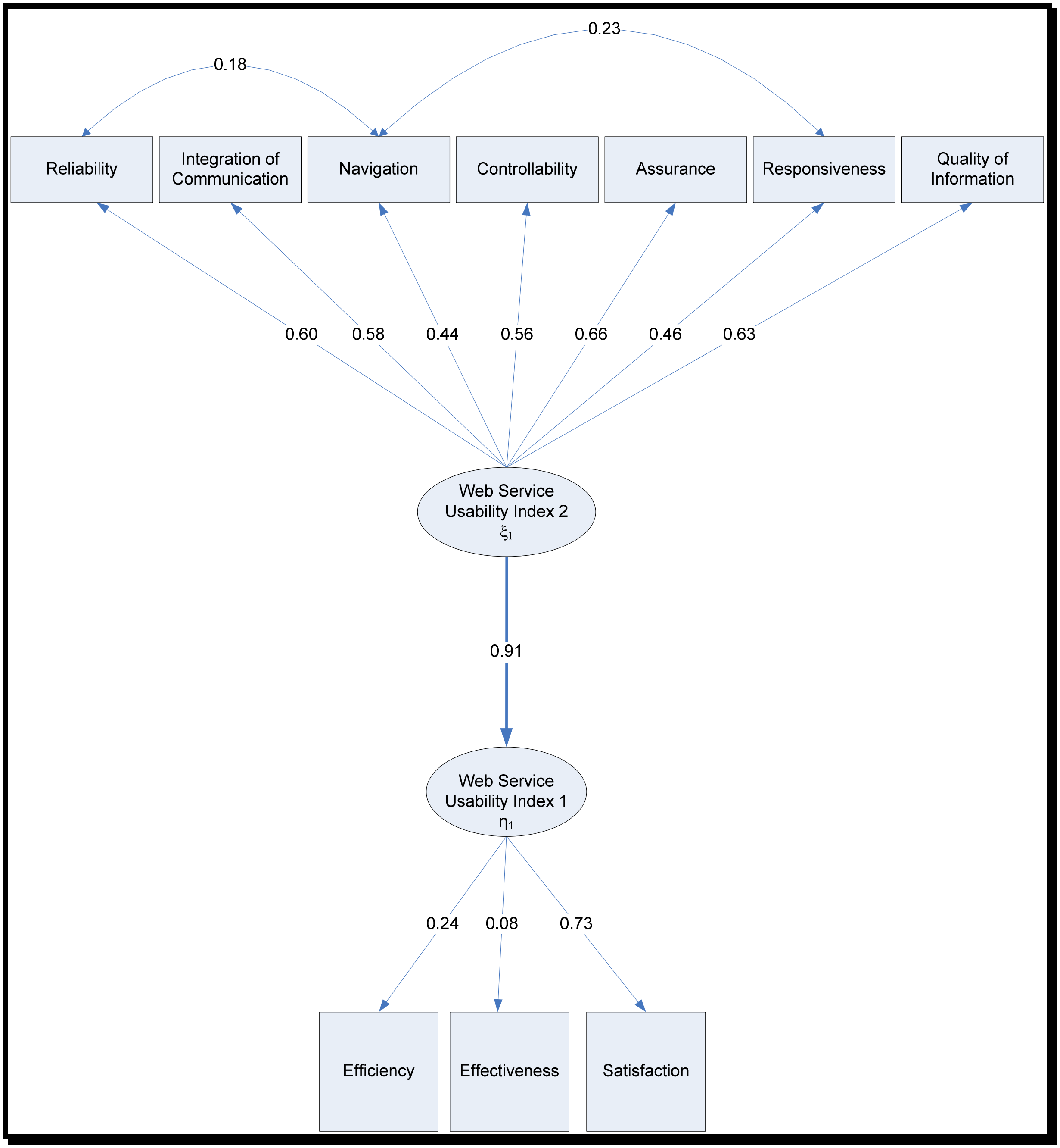
The model has one endogenous variable (dependent variable) WSUI1 and one exogenous variable (independent variable) WSUI2. The standardized regression weight for the relationship between WSUI2 and WSUI1 is 0.91 ($p<0.001$), providing a great deal of support for the hypothesis that Web Service Usability Index 2 has a significant positive direct impact on Web Service Usability Index 1. This high rate of influence of WSUI2 on WSUI1 means that if the web service designer improves the subjective measures of usability, he will be very successful to improve the overall usability performance.

Usually the designers don't have much time to tackle with all dimensions to improve the whole web service system. So they would like to know which dimension is the most influential one on the usability. According to case study results summarized in Figure 4, *assurance* has the highest importance for web service usability. The dimension that could be ignored while design improvements on this web service is *navigation.*

The most critical checklist item found is: "Are important control buttons represented on the screen and is it clear how they are working?" While changing the password the system doesn't give optional control buttons (i.e. cancel or ignore) besides the button of change. What will the user do next if he/she doesn't want to change the existing password? So the user can be confused if he/she wants to change the password.

This study found different weights for the objective measures of web service usability in comparison with the weights found in [15] as follows: for efficiency – 24% resp. 25%; for effectiveness - 8% resp. 50% and for satisfaction – 73% resp. 25%. In our case, the participants were familiar with the student university system that was tested. So the importance of efficiency and effective seem to be ignorable. In this case study, the user *satisfaction* has the greatest impact on usability.

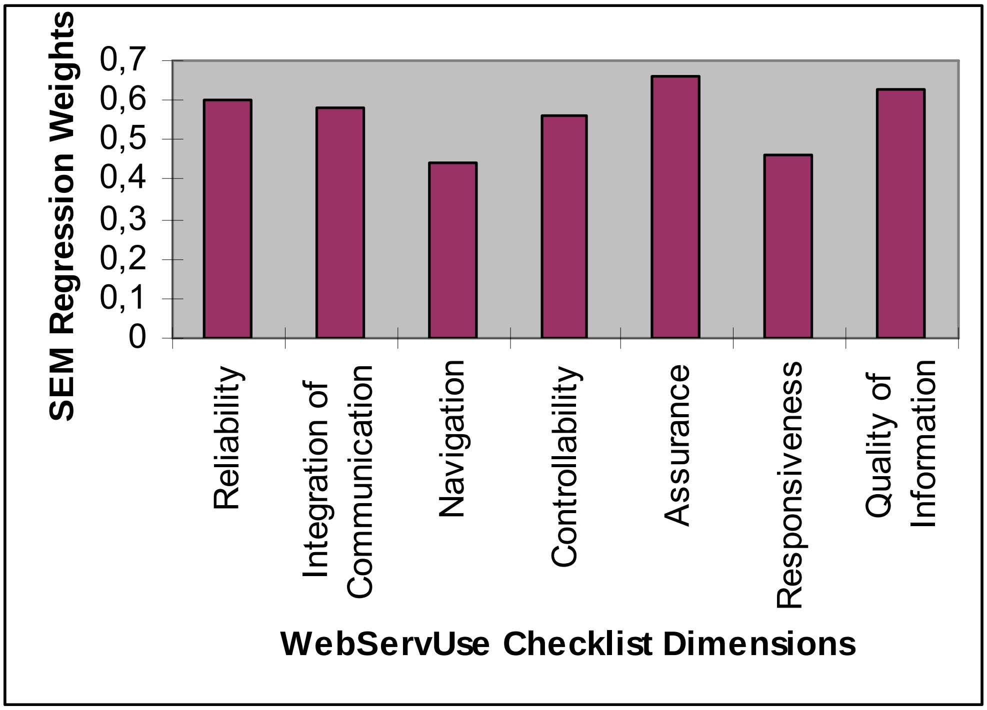
Figure 2. Inner and outer regression weights for SEM-based approach



4. CONCLUSIONS

For evaluation of the usability of web services a checklist is developed. It presents a modification of SERVQUAL model for measuring service quality (SEM) extended with usability dimensions. The data gathered by the checklist are aggregated to a quantitative objective usability index and to a quantitative subjective index by applying structural equation modeling. A case study with university student information system including 179 students is carried out. By structural equation modeling, the regression weights of the subjective measures of usability index are determined. The results of SEM showed that if the checklist dimensions (subjective measures of usability index) are improved, the usability (objective measures of usability index) is expected to improve significantly. The most significant checklist item influencing web service usability is connected with including more control buttons in the web service system. The least important checklist item tells us that there isn't much need to provide many navigational aids for system users.

Figure 3. SEM regression weights for checklist dimensions



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