An Instrument For Web Measurement: End User Evaluation Of Web Application Effectiveness

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Abstract

This research aims to develop an instrument for the assessment of Web application effectiveness. Analysis was conducted on 321 subjects in a laboratory experiment. Confirmatory Factor Analysis (CFA) was used to test the factor structure of the proposed instrument (Model 1). Results show that Model 1 did not fit the data well. Exploratory factor analysis was then employed to generate a new model (Model 2). Confirmatory factor analysis of Model 2 was carried out and showed that this model fitted the data well. This paper presents a model of the factors identified for inclusion in the measurement instrument for user evaluation of Web application.

Keywords

Web measurement, User evaluation, Web application effectiveness

INTRODUCTION

With the speedy growth of the World Wide Web, the Internet technology, Web commerce and emails in the past decade, tasks and activities performed on the Web are increasing exponentially. At present, users are often overwhelmed by the flood of information provided on the Web. The Web applications and Web-based systems available vary from high quality sites developed by professionals to low quality sites constructed by inexperienced Web developers. Many problems can arise when using these sites, including page loading time which is often lengthy, out-of-date site content, privacy concerns, access to site content, and security (Gehrke and Turban 1998, Rose et al. 1999, Selz and Schubert 1998).

The limitations of Web commerce site adoptions are primarily due to technical factors, while some are due to business: strategies and process, social and regulatory guidelines. Technological impediments to Web commerce development have been identified and classified into six categories: download delay, limitations in the interface, search problems, inadequate measurement of Web application success, security weaknesses and lack of internet standard (Rose et al. 1999). The management of these technical factors is neither simple nor straightforward.

The inadequate measurement of Web application effectiveness represents a major concern in the development and implementation of Web applications. Without appropriate Web assessment, it is unclear whether Web sites have been developed to serve the needs of the users or to perform the assigned tasks. Thus, it is necessary to find an assessment instrument which can predict user satisfaction in regard to Web quality and acceptability of Web applications performance or effectiveness. The current study focuses on the development and testing of a measurement instrument of Web application effectiveness. The hypothesized model was first developed based on the Task Technology Fit model (Goodhue, 1995) and other Web application measurements. The measurement validity of the model was then empirically tested on a sample of 321 students in a laboratory experiment. First, confirmatory factor analysis was applied to test the factor structure of the proposed model. Results revealed that the model did not fit the data well. Second, exploratory factor analysis was applied to the same data set to derive a new model. The study presents an instrument for end user evaluation of Web application effectiveness.

RESEARCH BACKGROUND

Although many studies of IS success measurement are available in various forms, currently, the empirical study of Web measurement is still in its infancy. Lack of an appropriate measure or metric of Web application success is critical for Web developers and users (Rose et al. 1999). Few studies have devoted serious attention to the measurement of user evaluation of Web application success (Ho 1997, Lincke 1998, Selz and Schubert 1998, 1999), and most of these have been case studies.

Generally, the first step in the development of Web application is the design stage. Gehrke and Turban (1998) suggested five determinants for successful Web site design. These include *page loading speed, business content of Web site, navigation efficiency, security,* and *marketing/consumer focus*. Of these five determinants, *page loading speed* is the essential factor in Web site design. Other factors that have been recently added to be considered are *navigation, efficiency, simplicity, consumer focus,* and *security,* respectively (Gehrke et al.1999).

A significant body of research work has indicated that *user information satisfaction, Information Systems (IS) attitudes*, and *MIS appreciation* are surrogates for *user evaluations of IS*. *User satisfaction* of IS has been investigated and reported in 39 papers (DeLone and McLean 1992). It is commonly accepted that user satisfaction with the system is an important and valid index of IS success (DeLone and McLean 1992, Doll et al. 1994). A number of user evaluation instruments designed in the past include the User Information Satisfaction scale (Bailey and Pearson 1983), the End-User Satisfaction instrument (Doll et al. 1994), and the Task Technology Fit Instrument for user evaluation of IS (Goodhue 1998, Goodhue and Thompson 1995). However, all these instruments focus primarily on the effectiveness of organisational IS, rather than on the evaluation of user-satisfaction of IS.

Different researchers have proposed different categories of measurements for Web applications. According to Vehovar (1999), these measurements can be classified into four categories: (1) machine to machine or software measurement such as 'log' files, and Web component counting by web analyzers (Bauer et al.1999); (2) economic or financial indicators of Web ownership, such as the impact of a Web application and the economic change resulting from the application; (3) survey measurements which mainly perform as sampling surveys, and include consumers' attitudes toward Web characteristics and usage; and (4) qualitative measurement, which while they can provide detailed insights into the complex characteristics of a system, are limited in their capacity to generalise findings to the larger population.

A recent study by Rangone and Balocco (1999) has proposed a model for assessing the effectiveness of virtual storage from the customer's point of view. The model consists of three components: a *Web interface, transaction management* and *informational content*. The Web interface is measured by the following indicators: *graphical effectiveness*, *navigability*, *download speed* and *compatibility*. Transaction management is assessed by two indicators: *effectiveness of order process* and *payment*. Lastly, informational content is classified as *commercial content* and *background content*. However, this model has not been tested systematically nor empirically.

Goodhue's (1995, 1998) "Task-Technology Fit model"(TTF) proposed a strong relationship between Information Systems and the correspondence between task needs and system functionality (task-technology fit). The core of this model is the assertion that the finishing tasks are of IS value, and that user evaluations of these tasks will reflect IS effectiveness. The model offers a theoretical basis for a user evaluation instrument which focuses on the measurement of organisational IS and services. The TTF instrument is a twelve-factor model which covers *level of detail*, *accuracy*, *currency*, *ease of use*, *presentation*, *compatibility* (across different sources), *meaning* (of data item), *confusion* (in file organization), *locatability* (of needed data), *accessibility* (of needed data), *assistance* and *system reliability*. Each of these factors comprises two items. Although the validity of the TTF instrument was empirically tested by using confirmatory methods. It should be noted that Goodhue's model does not include all factors considered essential for Web applications such as security (Gekrke and Turban 1999) and customer benefits (Selz and Schubert 1998, 1999).

The later study of E-commerce measurement, suggested a model for measuring the effectiveness of E-commerce applications, which include factors different from Goodhue's. These measurement factors are *structure of content, presentation, contact possibilities, performance, security, customer benefits* and *database interface* (see Table 1). However, the Selz and Schubert model (1999) was constructed on the basis of one case study only, and was not empirically tested.

Goodhue's factors (IS assessment)	Selz's factors (E-commerce assessment)
The right level of detail	Structure of Content
Accuracy	Structure of Content
Compatibility	-
Locatability	Presentation
Accessibility	Performance
Meaning	Structure of content
Assistance	Contact possibilities
Ease of use of hardware and software	Database interface
System reliability	Performance
Currency	Structure of content
Presentation	Structure of content
Confusion	Structure of content
-	Security
-	Customer benefits

Table 1: Comparison of various factors used in IS and E-commerce assessment.

As has been shown, the development of past measurement instruments has been primarily by means of exploratory techniques. More systematic techniques, using confirmatory methods (e.g., confirmatory factor analysis) are needed to confirm the construct validity of these measures. Such measures can provide developers with useful information about the status, effectiveness, and user acceptance of Web applications, as well as enhancing the developmental quality of Web sites. The model below proposes the way of providing more rigor model for the evaluation of Web application effectiveness.

Proposed Model

Goodhue's study (1998) suggested that there is a fit between task needs and technology, and this functionally leads to performance. By using his model users can also evaluate the task-technology fit of the Web systems they use. Thus, user evaluation of a Web application will lead to better assessment of its effectiveness. In this study, the end user evaluation of Web application effectiveness was hypothesised to be associated with *accuracy*, *locatability*, *accessibility*, *assistance*, *ease of use*, *system reliability*, *currency*, *clarity*, *simplicity* and *security* in a Web based system (see Figure 1a). The definition of each construct is presented in Appendix C. Most of assessment factors which were used in both the TTF instrument (Goodhue 1998) and the E-commerce assessment (Selz and Schubert 1999) were selected for building Web application measurement model (see Table 1) proposed in this study. These factors are *accuracy, locatability, accessibility, assistance, ease of use, system reliability, currency, presentation (clarity),* and *confusion (simplicity*). Two factors *presentation* and *confusion* were renamed as *clarity* and *simplicity*. Although the factors *right level of detail* and *meaning* were used in TTF instrument (Goodhue 1998) and E-commerce assessment (Selz and Schubert 1999), they were not selected for the present study. *Right level of detail* was not chosen because Web users always surf the Web at the levels, as they want to. The factor *meaning* was not chosen because it has been subsumed under *presentation*. In addition, the new factor, *security,* which is a significant issue in Web applications (Grehke and Turban 1999, Rose et al. 1999) was included. Users often hesitate to access and perform their tasks on the Web because the system has no guarantee of security.

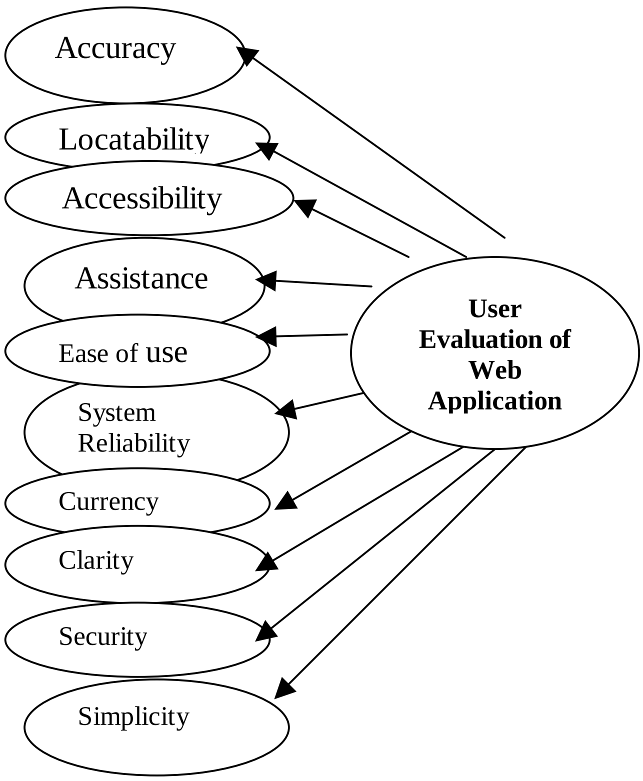

Figure 1(a): Conceptual model (Model 1)

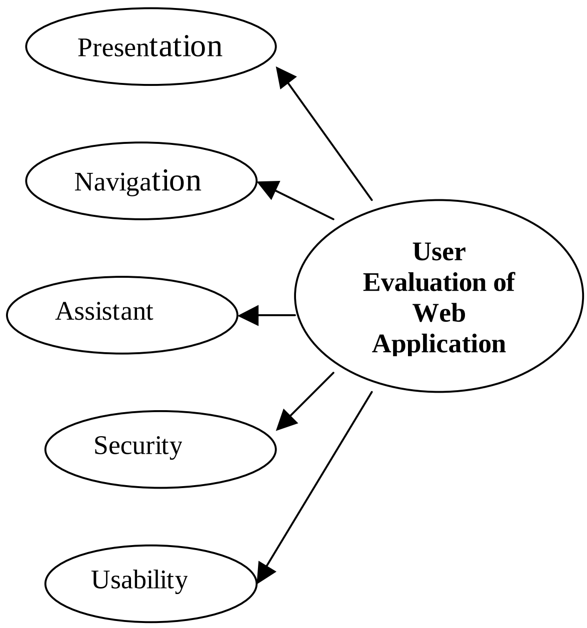

Figure 1(b): Generated model (Model 2)

METHODOLOGY

Model Testing

In terms of developing and testing the validity of standardised instruments for evaluation of IS by users, there are two methods of factor analysis: confirmatory and exploratory. According to Joreskog and Sorbom (1989) Confirmatory Factor Analysis (CFA) is concerned with the estimation of factor structure in a given model. Such a model will usually contain a set of latent variables (factors) to account for covariance among the given of observed variables. The model being tested will need to be based on prior theoretical or empirical study. Statistically, it will also need to be tested against sample data. Exploratory Factor Analysis (EFA) is then carried out to find the general discriminant validity in the given model and also to generate the number of factors that the given items actually represent. This kind of analysis generates a model which should then fit the sampling data.

There were three steps associated with the testing of the proposed instrument in this study (Figure 2). First, confirmatory methods were used to test a hypothesised measurement model (Model 1), using data collected from undergraduate students. To enhance external validity, different Web sites were selected by different users. Second, exploratory methods were used to generate hypothesised measurement models (Model 2) via the analysis of empirical data from the same sample data. Third, confirmatory methods were used to test the measurement model generated from the second step against the same sample set of data. Discriminant analysis of the correlated dimensions was also performed.

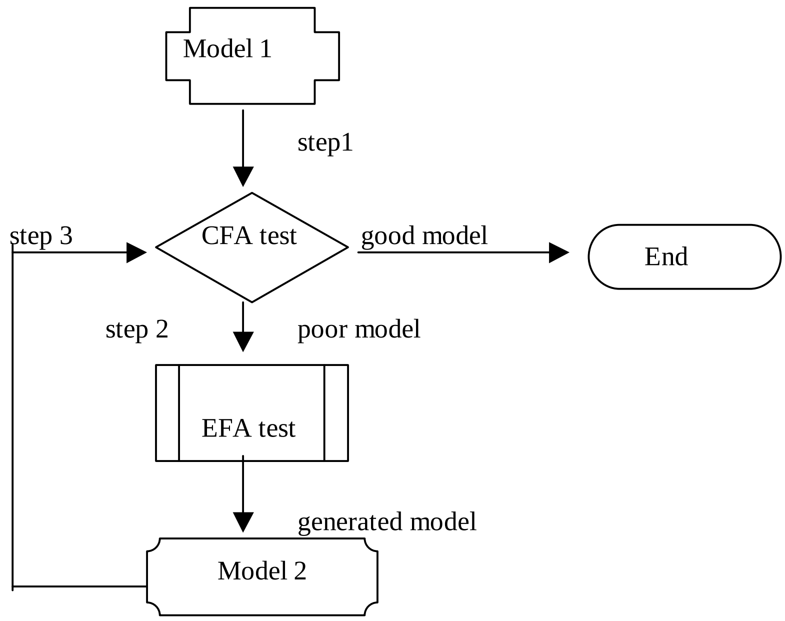

Figure 2: Diagram of model testing for user evaluation of Web application effectiveness.

Sample

The sample consisted of 321 second, third, and fourth year undergraduate students enrolled in an Information Systems class who surfed on the WWW for at least one year. Such a sample is likely to be the representative of WWW users now and in the near future. Of the sample, 35% were male and 65% were female. The students were enrolled in difference courses: natural sciences (58%), education (35%), humanities (3.5%) and social science (3.5%). Their ages ranged from 18 to 22 years. To evaluate the diversity of Web applications, fourteen different categories of Web sites (as classified by Yahoo.com) were chosen for the experiment. Eight categories including Business & Economy, Computer & Internet, Government, Health, News & Media, Entertainment, Recreation & Sports and Science were evaluated by natural science students. While the other including Art & Humanities, Education, Reference, Regional sites, Social Science and Society & Culture were evaluated by the remaining students of the class.

Materials

The survey questionnaire employed in this study was adapted from the one Goodhue (1998) employed in the Task-Technology Fit model and previous studies of measurements of Web application from Grehke and Turban (1999) and Selz and Schubert (1999). The questionnaire consisted of two sections. Section 1 was designed to gauge the participants' demographic characteristics including sex, age, computer experiences and their activities on computers. This section is not shown in the Appendices.

Section 2 consisted of 20 items designed to measure respondents' attitudes towards Web commerce sites. The 20 items represent the 10 factors proposed for the present model are *accuracy, simplicity, locatability, assistance, ease of use, system reliability, page loading, clarity, currency,* and *security* with two items representing each factor. Each item was rated on a 7-point Likert scale ranging from 1= strongly disagree to 7 = strongly agree.

Pretest

Questionnaires were distributed to 45 students enrolled in a computer class, which was part of a web-based teaching system. Based on the responses received, minor changes were made to the wording of the questionnaire to enhance its clarity. The final instrument is included in Appendix A. The distribution of the constructs is shown in Appendix B.

Statistical Analysis

The statistical package, LISREL VII (Joreskog and Sorbom 1989) was used to test the fit of hypothesised model (Model 1) against the sample data. Confirmatory factor analysis was employed to test the adequacy of the reliability and validity of the factors and items in the proposed model. The maximum likelihood technique was used to estimate the magnitude of the factor loadings of the observed variables. The fitness of the model was assessed as indicated by both the chi-square goodness-of-fit index, and the incremental fit indices such as normed fit index (NFI), goodness-of-fit index (GFI) and adjusted goodness-of-fit (AGFI). The latter indices are based on the chi-square statistics of the proposed model and the null model that hypothesises no relationship between any of the items. The evidence of good fit indices should be at least 0.90 which would imply the proposed model's ability to explain approximately 90% of the covariance among the measured variables (Marsh 1991).

RESULTS

Confirmatory Factor Analysis of Model 1

The fit of the 10-factor model (Model 1) was tested by means of chi-square statistics. The results, presented in Table 2, indicated that the chi-square value for Model 1 is large and highly significant χ^2 (df=125) = 436.43, $p<0.001$. This suggested that the hypothesised 10-factor model did not fit the data well. Further, the incremental fit indices (NFI=0.83, GFI=0.88, and AGFI=0.80) were all lower than the 0.90 criterion. Together, these results indicated that the fit of this 10-factor model was poor, that is, that the 20 items in the model did not adequately represent the factors in user evaluation of Web application effectiveness which they have been proposed as representing.

Model	X^2(N=321)	df	p	NFI	GFI	AGFI
Null model	2611.25	190	<0.00	0.00	0.00	0.00
Model 1	436.43	125	<0.00	0.83	0.88	0.80

NFI- Normed Fit Index, GFI- Goodness of Fit Index, AGFI- Adjusted Goodness of fit

Table 2: Comparison of null model and ten-factor model (Model 1)

Exploratory Factor Analysis

Based on the results from Table 2, it was concluded that Model 1 was not a good representative of the data. In order to identify the factor structure which would better cover the 20 items, and to generate a better fitting model, exploratory factor analysis was performed. Principal components analysis carried out on the 20 items (q1 to q20), suggested that four items (q4, q13, q9, q6) should be dropped from the model because of their low validity. The remaining items were then grouped into new factors as a result of their correlations. A new model (Model 2) comprising 5 factors was then created (Figure 1b). These factors were labeled *Presentation* (5 items), *Navigation* (2 items), *Assistance* (2 items), *Security* (2 items) and *Usability* (5 items). Two factors in Model 2 , *security* and *assistance,* were the same as Model 1. While the new three factors *Presentation, Navigation* and *Usability* were generated. In Model 2 – *Presentation* were coupled from *accuracy* (1 item), *clarity* (2 items) and *system reliability* (1 item). *Navigation* was resulted from combination of *ease of use* (1 item), and *simplicity* (1 item). Last, *Usability*, 5 item factor, derived from *locatability* (2 items), *accessibility* (1 item), *simplicity* (1 item) and *ease of use* (1 item), see Appendix B.

Confirmatory Factor Analysis of Model 2

The resulting model was tested for fitness by CFA. Table 3 presented the goodness-of-fit indices for Model 2. Although the χ^2 value was significant χ^2 (df =109) = 256.99, p<0.001, the incremental fit indices showed improvement over those obtained for Model 1, with two incremental fit indices being very close to 0.90 (NFI=0.89 and AGFI= 0.89) and the other being above 0.90 (GFI=0.93). This indicates the significant discrimination validity of the model.

Model	X^2(N=321)	df	p	NFI	GFI	AGFI
Null model	2311.99	136	<0.00	0.00	0.00	0.00
Model 2	256.99	109	<0.00	0.89	0.93	0.89

Table 3: Comparison of null model and five-factor model (Model 2).

Internal Consistency

Table 4 shows factor loadings of each item in the five factor model and each construct’s alpha. Factor loadings can be indicators of validity for the hypothesised factors. Almost all factor loadings in this model are greater than 0.6, indicating good construct validity. However, one item (q9) in the Navigation factor has a low value factor loading (0.43). Thus, it was deleted from this factor. This improved the factors reliability, by increasing alpha from

0.68 to 0.77. Alpha values for five latent factors ranged from 0.74 to 0.83, indicating acceptable reliability for all factors.

Observed Variables		Latent Variables	
Items	Factor Loading	**Factor**	Reliability (alpha)
q1.	0.68	Presentation	0.81
q10.	0.66		
q11.	0.73		
q12.	0.75		
q18.	0.64		
q19.	0.83	Navigation	0.77
q20.	0.74		
q9. *	0.43*		
q17.	0.92	Assistance	0.74
q16.	0.69		
q14.	0.83	Security	0.83
q15.	0.86		
q5.	0.67	Usability	0.77
q7.	0.68		
q8.	0.68		
q3.	0.80		
q2.	0.81		

*this item is dropped from the factor due to low loading factor (0.43)

Table 4: Factor loadings and reliability coefficients of Model 2.

DISCUSSION

This paper reported on the study concerned with the development of an instrument for evaluating user perception of Web application effectiveness. The instrument has demonstrated significant reliability and discriminant validity of 5 dimensions of the model. The validity tests showed the relationships between user evaluation of the Web application effectiveness and the tasks of users, the same as the link to perceived performance impacts. To further continue the discussion of the proposed model, it is suitable to compare this model to Task Technology Fit instrument (Goodhue 1998) of which is the underlying model. The present study has identified a five-factor model (*usability, presentation, assistance, security* and *navigation*), while the TTF instrument is a twelve-factor model including *level of detail, accuracy, currency, ease of use, presentation, compatibility* (across different sources), *meaning* (of data item), *confusion* (in file organization), *locatability* (of needed data), *accessibility* (of needed data), *assistance* and *system reliability*. A number of reasons may have accounted for this difference. First, according to the results from Confirmatory Factor Analysis, a model fit for one sample does not imply that it is the final solution for another sample. Second, the purpose of the TTF instrument is to measure effectiveness of organisational IS which were intended for mainframe, while the present study focused on Web applications which reside on different platforms and internet infrastructures. Third, the TTF instrument was developed from managerial use of data for decision making while this present instrument was focused on the individual usage of the Web with diversity of tasks including searching, surfing, commerce and entertainment.

As already mentioned, the tasks and user characteristics of Web users might be different from managerial IS users. Especially, Web application effectiveness users prefer *timely* (Ho 1997), *secure*

d, *business valued* and *efficiency systems* (Gehrke and Turban 1999). This corroborates the present study's results that the final factors for Web measurement are *usability*, *presentation*, *navigation* and *security*. Further, the factor: *security* which is not included in TTF instrument is presented here. This factor is the significant factors in Web applications (Gehrke and Turban 1999; Rose et. al. 1999).

Since starting and maintaining Web server applications are costly, the evaluation processes may be useful for ensuring their effectiveness. The measurement of the Web sites can predict the user perceptions of them. Organisations can also use the tested instrument for evaluating the gains arising from Web advertisements.

CONCLUSION

While the consuming of WWW is growing, the literature review shows very little work carried out on the study of Web application measurements. This limited the quality of Web application development and implementation. To overcome this deficiency, the present study proposed a measurement instrument for evaluating Web application effectiveness. A ten-factor model (Model 1) was developed primarily on a derivative of Task Technology Fit model and previous studies. Factors tapped, consisted of *accuracy*, *locatibilty*, *accessibility*, *assistance*, *ease of use*, *system reliability*, *currency*, *clarity*, *simplicity and security*. Statistical analysis, confirmatory factor analysis, based on laboratory experiment data showed that the model did not fit the 321 subjects form laboratory experiment well. Subsequently Exploratory Factor Analysis was performed and generated a new five-factor model from the same data set. Finally, Confirmatory Factor Analysis was used to test the fit of the generated model. The results indicating that this model fitted the data well. This model includes only five factors: *presentation*, *security*, *usability*, *assistance* and *navigation*.

Empirically, this study completes confirmatory-exploratory research cycle by rigorously validating the proposed instrument. End user evaluation model proposed here has been cross-validated in confirmatory studies. This instrument can be suggested as a standardised measure of user evaluation with Web sites or Web-based systems effectiveness.

This proposed instrument might be applied in the early stage of Web application development. The end-users can use this instrument to evaluate the performance of Web application prototype. The results would be directly applied to the improvement and changing to a new prototype. Moreover, in the implementation of Web application, this instrument might be used to assess the quality of Web application performance. The end-user evaluation will provide some characteristics of Web applications which they are satisfied or not satisfied. These suggestions would help Web application developers to tune up the systems in order to serve user requirements or perform the suitable tasks on the Web.

FUTURE RESEARCH

The experimental sample employed in this study consisted of students in one IS class. Students may not be representative of the Web users population. As such, the results from this study might not be generalisable. To overcome this limitation, data should be collected from Web users of different ages, occupation, education background and salary who surf on the WWW.

In this study, the suggested factors for user evaluation of Web measurement include *usability*, *navigation*, *security*, *assistance*, and *presentation*. Of these factors, the question arises as to which is the most important for Web users. Future study on user evaluation of Web application may be able to answer this. Moreover, each of the factors identified can be explored in greater depth in the future.

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APPENDICES

Appendix A: Web application instrument questionnaire.

Section I. Not Shown.

Section II

Please indicate the extent to which you agree or disagree with the following statements about your use Web application.

Strongly Disagree			Neither agree nor disagree			Strongly agree
1	2	3	4	5	6	7

1. The data is up-to-date enough for my purposes.
2. It is easy to learn how to use the Web sites that give me access to data.
3. It is easy to find out what data the Web sites maintains on a given subject.
4. There are accuracy problems in the data I use or need.
5. The Web sites that give me access to data are convenient and easy to use.
6. I can't get data that is current enough to meet my needs.
7. I am getting as quick a response from the Web sites as I need on requests for new page or data.
8. It is easy to locate the data on a particular issue, even if I haven't used that data before.
9. The data is subject to frequent system problems and crashes.
10. The data that I need is displayed in a readable and understandable form.
11. The data that I use or would like to use is accurate enough for my purposes.
12. The data is presented in a readable and useful format.
13. The system response time or page loading time is fast so I can get data quickly and easily when I need it.
14. I can count on the system that sensitive data is protected from those who should not have access it.
15. Data transfer is safeguard from unauthorised changed or use.
16. It is easy to get on-line assistance when I am having trouble finding or using data.
17. I am getting the help I need in accessing and understanding the data by using help section or email.
18. I can count on the system to be up and available when I need it.
19. There are so many different systems or files, each with slightly different data, that it is hard to understand which one to use in a given situation.
20. The data is stored in so many different places and in so many forms. It is hard to know how to use it effectively.

Appendix B: Comparisons of Factors in Model 1 and Model 2.

Factors (Model 1)	Question Numbers	Factors (Model 2)
Currency	1	Presentation
Simplicity	2	Usability
Locatability	3	Usability
Accuracy	4	-
Ease of use	5	Usability
Currency	6	-
Accessibility	7	Usability
Locatability	8	Usability
System reliability	9	-
Clarity	10	Presentation
Accuracy	11	Presentation
Clarity	12	Presentation
Accessibility	13	-
Security	14	Security
Security	15	Security
Assistance	16	Assistance
Assistance	17	Assistance
System reliability	18	Presentation
Simplicity	19	Navigation
Ease of use	20	Navigation

Appendix C: Definitions of constructs used for evaluation of Web application effectiveness (Model 1).

Construct	Definition
Accuracy	correctness of the data.
Locatability	ease of determining what data is available and where it is located from.
Accessibility	ease of access to desired data.
Assistance	ease of getting help on problems with the Web.
Ease of Use	ease of using the Web application for accessing and analyzing data.
System Reliability	availability of the systems.
Currency	timeliness of data.
Clarity	ease of reading and understanding.
Simplicity	ease of determining what each data element on the Web sites means.
Security	protection of data from unauthorized use.

Appendix D: Definitions of constructs used for evaluation of Web application effectiveness (Model 2).

Construct	Definition
Presentation	ease of reading, understanding and access to desired data.
Navigation	ease of learning the structure and content.
Usability	ease of use and determining what data available and where from.
Security	protection of data from unauthorized use.
Assistance	ease of getting help on problems with the Web.

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