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An Empirical Investigation of Decision-Making Satisfaction in Web-Based Decision Support Systems

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Abstract

Web-based information systems are increasingly being used for decision support applications. However few empirical studies have been conducted on web-based decision support systems (DSS). This experimental research endeavors to understand factors that impact decision-making satisfaction in web based decision support systems. Using structural equation modeling approach, the analysis reveals that information quality and system quality influence decision-making satisfaction, while information presentation does not have an effect on decision-making satisfaction.

Keywords:
Decision-Making Satisfaction, Web-Based Decision Support System, Information Quality, System Quality, e-Commerce, e-Business.

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Introduction

Web-based technologies are having a major impact on design, development and implementation processes for all types of decision support systems (DSS) [4] [10]. For instance, web technologies are being utilized for the development of DSS tools by leading developers of decision support technologies such as SAS Inc. [17]. Oracle is encouraging its customers to port their DSS applications, such as data mining, customer relationship management (CRM) and online analytic processing (OLAP) systems, to a web-based environment using their application server Oracle 9Ai [42]. Similarly, real-time data fed from manufacturing plants are now helping floor managers make decisions regarding production adjustment to ensure that high-quality products are produced and delivered [30].

Web-based decision support systems are being employed by organizations as decision aids for employees as well as customers. A common usage of web based DSS has been to assist customers configure product and service according to their needs. These systems allow individual customers to design their own products by choosing from a menu of attributes, components, prices and delivery options. For example, on web-sites of most desktop computer makers (www.dell.com, www.compaq.com and www.ibm.com), individuals can start with a basic configuration defined by a processor model and speed, and then go on to specify the full configuration with their choice of hard-drive size,

memory, and add-ons such as CD-ROMs, multi-media, monitors, and printers. Similar instances can be found in: 1) the apparel industry (www.landsend.com, www.blair.com, www.weddingchannel.com), which allows a user a virtual model to design one's dress before ordering; 2) in the finance industry (www.calvertgroup.com), which allows the user to try out various retirement saving plans; and 3) in the toys industry (www.vermontteddybear.com), where children can custom design the teddy bears they desire with respect to color, size and coat-type.

These web-based DSS self-services are being employed in various ways. Carpoint (carpoint.msn.com) has a web-Based DSS in which users can search a used car database and then use the *Kelley Blue Book* to establish a standard price for that particular make and model. The comparison feature permits pair-wise comparison of new car alternatives across multiple pre-specified attributes. In the health care industry, drkoop.com has a drug checker application to help make certain the medications a person takes do not interact with each other or with food to cause an adverse reaction. At drkoop.com, users also can use health calculators on topics such as stress, nutrition and fitness [43].

Ba, Kalakota, and Whinston [4] originally introduced and conceptualized the role of the web for decision support systems. Power [44] defined a web-based decision support system as a computerized system that delivers decision support information or decision support tools to a manager or business analyst using a "thin-client" Web browser like Netscape Navigator or Internet Explorer. This paper is one of the earliest examinations of factors that lead to the satisfactory usage and implementation of web-based DSS. It is based on the IS success model of DeLone and McLean [19]. The model has been

validated using confirmatory factor analysis, unidimensionality analysis, and reliability analysis, as well as convergent, discriminant, content and criterion-related validity tests. The research uses a structural equation model (SEM) to identify the factors that affect decision-making satisfaction in web-based DSS. The hypotheses of the model are tested through laboratory experiments and supported/rejected on the basis of statistical analysis.

This paper is organized as follows. The next section presents literature review. The section thereafter describes the conceptual model underlying the research. Then, the methodology and data analysis are presented in subsequent sections. Finally, the implications of the study and suggestions for future research are presented in the last section.

Literature Review

The web has now become the platform of choice for building DSS. The present research investigates these web-based decision support systems, with a focus on factors that affect decision-making satisfaction in web-based DSS. The field of DSS began with the seminal work of Bonczek, Holsapple, and Whinston [13], who conceptualized the DSS as consisting of three components - user interface, a knowledge processing system and a knowledge base. This model led to a wide stream of research in the area of DSS, resulting in many applications in the industry. Most DSS applications today are located on a single machine or are operating in a client server environment.

DSS on the web has precipitated three major changes to the environment where DSS is being employed: a change in the user community, a change in problem domains, and a

change in the underlying technology architecture. DSS applications have generally been implemented in commercial environments where users are employees of the firm. With the advent of web-based DSS, the user community is no longer limited to the managers and experts working on business-related problems. The examples cited in the beginning of the paper referred to web-based DSS targeted to general consumers using DSS for consumer decision-making. Similarly, the problem domain is being extended to interest communities such as consumers, students, children, and patients.

The new web platform has brought both promises and constraints. We are no longer limited to a single knowledge base nor does the knowledge processing need to take place locally, as DSS was first conceptualized in the Bonczek, Holsapple, and Whinston [13] model. However, the limitation of the bandwidth has an impact on the richness of the interaction, which has consequences on how processing is shared between the server and the browser-based client-end. These changes in DSS have made it incumbent on us DSS researchers to reexamine the factors that influence the efficacy of DSS in this new environment.

As people become computer-savvy, web-based decision support systems have the potential to aid them in making better decisions about products and services. Another example of a web-based DSS for customers is found at Landsend.com, where customers can choose the kind of chino pants they want and also build a virtual model of their bodies and then see how the chino pants looks on their virtual body [47]. These and other self-service information technologies that aid in decision-making are becoming quite prevalent. These web-based decision support systems are being used, but there is very

little research that has evaluated these systems from the perspective of users. Thus, more studies are needed that focuses on evaluating web-based decision support systems.

Information systems research has used cost-benefit analysis, system usage estimation and user satisfaction [36] [48] to measure IS effectiveness. IS effectiveness has been conceptualized and operationalized using several instruments [19] [27] [31] [34] [41] [48] [52]. Communication theory has also been used to understand the impact of information systems at the individual level. The IS success taxonomy [19], which is based on Mason's [39] theory, employs this approach.

Mason [39] used the communication model of Shannon and Weaver [46] as the basis for his model. The basic elements of the model are receipt of the information, the evaluation of the information, and the application of the information leading to a change in recipient behavior and a change in the system performance. Further, Mason [39] has illustrated the classes of output of an information system as technical level, semantic level and influence level.

Building on the work of Mason [39], DeLone and McLean [19] have developed a taxonomy of information systems success. According to DeLone and McLean [19], the concept of levels of output from communication theory demonstrates the serial nature of information (i.e. a form of communication). The information system creates information, which is communicated to the recipient. The recipient is or is not influenced by the information. The information flows through a series of stages from its production through its use or consumption to its influence on individual and/or organizational performance.

DeLone and McLean's [19] IS success model suggests system quality and information quality singularly and jointly affect both use and user satisfaction. Use and user satisfaction are direct antecedents of individual impact. Lastly, the impact on individual performance should eventually have some organizational impact. This research model is partially based on the IS success model. The paper employs the constructs at the technical level, namely system quality and information quality, and investigates the influence of web-based DSS at the individual level, specifically on decision-making satisfaction.

Conceptual Model

The IS success model [19] explains the impact of IS at the individual and organizational levels. This research model (Figure 1) builds on the constructs of system and information quality and their impact on user satisfaction, as it is partly based on the IS success model. The dependent construct in the model is "decision-making satisfaction." The dependent variable is directly and positively influenced by three independent constructs: system quality, information quality and information presentation.

Dependent Construct: Decision-Making Satisfaction

Decision-making satisfaction scrutinizes the ability of a system to support decision-making and problem-solving activities. The items in this construct determine whether the system supports the individual in recognizing problems, structuring problems, and making decisions related to the goal of controlling a business process [23].

In the information system framework proposed by Chervany, Dickson, and Kozar [14], decision effectiveness was used. Other measures such as decision confidence [28] [29] [53] and time to decision [6] [7] [32] have also been employed. The construct uses decision effectiveness and decision confidence for the decision-making satisfaction construct.

Independent Construct: System Quality

System quality is manifested in the system's overall performance, which can be measured by individual perceptions of this quality. This quality is a manifestation of system hardware and software. Perceptual measures such as ease of use [6], convenience of access [5], system reliability and flexibility [48] have been used in previously tested survey instruments to measure system quality. In this study, these four measures have been adopted for the system quality construct.

Hypothesis 1: System quality will positively contribute to decision-making satisfaction.

Independent Construct: Information Quality

Quality of information influences decision-making satisfaction. The decision-maker estimates the value of an information system. Gallagher [22] has used user perception of the value of the information system to determine the information quality of the system. Another study [37] underscores the perceived importance and usableness of information. In some studies, information quality has not been considered separately, but as an integral part of user satisfaction [5] or user information satisfaction [33]. The measures that have

been employed for information quality are information accuracy [5] [38] [41] [48], information completeness [5] [41], information relevance [5] [35] [41] [48], information content needs [20] and information timeliness [5] [35] [38] [41] [48]. These five measures have been used for the information quality construct.

Hypothesis 2: Information quality will positively contribute to decision-making satisfaction.

Independent Construct: Information Presentation

Information presentation is an area of research that examines how information is displayed. Numerous studies have looked at factors such as display formats, color, and graphs versus tables and how these factors aid in decision-making [51]. Improperly designed screens and interfaces can cause users unnecessary work and negatively influence their decision-making environment. Evaluation of the interface should include characteristics of the interface in terms of presentation, format and processing efficiency [49]. The measures of information presentation are graphics, color, presentation style, and navigational efficiency.

Hypothesis 3: Information presentation will positively contribute to decision-making satisfaction.

Experimental Design and Data Collection

The survey was operationalized using measures of several instruments borrowed from research literature (Table I). A small group of fifteen undergraduate students participated in the pre-test of the survey. Comments were received from the participants and the survey was modified accordingly. The survey instrument was administered in a laboratory setting, which had twenty four PCs running wintel platform. The subjects were senior year business school undergraduates and graduate MBA students at two different Universities.

The researcher/s introduced the experiment to all the subjects, who had voluntarily agreed to take part in the experiment. A sheet with the experimental procedure was handed out to the subjects. Each subject was randomly assigned a website with a web-based DSS, which was used to aid the customer in making a decision. These sites were owned by different firms but were of a very similar nature. The subjects completed all the tasks as per the procedure. After the procedure was completed each subject filled the survey questionnaire. The total sample for the experiment was 210.

Data Analysis

The study analyzed the data using the structural equation modeling (SEM) approach. Structural equation modeling allows the specification of measurement errors within a broader context of assessing measurement properties, and subscribes to a causal – indicator model – where the operational indicators are reflective of the unobserved theoretical construct. It has been suggested in the past that the structural equation model should not have too many indicator variables and about 20 indicator variables or less is an ideal number [9]. Following this recommendation, the framework has less than 20

indicator variables. This research is a confirmatory study as it is investigating a well-established theory-base. As a covariance-based structural equation modeling technique or package like AMOS should be used as confirmatory and not as an exploratory method [25], the study has applied an appropriate technique for data analysis.

Before the data can be analyzed and results can be discussed, the extent to which the operational indicators map to their higher order constructs needs to be ascertained. In order to validate the construct, the different tests that have been conducted are: confirmatory factor analysis, content validity, unidimensionality analysis, reliability analysis, convergent validity, discriminant validity, and criterion-related validity.

Confirmatory Factor Analysis

To assess the measurement properties of the survey instrument a confirmatory factor analysis was performed. Confirmatory factor analysis is conducted by specifying a measurement model consisting of the collection of scales, each defined according to a weighted linear combination of the items. The fit of the specified measurement model to the data is determined and the causal-indicator model is specified and analyzed for each theoretical construct separately [1] [45] [50]. These guidelines were followed for all the constructs with more than four or more indicators. In the study one construct (decision-making satisfaction) has two indicators. In this case, the constructs were pooled together with constructs having four or more indicators and analyzed in order to have adequate degrees of freedom for estimation of model parameters.

Using the recommended scale validation guidelines [3] [12] [15], analysis of the survey instrument was conducted. The analysis was done to assess content validity, unidimensionality, reliability, convergent validity, discriminant validity and criterion related validity.

Content Validity

The scales must be tested for content validity before any other analysis can be undertaken. It is important that the constructs are defined using the literature. "One can imagine a domain of meaning that a particular construct is intended to measure. Content validity refers to the degree that one has representatively sampled from that domain of meaning" [11, pg. 98]. The scope of the construct should adequately reflect the items as a group and then only content validity will exist [21]. Unfortunately, there is no rigorous way to assess content validity [11, pg. 100]. Multiple items are typically used to measure constructs so that construct measurement can be thorough [16]. In the survey instrument multiple items were used to measure the constructs. Since the items corresponding to various constructs of the instrument are derived from a comprehensive analysis of relevant literature, content validity can be ensured [11].

Unidimensionality Analysis

A scale has to be unidimensional in order to have reliability and construct validity [26]. Multidimensional construct, which aids with content validity, is acceptable as long as the scales are unidimensional. When the items of a scale estimate one factor then the scale is unidimensional. A good fit of the measurement model, as measured by the goodness of fit index (GFI), indicates that all items load significantly on one underlying latent variable.

A GFI of 0.90 or higher for the model indicates that there is no evidence of lack of unidimensionality. The GFI indices for all the scales are summarized in table II. The results suggest that all the scales are unidimensional.

Reliability

Reliability is the degree of dependability, consistency or stability of a scale [24]. Unidimensionality does not provide a direct assessment of construct reliability. The scale is said to be reliable if the items of a scale explain the majority of the variation in the construct vis-à-vis measurement error. The reliability is assessed in terms of Cronbach's alpha coefficient [18]. A scale is considered reliable if the alpha coefficient is greater than 0.70. The alpha coefficients are shown in table II. The results indicate that the scale is reliable.

Convergent Validity

Convergent validity is the extent to which different approaches to measurement of construct yield the same results. The commonly used way to assess convergent validity is to consider each item in the scale as a different approach to measure the construct. Convergent validity is checked using the Bentler-Bonett coefficient (Δ) [8]. The Bentler-Bonett coefficient (Δ) is the ratio of the difference between the chi-square value of the null measurement model and the chi-square value of the specified measurement model to the chi-square value of the null model. A scale with Δ value of 0.90 or above demonstrates strong convergent validity [1]. Table II summarizes the Bentler-Bonett

coefficient (Δ) value corresponding to all the scales. All the scales had the Bentler-Bonett coefficient (Δ) value above 0.90.

[TABLE II HERE]

Discriminant Validity

Discriminant validity is the degree to which measures of different scales of the survey instrument are unique from each other [50] and, especially, tautologies between scales increases the chance of a lack of discriminant validity. Even if there are no clear tautologies it is possible that an item in one scale is reflecting the value of a construct of another scale. Comparing the chi-square value of a model with a perfect correlation with that of an unconstrained model can test discriminant validity. A significant difference between the constrained model chi-square and that of the unconstrained model indicates that the two constructs are distinct [1] [50]. Table III shows the results of the 6 pairwise tests conducted for discriminant validity. All of the 6 tests indicated strong support for discriminant validity criteria at a p-value less than 0.1. Thus these scales satisfy the discriminant validity criterion.

[TABLE III HERE]

Criterion-Related Validity

Criterion-related validity measures how well scales predict theoretically related outcome variables. In order to determine criterion-related validity of various constructs, the scale scores are correlated with the primary outcome construct decision-making satisfaction [1] [50]. Structural equation modeling was used to correlate the various constructs with

decision-making satisfaction. Table IV shows the correlations of the various constructs with decision-making satisfaction construct. Note that all the scales have a statistically significant positive correlation with decision-making satisfaction. Therefore, criterion-related validity is supported for all the scales.

[TABLE IV HERE]

SEM is also known as latent variable analysis or causal modeling as it provides parameter estimates of the direct and indirect links between observed variables. AMOS 4.0, a structural equation-modeling tool from SPSS, and SPSS 10.1 were used for the analysis. The overall validity of the hypothesized model was tested using the fit criteria. The chi-squared value for the model is 252.57 for a degree of freedom of 84. A ratio of chi-squared to degree of freedom of no more than four-to-one is considered a good fit of the model [40]. A value of 3.01 is indicative of a good fit of the model.

Results and Discussion

The path coefficients calculated for the estimated model support the hypothesized relationships in both direction and magnitude. The statistical conclusions partially support the research model. Two of the hypotheses have been validated using the data. System quality is directly and positively correlated to decision-making satisfaction (H-1), so an increase in the quality of the system leads to an increase in decision-making satisfaction. Information quality is directly and positively correlated to decision-making satisfaction (H-2), so an increase in the quality of the information leads to an increase in decision-making satisfaction. Presentation is not directly and positively correlated to decision-

making satisfaction (H-3), so a positive change in presentation does not lead to a positive change in decision-making satisfaction As with all regression and structural equation modeling techniques, correlation does not prove the causality of the relation. Since these causal relationships are based on an established literature and the theoretical grounding of the causality is adequate, it is reasonable to concur with the causality, where it has been validated [25].

System quality includes system ease of use, convenience of access, and system reliability. Thus, a net positive effect from these factors will result in a positive effect on decision-making satisfaction. In web-based DSS, as in other systems, the ease of use of the system, convenience of access, and system reliability remain important considerations for the user.

Information relevance, accuracy, completeness and timeliness constitute the construct information quality. Thus, a net positive effect from these factors will result in a positive effect on decision-making satisfaction. The web-based DSS should provide relevant, accurate, complete and timely information for better decision-making satisfaction.

Graphics, color, presentation style, and navigational efficiency measures information presentation. Therefore, information presentation measures how information is displayed. Thus, it was hypothesized that a net positive effect from graphics, color, presentation style, and navigational efficiency will result in a positive effect on decision-making satisfaction. The data did not support this hypothesis.

The results from the research model also demonstrate that the relative weightage of information quality is higher than system quality. According to end-users, the quality of the information being provided is more important than the quality of the system. As compared to system quality, information quality will result in higher decision-making satisfaction.

Implications and Future Research

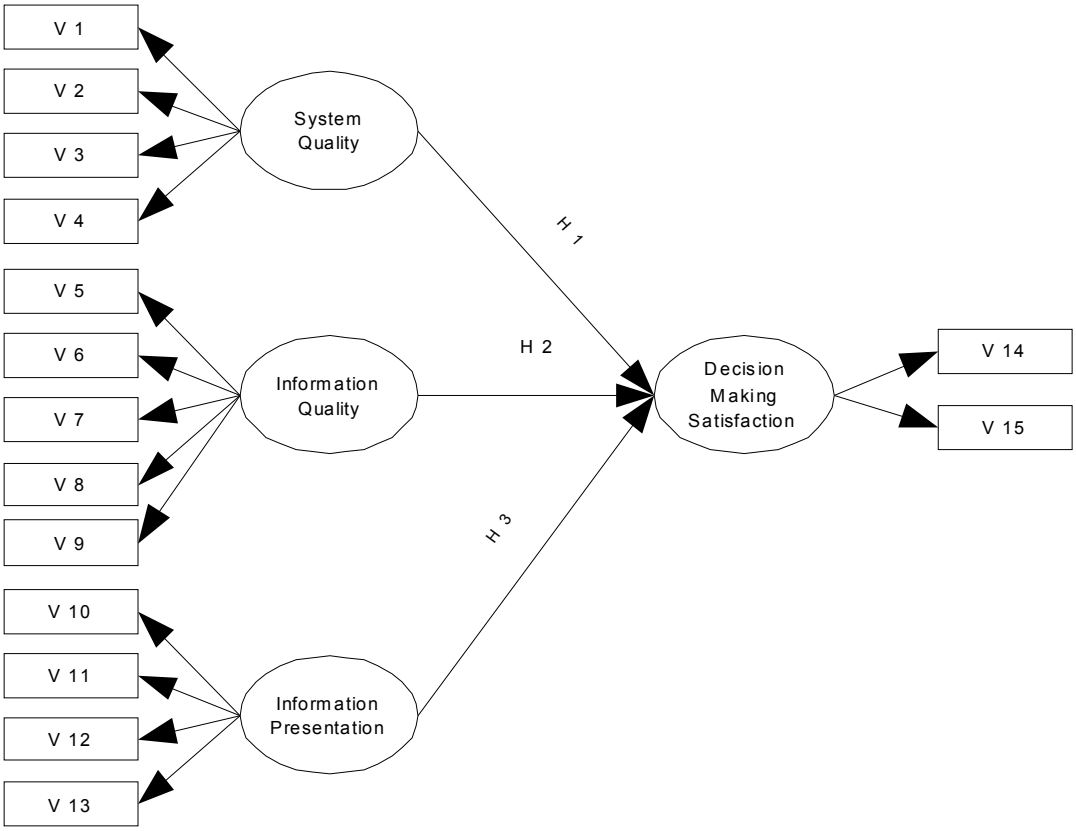
The research results empirically demonstrate the relationships between decision-making satisfaction, system quality, information quality and information presentation. These relationships are useful in determining the decision-making satisfaction of web-based DSS users. IS professionals need to understand these relationships in order to achieve better decision-making satisfaction. This research provides an understanding of the relationships.

According to conclusions derived from our research, in web-based DSS, the quality of information influences decision-making satisfaction the most. So, for example, for web-based DSS in the medical industry, such as drkoop.com, our research suggests that users would value complete, accurate and relevant information about medications and their interactions with other drugs or foods the most. Similarly, users will have better decision-making satisfaction with timely, accurate and complete information provided by the web-based product configuration DSS sites such as for desktop computers.

Our research suggests that ease of use, convenience of access, and system reliability also influence the decision-making satisfaction of users. The web-based DSS, other than just being available and accessible, should also be easy to use. The web-based product configurators and car portals are fairly easy to use. The same is true for the health calculators on nutrition at the medical web sites.

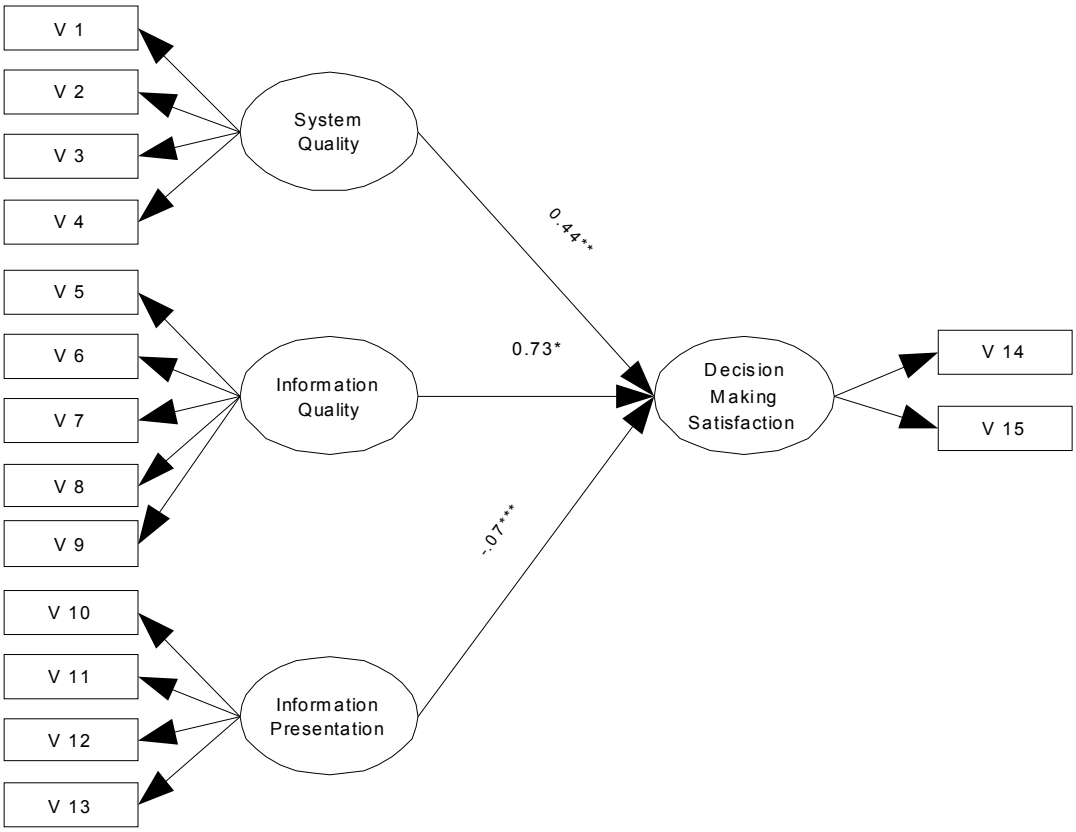
The empirical data suggest that the presentation of information is not important to the user for decision-making. The users are not particularly taken back by color, graphics and presentation style, but are more interested in the pertinent information being provided to them via the web-based DSS. This is an interesting result because in the recent past, there has been an increase in color and graphics on web sites, but this presentation is of limited use if these web sites are not able to provide the desired quality of information.

This research has examined the perceptions of users on decision-making satisfaction and, in doing so, has validated part of the proposed model using the data. Even the hypothesis that was not validated has provided interesting insight. Similar studies on web-based DSS should be conducted to test the relationships between decision-making satisfaction and system quality, information quality and information presentation. These studies will help build a wider body of research, which is needed for web-based DSS. Further studies should also be conducted using other web-based DSS so as to test if the results of the present study can be extended to other situations.



Note: Error and disturbance terms are not shown for the sake of brevity.

Figure I: Conceptual Model



* p<.01; ** p<.1; *** Statistically insignificant

Note: Error and disturbance terms are not shown for the sake of brevity.

Figure II: Model with Results

Table I: List of Sources and Instruments

Independent / Dependent Construct	Construct Name	Item No.	Item Measured	Reference
Independent	System Quality	V 1	System reliability	Srinivasan, 1985
		V 2	Convenient to access	Bailey and Pearson, 1983
		V 3	System ease of use	Belardo, Karwan, and Wallace, 1982
		V 4	System flexibility	Srinivasan, 1985
Independent	Information Quality	V 5	Information accuracy	Bailey and Pearson, 1983; Mahmood, 1987; Miller and Doyle, 1987; Srinivasan, 1985
		V 6	Information completeness	Bailey and Pearson, 1983; Miller and Doyle, 1987
		V 7	Information relevance	Bailey and Pearson, 1983; King and Epstein, 1983; Miller and Doyle, 1987; Srinivasan, 1985
		V 8	Information content needs	Doll and Torkzadeh, 1988
		V 9	Information timeliness	Bailey and Pearson, 1983; King and Epstein, 1983; Mahmood, 1987; Miller and Doyle, 1987; Srinivasan, 1985
Independent	Information Presentation	V 10	Presentation graphics	Swanson, 1985-86; Vessey, 1994
		V 11	Presentation color	Swanson, 1985-86; Vessey, 1994
		V 12	Presentation style	Swanson, 1985-86; Vessey, 1994
		V 13	Navigationally efficient	Swanson, 1985-86; Vessey, 1994

Independent / Dependent Construct	Construct Name	Item No.	Item Measured	Reference
Dependent	Decision Making Satisfaction	V 14	Decision confidence	Goslar, Green, and Hughes, 1986; Guental, Surprenant, and Bubeck, 1984; Zmud, Blocher, and Moffie, 1983
		V 15	Decision effectiveness	Chervany, Dickson, and Kozar, 1972

Table II: Tests for Unidimensionality, Reliability and Convergent Validity

No.	Construct	No. of indicators	Unidimensionality [Goodness of Fit Index (GFI)]	Reliability [Cronbach's α]	Convergent Validity [Bentler Bonnet Δ]
1.	System Quality	4	.99	.73	.98
2.	Information Quality	5	.97	.85	.96
3.	Information presentation	4	.92	.83	.91
4.	Decision-making satisfaction*	2		.83	
	- System Quality		.95		.93
	- Information Quality		.96		.95
	- Information presentation		.92		.92

* A combined model was run for this construct.

Table III: Test for Discriminant Validity

Test #	Description	Chi-Squared Constrained Model (df)	Chi-Squared Unconstrained Model (df)	Difference
1	System Quality with Information Quality	120.9 (27)	113.4 (26)	7.5**

Test #	Description	Chi-Squared Constrained Model (df)	Chi-Squared Unconstrained Model (df)	Difference
2	System Quality with Information presentation	99.5 (20)	83.6 (19)	15.9**
3	System Quality with Decision-making satisfaction	34.5 (9)	29.5 (8)	5*
4	Information Quality with Information presentation	110.2 (27)	89.7 (26)	20.5**
5	Information Quality with Decision-making satisfaction	36.3 (14)	30.7 (13)	5.6*
6	Information presentation with Decision-making satisfaction	61.0 (9)	47.1 (8)	13.9**

* $p<0.05$; ** $p<0.01$

Table IV: Test for Criterion-Related Validity

No.	Construct	Decision-making satisfaction γ
1	System Quality	0.66**
2	Information Quality	0.68**
3	Information Presentation	0.47**

** $p<0.01$

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