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Abstract:

While many studies have investigated the relationship between information systems (IS) characteristics and IS use, the results have been inconsistent. We argue that this inconsistency may be due to the modeling of information and system quality and the importance of the system usage context. We extend Wixom and Todd's (2005) integrated model of IS satisfaction by proposing and modeling information and system quality as second-order constructs and by testing the model in the system administration context. Our findings provide support for modeling information and system quality as second-order constructs in the integrated model. Furthermore, our findings support using additional constructs, unique to the context studied, in the integrated model. We contribute to current literature by 1) enhancing the construct validity of information and system quality, which ultimately improves statistical conclusion validity and internal validity for studies that focus on information and system quality; and 2) testing the extended model in the system administration context. Our findings suggest that future research should measure information quality and system quality as second-order constructs and that including context-specific information and system characteristics provides researchers and practitioners with a better understanding of IS characteristics important in system administration.

Keywords: Information Systems (IS) Success, Information Quality, System Quality, Second-order Construct, System Administration.

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1 Introduction

Researchers have long been interested in information systems (IS) success in various contexts and sought to better understand the relationship between system characteristics and how those characteristics influence systems' quality, success, and use. In evaluating these system characteristics, studies have generally modeled system characteristics as first-order constructs that, in turn, influence first-order quality constructs (e.g., Nelson, Todd, & Wixom, 2005; Wixom & Todd, 2005). Such models may be appropriate for relatively simplistic constructs; however, the theoretical definition of more complex constructs suggests that one should employ different modeling approaches. Due to advances in path modeling techniques (Wetzels, Odekerken-Schröder, & Van Oppen, 2009) and clearer model specification guidelines (MacKenzie, Podsakoff, & Podsakoff, 2011), it is appropriate to rethink model specifications for information quality and system quality as second-order constructs.

When evaluating user perceptions of information technology (e.g., DeLone & McLean, 1992), researchers have often used theories of technology acceptance (e.g., Davis, 1989; Venkatesh, 2000) and user satisfaction (e.g., Bailey & Pearson, 1983; Schneiderman, 1997). To leverage the strengths of these research streams, Wixom and Todd (2005) developed an integrated user satisfaction model (hereafter WT model). Their model provides a deeper understanding of the technology characteristics that comprise information quality and system quality and how these characteristics lead to information and system satisfaction and subsequent technology acceptance. However, despite the theoretical definitions employed in WT and similar research streams, researchers have treated information quality and system quality as relatively simplistic constructs. We believe that researchers should periodically reevaluate their research streams' state of affairs and assess whether the field has adopted emergent best practices or has persisted in reapplying existing methodologies and existing measurement/modeling techniques. Because of the integral position of information quality and system quality in the WT model, we use the WT model to illustrate the use of modeling techniques that are more consistent with the complex theoretical definitions of information quality and system quality.

In addition to investigating the modeling of quality constructs as second-order constructs, we conduct our study in a new domain. Wixom and Todd (2005) originally tested the WT model in the context of data warehousing systems, and we need to test the model in other contexts for two reasons. First, researchers should "investigate whether there is a core set of system characteristics that apply broadly across a wide range of systems" (Wixom & Todd, 2005, p. 100). While researchers have tested the WT model across a variety of contexts, in some contexts, the measurement model does not demonstrate clear construct validity[1], which leads to questions regarding the existence of contextual boundary conditions in the core WT model. A boundary condition is a condition or context in which the expected pattern of relationships is invalid. For example, when one tests an established model in a new context, the expected relationships among constructs may no longer hold or the measurement model may not demonstrate convergent and discriminant validity; in such a case, the new context may be a boundary condition for the model. Second, studies should identify and investigate any additional system characteristics specific to alternative technology and contexts (Whetten, 1989). We answer these calls by conducting our study in a new context: system administration.

To summarize, our study makes two main contributions to the IS field. First, by modeling information quality and system quality more accurately as second-order constructs, we enhance the construct validity of information and system quality, which ultimately improves statistical conclusion validity and internal validity for studies with information quality and system quality (MacKenzie, 2003). Second, by testing the WT model in the context of system administration, we help develop a deeper understanding of the characteristics of information quality and system quality relevant for system admins and identify potential system characteristics that future studies should include in the core set of system characteristics. When one brings these two contributions together, we demonstrate that, by updating our modeling techniques to model and evaluate information quality and system quality as second-order constructs, we can resolve the apparent boundary condition of the core WT information quality and system quality characteristics that appears in some contexts.

[1] Based on data collected from experienced system administrators, when one models information quality and system quality as first-order constructs—consistent with WT—information quality and system quality failed to discriminate from each other. Additionally, 22 percent of the items used to measure information quality and system quality in WT were not significantly related to these constructs, which suggests the existence of a potential boundary condition in the core WT system characteristics. For more detail, see Section 7.1.

This paper proceeds as follows: in Section 2, we discuss the WT model in the context of system administration. In Section 3, we review previous literature and describe in detail the underlying rationale to measure information and system quality as second-order constructs. In Section 4, we discuss the context of the empirical study and propose additional relevant system characteristics. In Section 5, we present the research methodology used to examine the model and, in Section 6, the results. In Section 7, we conclude the paper by discussing our results and their implications.

2 Integrated User Satisfaction Model

Researchers have proposed several models of information systems success that most often build on DeLone and McLean's (1992) model of information systems user satisfaction or the technology acceptance model (Davis, 1989). To leverage the strength of both the technology acceptance and user satisfaction theories, Wixom and Todd (2005) developed a model that links system and information satisfaction constructs from user satisfaction literature (DeLone & McLean, 1992) with the behavioral predictors found in the technology acceptance literature (Davis, 1989) (see Figure 1). DeLone and McLean (1992) argue that the object-based attitudes and beliefs expressed in system quality, information quality, system satisfaction, and information satisfaction central to information satisfaction literature affect the behavioral beliefs that are central to technology acceptance literature, which ease of use and perceived usefulness capture (Davis, 1989).

The WT integrated model suggests that external variables (e.g., IS characteristics) influence object-based beliefs, which are operationalized as information quality and system quality. In turn, information quality and system quality affect object-based attitudes of information satisfaction and system satisfaction. As object-based attitudes, information and system satisfaction influence one's behavioral beliefs of perceived usefulness and ease of use, respectively. Behavioral beliefs then affect one's attitudes toward using the system. Finally, one's attitudes influence behavior (i.e., using or not using a system). We describe these relationships below.

Based on the theory of reasoned action (TRA) (Ajzen & Fishbein, 1980; Ajzen, Fishbein, & Zanna, 2005), the WT model posits that behavioral beliefs affect behavioral attitude. Ease of use reflects a user's belief about the effortlessness of using a particular system, which contributes to their beliefs about a system's usefulness (Davis, 1989). Ease of use is a behavioral belief that influences a user's behavioral attitude about using a particular system (Davis, 1989, Wixom & Todd, 2005). Perceived usefulness reflects a user's behavioral beliefs about the impact of a particular system on their job performance, which impacts their behavioral attitude about using a particular system (Davis, 1989; Wixom & Todd, 2005). This behavioral attitude, together with perceived usefulness, affects behavioral intention (Davis, 1989, Venkatesh, Morris, Davis, & Davis, 2003).

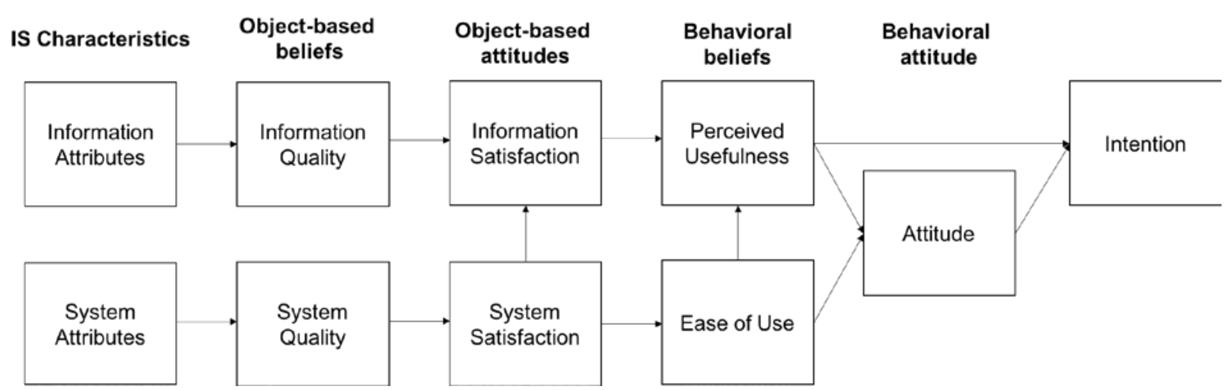


Figure 1. Wixom and Todd's (2005) Integrated Model with IQ and SQ as First-order Constructs

As the user satisfaction literature explains (e.g., Baroudi & Orlikowski, 1988; DeLone & McLean, 1992; Doll & Torkzadeh, 1988; Ives, Olson, & Baroudi, 1983), information quality and system quality are users' perceptions of a system and its information. Consistent with previous literature on user satisfaction, the model proposes that information and system quality affect information and system satisfaction, respectively. Wixom and Todd (2005) conceptualize information and system quality as object-based beliefs and information and system satisfaction as object-based attitudes. This conceptualization is consistent with attitude-behavior theories, which state that object-based beliefs affect the object-based attitudes users have toward that system (Ajzen et al., 2005). Furthermore, object-based attitudes are antecedents to behavioral beliefs. Although user attitude theories support these behavioral and object-based beliefs, we believe that one can strengthen the model by carefully examining information quality and system quality and their modeling as second-order constructs. We describe our reasoning in Section 3.

3 Information Quality and System Quality as Second-order Constructs

To better understand the modeling of information quality and system quality as latent constructs, we conducted a thorough literature search on relevant papers published since 2000. Specifically, we searched the EBSCO database using the key words "information quality", "system quality", and "information systems success model". This search resulted in 19 papers, which we present in Appendix A. Three observations about information quality and system quality emerge from reviewing these 19 studies: 1) their multidimensionality, 2) the context dependence of their characteristics, and 3) the need for second-order modeling. We discuss each observation in Sections 3.1 to 3.3.

3.1 Multidimensionality of Information Quality and System Quality

While some studies using information quality and system quality have modeled them as first-order constructs with "global" indicators, which are influenced by a parsimonious set of system characteristics, the majority of studies presented in Appendix A recognize the multidimensionality of both information quality and system quality. The number of sub-dimensions for each construct ranges anywhere from two to nine. The need for sub-dimensions arises because information quality "reflects perceptions of the system itself and the way it delivers information" (Wixom & Todd, 2005, p. 91) and because system quality "represent(s) user perceptions of interaction with the system over time" (Nelson et al., 2005, p. 205). Furthermore, those system characteristics are defining characteristics for information and system quality, and a change in just one system characteristic will likely affect information or system quality. For example, enhancing a system's reliability can improve system quality. On the other hand, an increase in system reliability is not necessarily associated with an increase in system flexibility, and an increase in system quality may not produce increases in all of the other system characteristics. While we can view each characteristic as a separate construct, these characteristics are all essential parts of information quality or system quality constructs at a more abstract level and represent their sub-dimensions.

3.2 Context-dependence of Characteristics

The characteristics of information quality and system quality are context dependent. That is, various contexts may have a different set of information and system characteristics relevant to information and system quality. In addition to generic characteristics, such as accuracy and timeliness for information quality and reliability for system quality, new characteristics emerge. Information quality characteristics are extended by understandability and conciseness for ERP systems (Gable et al., 2008), scope for mobile data services (Lee, Shin, & Lee, 2009), and value-added and richness for virtual communities (Zheng, Zhao, & Stylianou, 2013). System quality characteristics are extended by flexibility, sophistication, integration, and customization for ERP systems (Gable, Sedera, & Chan, 2008); integration for data warehouses (Wixom & Watson, 2001); and appearance, security, and interactivity for virtual communities (Zheng et al., 2013). Therefore, there is a demonstrated need to continuously develop corresponding measures of information and system quality in additional contexts. Since we did not find any study that develops measures of information and system quality in the context of system administration, our study can make valuable contributions to the existing literature in this context and to related contexts, such as those of other technical professionals, those who work in high risk or complex work environments, or those whose work is characterized by interruptions (see Section 4 below).

3.3 Need for Second-order Modeling

Based on our discussion above, we can conclude that researchers have often not defined latent constructs in a unidimensional way (MacKenzie et al., 2011); in these cases, the level of abstraction used to define the construct should be followed to determine whether it is viewed as unidimensional or multi-dimensional and whether one can better measure it as a first-order construct or a second-order construct (Jarvis, MacKenzie, & Podsakoff, 2003).

While we agree with the importance of each of these information and system quality characteristics, we can improve the model specification that uses first-order constructs that are influenced by these characteristics. According to Jarvis et al. (2003), one may specify the conceptual definitions of constructs at a more abstract level, which includes multiple first-order constructs. Because researchers define information quality and system quality at a more abstract level, it may be appropriate to measure them as second-order constructs, which include first-order constructs that cover their essential aspects, such as reliability and flexibility (Jarvis et al., 2003). One aim of measurement is to ensure that 1) all important aspects of the conceptual definition are included, 2) the items are not contaminated by including irrelevant items, and 3) the indicators are properly worded (e.g., unambiguous and specific) (MacKenzie, 2003). Thus, using "global" indicators may not be appropriate because global indicators may make the question cognitively complex, and there is no way to tell precisely how participants combine different dimensions and generate their response to the question. For example, consider system quality, which one usually measures as a first-order construct with the following three indicators: 1) in terms of system quality, I would rate <the system> highly, 2) overall, <the system> is of high quality, and 3) overall, I would give the quality of <the system> a high rating (Nelson et al., 2005; Wixom & Todd, 2005). These indicators can be ambiguous in their definition and construction of system quality. Specifically, these items rely on an implicit definition of quality rather than a specific one, and there is no way to know how participants come to their responses. Thus, these first-order quality indicators may not accurately measure the relevant characteristics that comprise information and system quality, which undermines the construct validity of information and system quality and, in turn, weakens the statistical conclusion validity and internal validity of studies that use these constructs.

Therefore, it may be more appropriate to remove the "overall quality" measures used to capture information quality and system quality as first-order constructs and instead measure these two constructs as second-order constructs. First, the indicators for each information or system characteristic first-order construct can be specific and unambiguous. Second, these information or system characteristic first-order constructs can collectively capture all essential aspects of the conceptual domain of information quality or system quality. Note that we do not mean to suggest that information and system quality should never be measured as first-order constructs. Rather, we argue that developing a measurement to capture information quality and system quality as first-order constructs can be quite challenging. Also note that we call attention to this issue not to criticize the original research but to emphasize the challenge of developing measures and to propose an alternative method to measure information quality and system quality.

Using second-order constructs for information and system quality is even more desirable because of these measures' multidimensional nature. For example, prior research (e.g., Wixom & Todd, 2005) has suggested system quality is influenced by four system characteristics (reliability, flexibility, integration, and timeliness), which represent relatively unique aspects of system quality. Therefore, one may more appropriately model information and system quality as second-order formative constructs (MacKenzie et al., 2011).

Previous research has shown the validity of modeling quality constructs at the second-order. For example, researchers have modeled service quality as a second-order construct while examining research questions concerned with the hotel industry (Sánchez-Hernández, Martinez-Tur, Peiró, & Ramos, 2009), airline industry (Koufteros, Babbar, & Kaighobadi, 2009), and IS service (Kettinger, Park, & Smith, 2009). Agarwal, Malhotra, & Bolton (2010) empirically tested and demonstrated that the second-order service quality model was statistically superior to other, first-order service quality models used in prior literature. Loiacono, Chen, and Goodhue (2002) used a second-order model for testing previous work with WebQual, and confirmatory factor analysis showed that, as a second-order construct, five first-order constructs (usefulness, response time, trust, ease of use, and entertainment) influenced WebQual perceptions (see also Kim & Stoel, 2004). In another study, McKinney et al. (2002) decomposed website quality into system quality and information quality. They designed and tested second-order constructs for measuring Web-customer expectations, disconfirmation, and perceived performance regarding information quality and system quality (McKinney, Yoon, & Zahedi, 2002). Previous studies have also measured information quality and system quality as second-order constructs (e.g., Setia, Venkatesh, Joglekar, 2013; Zheng et al., 2013). These studies suggest that quality in general, and information and system quality in particular are quite complex and that modeling these constructs as second-order constructs may be more appropriate than modeling them as first-order constructs.

While previous studies have recognized the multidimensional nature of information quality and system quality, we identified only two studies using second-order formative constructs for information or system quality (see Setia et al., 2013; Zheng et al., 2013). However, these studies use relatively few information and system quality characteristics (no more than three) and study a much simpler model while focusing on DeLone and McLean's (1992) original model of information systems success. Our review suggests that IS research would be wise to heed methodological advances and research findings about measuring information quality and system quality, and it may become necessary to consider including additional characteristics specific to the context of interest (Galletta & Lederer, 1989).

4 The WT Model in the Context of System Administration

4.1 Context of Interest: System Administrators

In this section, we discuss the specific context for this study and identify relevant information and system characteristics beyond those found in the extant literature. System admins are information technology professionals who execute the system administration tasks for their organization even though their job titles may not designate them as such (Sage, 2008). System admins' responsibilities include configuring, maintaining, troubleshooting, and backing up systems, networks, databases, and servers (Sage, 2008). Their work provides technical services to their organizations and requires significant knowledge of operating systems, hardware components, applications, databases, networking, and the complex interrelationships among system components (Bailey, Kandogan, Haber, & Maglio, 2007; Barrett, Chen, & Maglio, 2003; Barrett et al., 2004; Haber & Kandogan, 2007; Patterson et al., 2002; Sage, 2008). A single system admin can support anywhere from a single end user to over 16,000 end users, though most support approximately 45 (Sage, 2008). With the growing complexity of computing infrastructures (Bailey et al., 2007; Barrett et al., 2004; Patterson et al., 2002), efficiently maintaining and managing these systems has grown in importance (Horn, 2001). Additionally, the high costs associated with this complex work have attracted many companies' attention (HP, 2007; Sun Microsystems, 2006; Horn, 2001). While the costs of actual hardware components continues to fall, the cost of administering these systems has increased and surpassed hardware and software costs (Kephart & Chess, 2003; Patterson et al., 2002; Horn, 2001). In summary, system admins are subject matter experts whose work is highly complex and expensive.

In this context, companies provide system admins with tools to support their work and help them be more effective and efficient (e.g., Horn 2001; HP, 2007; Khalifa & Davison, 2006; Lenchner et al., 2009; Sun Microsystems, 2006). Because system admins deal mostly with software and hardware, many of their tools are computerized, and such tools can include various information systems and software programs (Haber & Kandogan, 2007; Velasquez & Weisband, 2008). Organizations can develop these tools in-house or buy them from vendors or third parties (which they can then either customize or not) (Barrett et al., 2004). When working on a task, system admins have reported selecting and using the tool that uniquely suits the problem at hand (Velasquez & Weisband, 2008). However, research has not yet investigated the information and system quality characteristics important in the tools that system admins use. In Section 5, we presents the unique needs of system admins with respect to information and system quality in the WT model.

4.2 The WT Model in this Context

We extend the WT model in the context of our study, system administration, by referencing recent studies on system admins and their work practices to gain "a better understanding among researchers, and among many system designers too, about the "users" of computer systems and the settings in which they work" (Bannon, 1991, p. 25). Studies on system administration and system admins' work practices suggest that these users may have unique information and system needs (Barrett et al., 2004; Velasquez & Weisband, 2008). For example, when checking on system use or system performance, a system admin may use a reporting tool that presents the information in an easy-to-understand graphical format even if generating these reports takes a few minutes (e.g., formatted reports such as bar charts and pie charts). Alternatively, when monitoring system status, system admins may prefer a tool with much faster response times and basic text output. Researchers who have analyzed system admins' work practices have identified the following relevant information and system characteristics (Velasquez and Weisband, 2008): reliability, flexibility, integration, accessibility, credibility, scalability, scriptability, situation awareness, monitoring, speed, completeness, accuracy, format, currency, logging, and verification. Consistent with

McKnight (2005), we have expanded credibility to include three dimensions: functionality, predictability, and helpfulness. We have also operationalized situation awareness to account for current states (situation awareness) and future states (mental model) (Hrebec & Stiber, 2001). Table 1 provides definitions of these characteristics, which we modeled as first-order constructs in our study (see Figure 2).

Table 1. System and Information Characteristics Important to System Admins (Adapted from Velasquez & Weisband, 2008)

Information characteristics	Definition
Completeness[1]	The degree to which all necessary information is provided.
Accuracy[1]	The degree to which the information is correct.
Format[1]	The degree of how well the information is presented.
Logging[2]	The degree to which the information reflects previous actions taken.
Verification[2]	The degree to which the information echoes or repeats the outcomes of previous actions.
System characteristics	
Reliability[1]	The dependability of system operation.
Flexibility[1]	The way the system adapts to changing demands of the user.
Integration[1]	The degree to which the system allows data to be integrated from various sources.
Accessibility[1]	The ease with which information can be accessed or extracted from the system.
Credibility (functionality)[2]	The degree to which the functionality of the system meets the needs of the user.
Credibility (predictibility)[2]	The degree to which the system operates in a predictable way.
Credibility (helpfulness)[2]	The degree to which the system's embedded Help function is helpful.
Scalability[3]	The ability of a system to scale to large or complex computing environments.
Scriptability[3]	The degree to which the system provides the ability to script add-ons or automate tasks.
Situation awareness[2]	The degree to which the system provides information about the overall state of the system that can be used to guide current actions.
Mental model[2]	The degree to which the system provides information that can be used to anticipate future events and formulate plans.
Monitoring[3]	The degree to which the system provides the ability to monitor for certain events or conditions.
Speed[3]	The degree to which the system executes commands, including the speed of startup / initiation.
Timeliness[4]	The degree to which the system provides timely responses to requests for information or action.

[1] Characteristics significant in Wixom and Todd (2005).
[2] New characteristics identified by Velasquez and Weisband (2008); expanded to include three dimensions of trust (functionality, predictability, and helpfulness) (McKnight, 2005) and both current/future dimensions of system state (Hrebec & Stiber, 2001).
[3] New characteristics identified by Velasquez and Weisband (2008).
[4] Characteristics not significant in Wixom and Todd (2005) but included in Velasquez and Weisband (2008).

In summary, our model (see Figure 2) tests the WT model with information and system quality re-specified as second-order constructs in the context of system admins. This model expands the core set of system and information quality characteristics to include those that prior research analyzing system admins' work practice has suggested (Velasquez & Weisband, 2008). We exclude service quality (e.g., Chen, 2010; Negash, Ryan, & Igbaria, 2003) from the model because system admins provide rather than consume a service. Testing this model will provide further empirical evidence on which characteristics one should include in the core set of system characteristics and can also inform practitioners regarding which features they should implement.

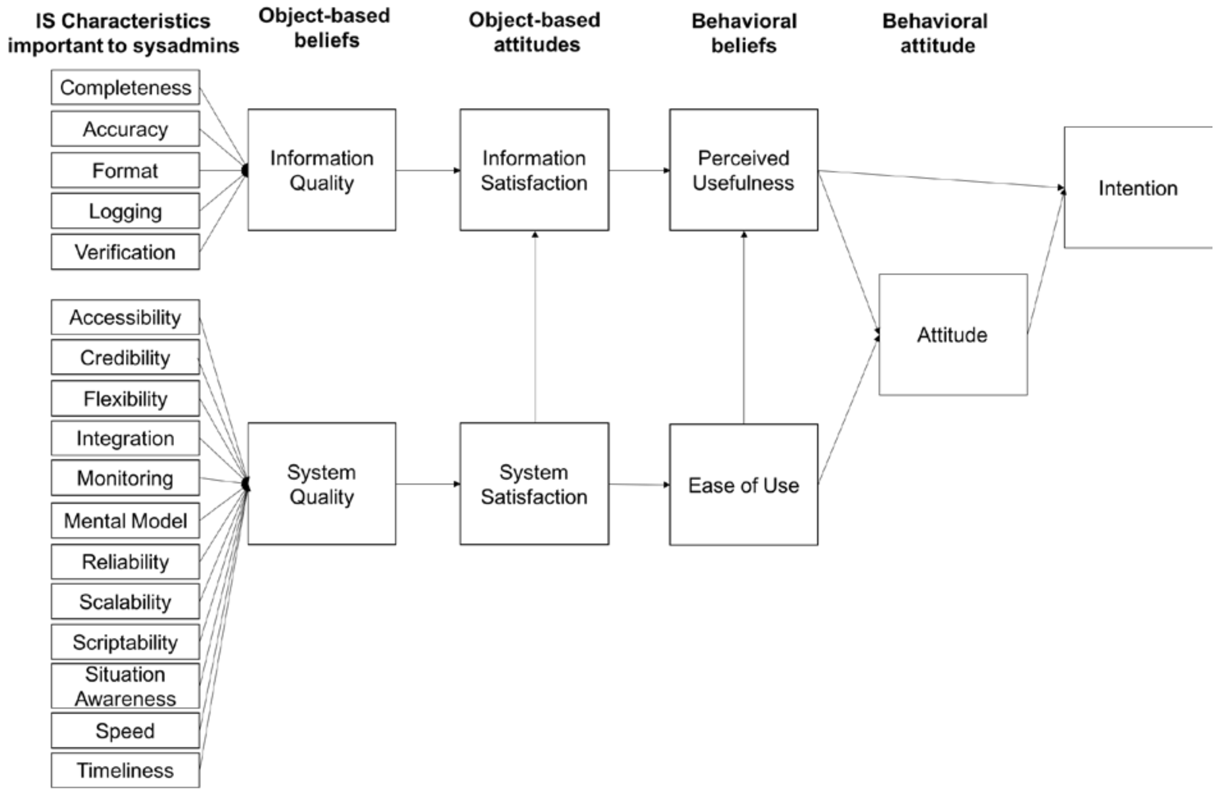


Figure 2. The WT Model in the Context of System Admins with IQ and SQ as Second-order Constructs

5 Method

5.1 Measurements

We use the Wixom and Todd (2005) instrument to measure the constructs adapted from the WT model and adapt measures from McKnight (2005) for credibility items. We developed items to measure new constructs (i.e., logging, verification, scalability, scriptability, situation awareness, mental model, and monitoring) following Churchill's (1979) methodology. We created items based on construct definitions and components identified in the literature (e.g., Endsley, 1995; Fogg & Tseng, 1999). Next, we used a sorting task to determine face and discriminant validity. We wrote each measurement item on a 3x5 note card and shuffled all cards. We asked three professional system admins who did not participate in the pilot or final survey to sort the cards into logical groups and name each group. Each system admin sorted the items into groups and specified similar identifying terms. We measured each item on the final survey on a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). Based on the feedback from three professional system admins, we slightly modified the wording on some items. Before implementing the survey, we pilot tested it was with 24 professional system admins at a professional system administrator conference. We invited participants to email the researcher with any suggestions or modifications not included in their survey responses.

Although organizations may play a role in selecting or purchasing tools, system admins primarily use a self-selected suite of tools to perform their work, and system admins in the same organization and even on the same team use different tools to perform the same tasks. Given this variability, we faced difficulty in gathering survey responses from hundreds of system admins on one particular tool. As such, we asked each participant to identify the tool they used most often in their jobs and complete the survey with that one particular tool in mind. Appendix B lists the final instrument of this study.

5.2 Sampling and Data Collection

We used a Web-based survey to collect data. The population of interest was system admins of all specialties (e.g., network, operating system, web, etc.). We posted an invitation to participate in this study on professional system administrator association message boards. We also invited participants to refer fellow system admins to the study. All surveys were confidential (we collected no identifying information) and all questions were optional.

After removing incomplete responses, we had 230 fully completed surveys. A total of 517 subjects viewed the survey and 237 completed it for a 45.8 percent completion rate. More than half of the survey participants worked for for-profit organizations (53.5%), including those in the manufacturing, high tech, and finance industries. The next largest number of respondents worked in academic settings and in not-for-profit organizations or government agencies (both 16.1%). Of the survey respondents, 94.8 percent were male and 4.3 percent were female. The age of respondents ranged from 20 to 62 with an average age of 38.1. Participants reported working at their current organization for an average of five years (ranging from less than one month to 35 years) and reported working as a system admin for an average of 13.8 years (ranging from one year to 32 years). Our participants' demographics were similar to those found in the Salary Survey for 2007 (Sage, 2008), considered the most recent and comprehensive survey of system admin personal and work demographics. These similarities suggest the survey sample represents the system admin population. Table 2 shows the demographics that were available for direct comparison. In addition, we compared early and late respondents and found no significant differences, which indicates that nonresponse bias was likely not an issue in our study.

Table 2. Study v. 2007 Sage Salary Survey (2008)

Measure	Study Statistics	SAGE Statistics
Years' experience (mean)	13.83	9.74
Years' experience (stddev)	7.2	6.3
Age (mean)	38.1	34[1]
Male respondents	94.8	86.6%
Female respondents	4.3	13.4%
Earned undergraduate degree	67.4%	59.1%
[1] Approximated from available data.		

To begin our analysis, we examined whether common method bias was a concern in our study. Following Podsakoff, MacKenzie, Lee, and Podsakoff (2003) and Lindell and Whitney (2001), we performed two common method variance (CMV) tests. First, an exploratory factor analysis of all items extracted 17 factors explaining 78 percent of the variance with no single factor accounting for significant loading (at the $p < 0.10$ level) for all items. However, because Harmon's single-factor test is known to insufficiently detect moderate to small levels of CMV (Malhotra, Kim, & Patil, 2006), we also used the marker-variable technique (Lindell & Whitney, 2001), which offers two alternative methods for assessing CMV. In the first alternative, one can identify and incorporate a marker variable that is theoretically unrelated to at least one variable in the study into the instrument. The correlation between the marker variable and the dependent variable is a reliable estimate of CMV. In the second alternative, the second-smallest positive correlation among the manifest variables provides a conservative estimate for CMV. Given our study design, we employed the second method. After adjusting for the second smallest positive correlation, all significant correlations remained significant. Based on the results of these two tests, we can conclude that CMV was not a concern for our data set.

6 Analysis and Results

Following previous literature (Chin, 1998, 2010; Gefen, Straub, & Rigdon, 2011; Hulland, 1999), we tested the proposed research model using partial least squares (PLS), a structural equation modeling method suitable for complex predictive models and theory building (Barclay, Higgins, & Thompson, 1995; Chin, 1998; Lohmoller, 1989). We used SmartPLS version 2.0 (Ringle, Wende, & Will, 2005) for the analysis and the bootstrap re-sampling method (using 1,000 samples) to determine the significance of the paths in the structural model. PLS is a preferred analytical technique for several reasons: first, PLS is quite useful to support an incremental study. As Chin (2010) suggests, PLS is appropriate where a researcher "builds on a prior model by developing both new measures and structural paths" (p. 660), which is what our study presents. By using PLS, researchers can "constrain the new construct and measures to its immediate nomological neighborhood of constructs and avoid possible covariance-based structural equation modeling (CBSEM) estimation bias that can be affected by minor modeling or item selection errors" (p.

660). Second, our study models IQ and SQ as second-order formative constructs. As Chin (2010) and Gefen et al. (2011) suggest, one can easily implement formative measurement with PLS but not so easily with CBSEM. Further, in CBSEM, researchers are limited to only second-order reflective constructs, while PLS can easily model both second-order reflective and formative constructs (Chin, 2010; Wetzels et al., 2009). Third, PLS is appropriate for complex models. As the number of items increases and the model becomes more complex, researchers will likely obtain a poor model fit due to the model's complexity (Chin, 2010). Our study has a complex model with 82 items, and PLS is well suited to analyze our model. Fourth, PLS works well with small-to-medium sized samples (Chin, 2010). Fifth, PLS is better suited to predictive models than CBSEM, which focuses instead on model fit (Chin, 2010), and the model we tested predicts IS intention. Finally, this study is an extension and comparison to a study that used PLS analysis (Wixom & Todd, 2005), and easily interpretable comparisons to the original study suggest using PLS.

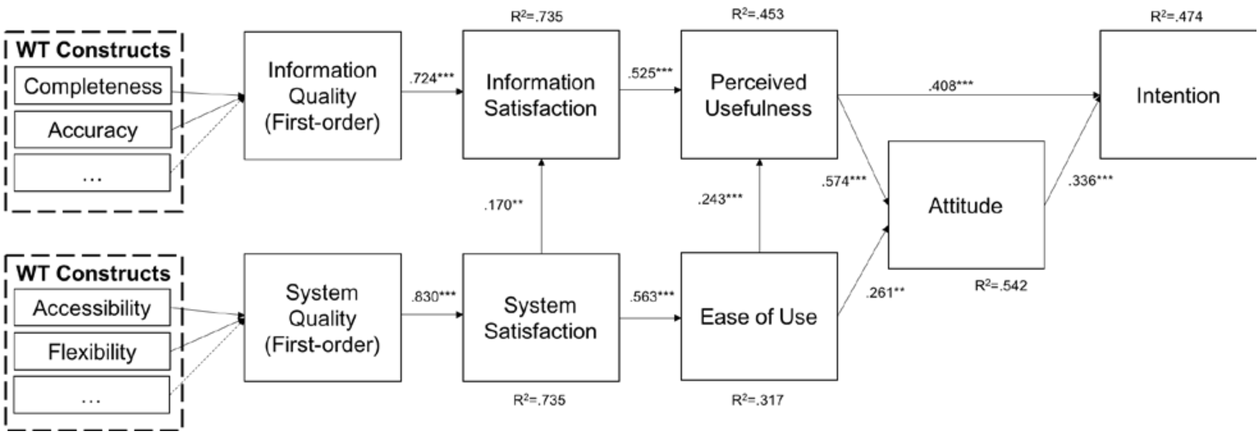
A rule-of-thumb for PLS sample size is ten times the largest structural equation or the largest measurement equation (Barclay et al., 1995, Gefen, Straub, & Boudreau, 2000). In our case, the largest structural equation was the system quality construct with 14 paths in the measurement model; our sample size of 230 exceeded the minimum suggested sample size of 140.

Following recommended methods, we analyzed the data in two stages (Gefen & Straub, 2005). In the first stage, we assessed the measurement model, and, in the second stage, we assessed the structural model (Hulland, 1999). In assessing the measurement model, we first specified a null model with all first-order latent variables (including first-order IQ and SQ) (Wetzels et al., 2009). We established convergent validity by satisfying three criteria (Gefen & Straub, 2005; Hulland, 1999). First, each item loaded significantly on its respective construct, and no items loaded on its construct below the cutoff value of 0.60 (see Appendix B, Table B2). Second, composite reliability (CR) for each construct was over 0.70 (Appendix B) (Chin, MArcolin, & Newsted, 2003). Finally, the average variance extracted (AVE) of each construct exceeded the threshold value of 0.50 (Appendix B). Therefore, the measurement model demonstrated good convergent validity. Discriminant validity was confirmed because the correlations between constructs were below 0.85 (Brown, 2006) and, for each construct, the square root of AVE exceeded all correlations between that factor and any other construct (Gefen & Straub, 2005). The measurement model demonstrated good discriminant validity except for first-order information quality. The correlation between information quality and information satisfaction was 0.85 (compared to 0.77 in Wixom and Todd (2005)) (Appendix C), which is too high (Brown 2006) and indicates that information quality measured as a first-order construct may not sufficiently discriminate from related constructs. We discuss the implications of this issue in Section 7.1.

We tested the structural model in four related steps. In Section 7.1 (analysis A), we present the results of the original WT model, which includes only the WT original constructs, with information quality and system quality as first-order constructs. In Section 7.2 (analysis B), we test this model (with WT original constructs only) with second-order constructs. In Section 7.3 (analysis C), we expand analysis B by including system admin-specific information and system quality characteristics constructs and by keeping information and system quality as second-order constructs. Finally, in Section 7.4 (analysis D), we test the expanded WT model with information quality and system quality as first-order constructs.

6.1 Analysis A: WT Model (WT Constructs Only) with Information Quality and System Quality as First-order Constructs

As a baseline, we first replicated the WT model in the system administrator context with information quality and system quality as first-order constructs (see Figure 3). The measurement model had good convergent validity but not good discriminant validity due to a high correlation between information quality and information satisfaction (see Table C1). For the structural model, we examined the paths between information characteristics and information quality and between system characteristics and system quality.inf. As Table 3 shows, for information characteristics, currency was not significantly related to information quality; for system characteristics, integration was not significantly associated with system quality. In other words, these results suggest that currency is not meaningfully related to information quality and that integration is not meaningfully related to system quality in the context of system admins. These results are not consistent with Wixom and Todd (2005), who found that all four information characteristics were significantly related to information quality, that integration was significantly related to system quality, and that timeliness was not related to system quality.



*** *p* < .001, ***p* < .01

Figure 3. Structural Model for Analysis A

Table 3. Assessing the WT Structural Model for Information Quality and System Quality as First-order Constructs (Analysis A)

Path weights	Information quality	System quality
Accuracy	0.397 ***	
Completeness	0.202 ***	
Currency	0.098	
Format	0.265 ***	
Accessibility		0.201 *
Flexibility		0.181 **
Integration		-0.0004
Reliability		0.404 ***
Timeliness		0.219 ***
Note: **p* < 0.05, ** *p* < 0.01, *** *p* < 0.001		

Next, we analyzed the full structural model. Similar to linear regression, PLS examines the significance of construct relationships and provides R2 measures (Gefen et al., 2000), which represent the amount of variance explained by the independent variables. One can use path coefficients to test hypotheses and indicate the strength and significance of relationships between constructs. Together, the R2 and the path coefficients indicate how well the data support the hypothesized model. Figure 3 shows the results of our analyzing the original WT structural model. Our analysis reveals that all of the paths were significant, which reaffirms the WT model in the system administrator context. On the other hand, one should remember that information quality as a first-order construct does not exhibit good discriminant validity in the system administrator context. Therefore, one should interpret the results in Figure 3 with caution.

We also compared the results from Wixom and Todd (2005) to those from analysis A (Table 4). For path weights, we can see that, while all were significant, the paths from the two studies were not quite similar. For example, the path weight between system satisfaction and information satisfaction from Wixom and Todd (2005) was 0.50, which is much larger than that from analysis A (0.17). In contrast, some other paths from analysis A were much larger than those seen in WT, such as the path weight between information quality and information satisfaction (0.724 in analysis A and 0.43 in Wixom and Todd (2005)).

The R^2 values were also quite different. Most importantly, the R2 measures from information quality and system quality were much lower from analysis A than those from Wixom and Todd (2005). Thus, we can conclude that the original information and system characteristics can only explain a small portion of variance of information quality and system quality in the system admin context and that we need additional information and system characteristics.

Table 4. Results Comparison between Wixom and Todd (2005) and Analysis A

Path weights	Wixom and Todd (2005)	Analysis A
Information quality → information satisfaction	0.43***	0.724***
System quality → system satisfaction	0.73***	0.830***
System satisfaction → information satisfaction	0.50***	0.170***
Information satisfaction → perceived usefulness	0.64***	0.525***
System satisfaction → perceived ease of use	0.81***	0.563***
Perceived ease of use → perceived usefulness	0.25***	0.243***
Perceived usefulness → attitude	0.42***	0.574***
Perceived ease of use → attitude	0.50***	0.261***
Perceived usefulness → intention	0.47***	0.408***
Attitude → intention	0.36***	0.336***
R^2		
Information quality	0.75	0.572
System quality	0.74	0.654
Information satisfaction	0.71	0.735
System satisfaction	0.53	0.735
Perceived usefulness	0.67	0.453
Perceived ease of use	0.65	0.317
Attitude	0.69	0.542
Intention	0.59	0.474

Note: ** p < 0.01, *** p < 0.001

Finally, a PLS goodness-of-fit index (GoF) for this model was 0.6813. GoF represents an operational solution to evaluate the fit of the overall model and was proposed by Tenenhaus, Amato, and Esposito (2004). The GoF measure provides a single index for the overall prediction performance of the model[2], and one computes it as the geometric mean of the average communality index and the average R^2. The higher the value of GoF, the better the model's predictive performance.

6.2 Analysis B: WT Model (Original WT Constructs Only) with Information Quality and System Quality as Second-order Constructs

We built the second-order information quality and system quality constructs by relating them to the blocks of the underlying first-order constructs (Wetzels et al., 2009). As Chin (2010) suggests for formative constructs, AVE, composite reliability, and item loadings do not apply. Rather, the interpretation should be based on the weights, which indicate the relative importance of each indicator. Table 5 shows the correlations between the constructs. Here, first-order constructs function as formative indicators for the corresponding second-order construct.

Table 5. Assessing the WT Structural Model for Information Quality and System Quality as Second-order Constructs (Analysis B)

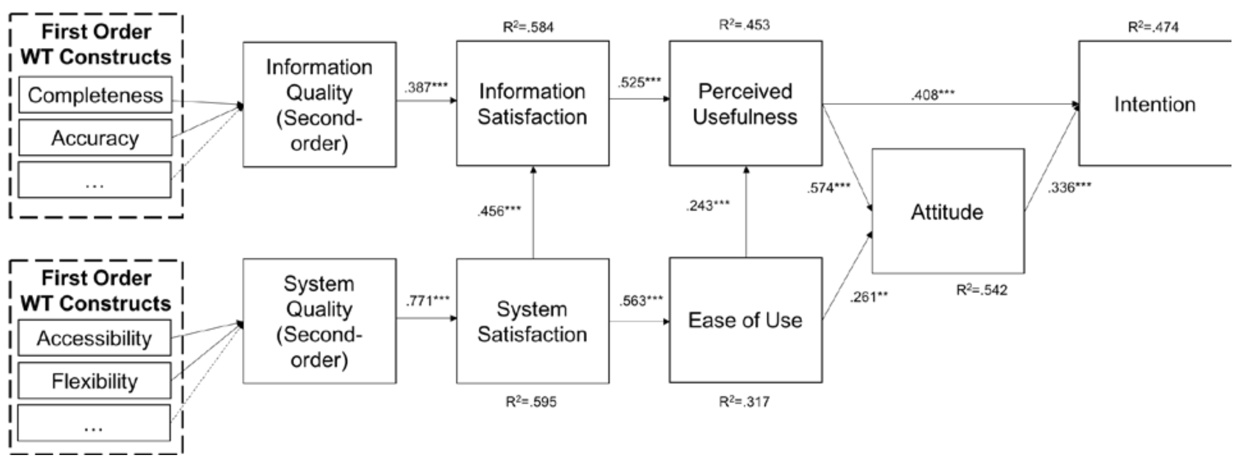
Path Weights	Information quality	System quality
Accuracy	0.302***	
Completeness	0.301***	
Currency	0.339***	

[2] GoF has a different conceptual meaning from fit indices in CBSEM. Recent literature has challenged its usefulness and suggested that GoF cannot separate valid models from invalid ones (Henseler & Sarstedt, 2013). Therefore, the reader should use caution when interpreting PLS GoF statistics.

Table 5. Assessing the WT Structural Model for Information Quality and System Quality as Second-order Constructs (Analysis B)

Format	0.358***	
Accessibility		0.328***
Flexibility		0.261***
Integration		0.145***
Reliability		0.333***
Timeliness		0.285***
Correlation		
Information satisfaction	0.68	0.69
System satisfaction	0.64	0.77
Note: *** p < 0.001		

This measurement model had good convergent and discriminant validity. The correlation between information satisfaction and information quality was 0.68. To compare the differences between the two correlations in analysis A and analysis B (0.85 and 0.68, respectively, in analysis A), we performed a significance test following Meng, Rosenthal, and Rubin (1992). This test indicated a significant difference between the two values ($p < 0.05$). As Table 5 also shows, when we modeled information quality and system quality as second-order constructs, all of the path weights were significant, which indicates that all of the system characteristics are relevant to information quality and system quality. Therefore, combined with the theoretical rationale, these results support using second-order constructs to model information quality and system quality. Figure 4 shows the results of our analyzing the structural model, and all of the paths were significant. The GoF for analysis B (0.6964) was greater than that for analysis A (0.6813), which further supports using second-order constructs to model information quality and system quality.



*** $p < .001$, ** $p < .01$

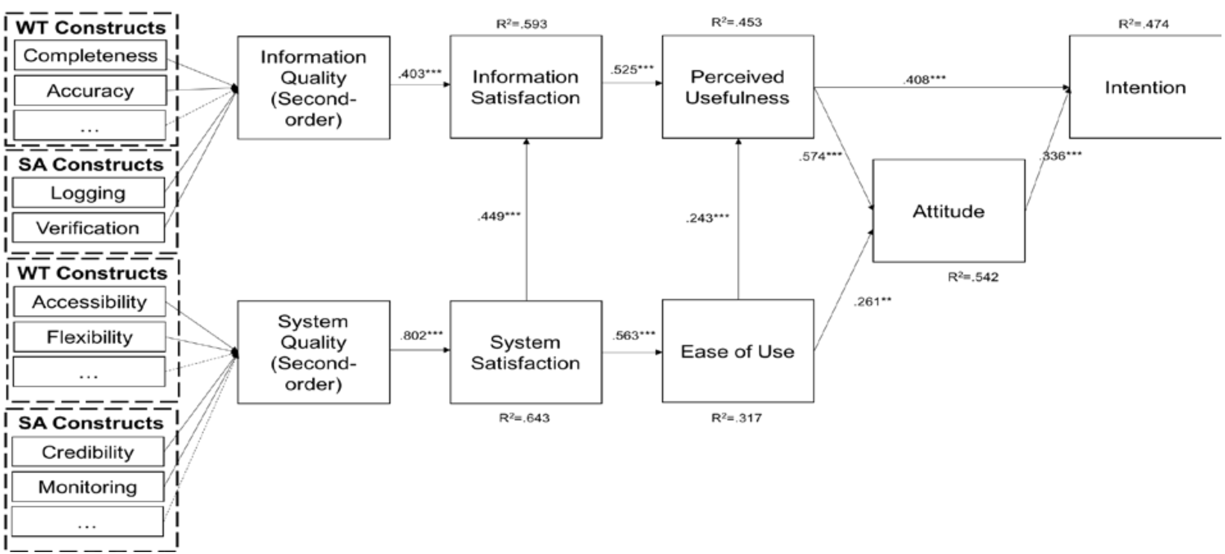
Figure 4. Structural Model for Analysis B

6.3 Analysis C: Extended WT Model with Information Quality and System Quality as Second-order Constructs

In this model, we extended the WT model in which we modeled information quality and system quality as second-order constructs by including additional system admin-specific constructs. Table 6 displays the path weights between each second-order construct and its underlying first-order constructs. All of these weights were significant, which indicates that these additional system characteristics are relevant to information quality and system quality in the system admin context (see Appendix D for additional analyses that support including these context-specific characteristics). Figure 5 shows the results of the structural model, and all paths were significant. The GoF for analysis C (0.7007) was the highest of the three models tested thus far. This result provides further support for the extended WT model with context-specific characteristics.

Table 6. Assessing the Extended WT Structural Model for Info Quality and Sys Quality as Second-Order Constructs (Analysis C)

Weights	**Information quality**	**System quality**
Accuracy	0.258***	
Completeness	0.268***	
Currency	0.281***	
Format	0.299***	
Logging	0.194***	
Verification	0.187***	
Accessibility		0.124***
Credibility (functionality)		0.160***
Credibility (help)		0.131***
Credibility (predictability)		0.132***
Flexibility		0.097***
Integration		0.057***
Mental model		0.104***
Monitoring		0.049***
Reliability		0.123***
Scalabilty		0.089***
Scriptability		0.063***
Situation awareness		0.129***
Speed		0.118***
Timeliness		0.108***
Correlation	**Information quality**	**System quality**
Information satisfaction	0.69	0.74
System satisfaction	0.63	0.80
Note: *** p < 0.001		



*** $p < .001$, ** $p < .01$

Figure 5. Structural Model for Analysis C

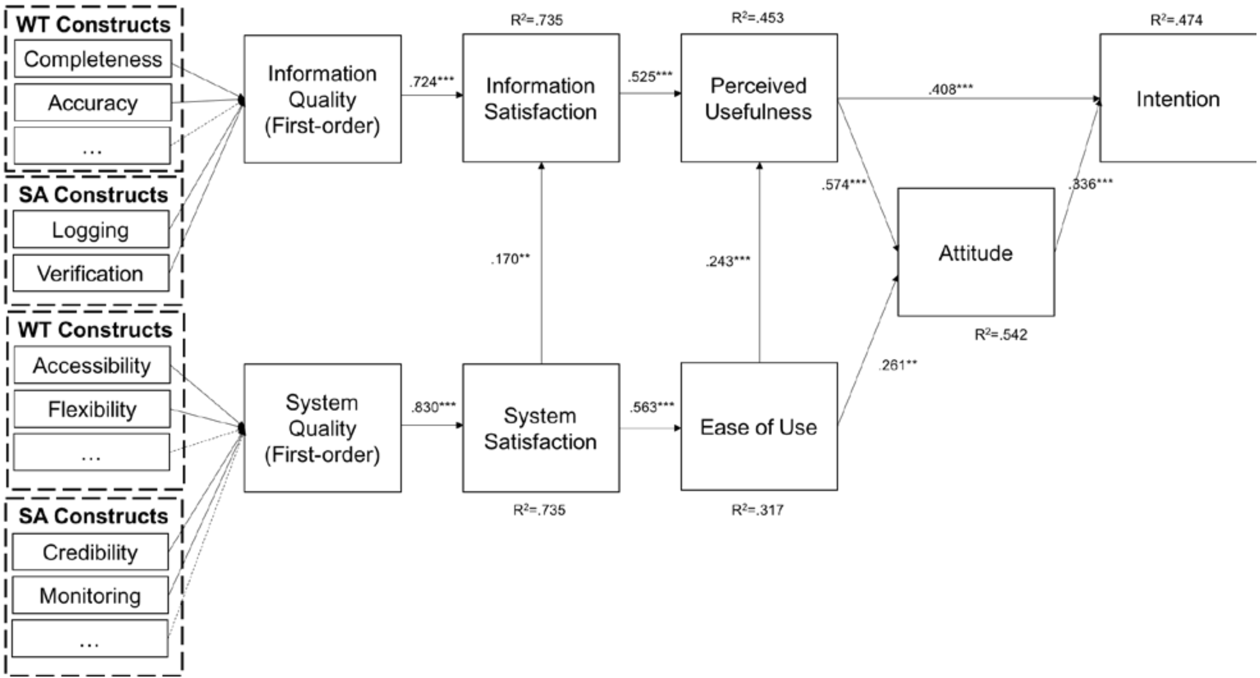
Lastly, we evaluated the extended WT model with information quality and system quality as first-order constructs. As Table 7 shows, neither information quality nor system quality exhibited good discriminant validity when modeled as a first-order constructs because several path weights were not significant. Figure 6 shows the structural model[3]. The GoF for this model (0.6837) was lower than that for analysis B (0.6964) and C (0.7007) and slightly larger than that for analysis A (0.6813), which supports not only adding system admin-specific constructs but also modeling information quality and system quality as second-order constructs.

Table 7. Assessing the Extended WT Structural Model for Information Quality and System Quality as First-order Constructs (Analysis D)

Path weights	Information quality	System quality
Accuracy	0.360 ***	
Completeness	0.150 **	
Currency	0.115	
Format	0.273 ***	
Logging	0.150 **	
Verification	0.039	
Accessibility		0.101
Credibility (functionality)		0.148 *
Credibility (help)		0.109 *
Credibility (predictability)		0.180 **
Flexibility		0.108 *
Integration		-0.072
Mental model		-0.058
Monitoring		-0.042
Reliability		0.215 *
Scalability		0.123 **
Scriptability		0.017
Situation awareness		0.117
Speed		0.072
Timeliness		0.065

* p< 0.05
** p< 0.01
*** p< 0.001

[3] Here the results of structural model from Analysis D are exactly the same as those from Analysis A. In both analyses, information quality and system quality are modeled as first-order constructs. Therefore, their values do not change after adding additional SA constructs. On the other hand, the path weights between system characteristics and information quality and system quality change after adding additional SA constructs, and those changed weights are shown in Table 7.



*** $p < .001$, ** $p < .01$

Figure 6. Structural Model for Analysis D

To summarize, our results show that the WT model using information quality and system quality as first-order constructs did not exhibit good discriminant validity. The same was true when we added additional indicators unique to the system admin context. We achieved the best results when testing the extended WT model that used both information quality and system quality as second-order constructs. This model had not only the best discriminant validity but also the highest GoF (see Table 8 for model comparison).

Table 8. Results Summary

	IQ and SQ as first-order constructs	IQ and SQ as second-order constructs
WT model with original constructs	**Analysis A** Measurement model: Good convergent validity but poor discriminant validity Relationship between system characteristics and quality: Non-significant paths GoF: 0.6813	**Analysis B** Measurement model: Good convergent validity and discriminant validity Relationship between system characteristics and quality: All paths significant GoF: 0.6964
Extended model with additional constructs	**Analysis D** Measurement model: Good convergent validity but poor discriminant validity Relationship between system characteristics and quality: Non-significant paths GoF: 0.6837	**Analysis C** Measurement model: Good convergent validity and discriminant validity Relationship between system characteristics and quality: All paths significant GoF: 0.7007

7 Discussion

With this work, we contribute to the literature by extending the WT integrated model of information system satisfaction by proposing and modeling information quality and system quality as second-order constructs and by testing the model in the system administration context. Literature suggests that measures of information and system quality as first-order constructs can be problematic, particularly when the level of abstraction is not consistent with the theoretical definitions used in the research design (e.g., Jarvis et al., 2003). Furthermore, developing indicators to precisely measure information quality and system quality as first order constructs can be challenging (MacKenzie et al., 2011). Therefore, modeling information quality and system quality as second-order constructs consistent with well-established conceptual definitions (c.f. Nelson et al. 2005; Wixom and Todd, 2005) is more appropriate (Jarvis et al., 2003; MacKenzie, 2003; MacKenzie et al., 2011). Through comparative modeling of alternatives, we also highlights potential boundary conditions that exist when one models information and system quality as first-order constructs in new contexts. That is, when one tests an established model (such as WT) in a new context (such as system administration), the expected relationships among constructs or the measurement model itself may no longer hold; this new context would represent a boundary condition for the existing model.

We also contribute to the literature by evaluating information and system quality constructs used in studies of information systems success, which we accomplished by examining the "core" set of system and information characteristics presented in the WT study (Wixom & Todd, 2005) in a new context: system administration. Also, we evaluated including additional characteristics relevant to the context studied (Velasquez & Weisband 2008) following Galletta and Lederer's (1989) call for including characteristics specific to IS use in situ. Our analysis suggests that the core set of characteristics are relevant in system administration, provides support for including additional characteristics specific to the context of interest, and, thus, extends the core set to include factors that future studies should consider including. When combined, these two contributions show that updated modeling techniques and careful selection of appropriate information and system characteristics can resolve the apparent boundary conditions in the core WT model. We now discuss our findings for the sub-dimensions of information quality and system quality.

All of the characteristics that previous research has proposed to influence information quality were significant (Analysis C, Table 6). Previous studies on system admins' work practices support the relevance of the core information constructs of accuracy, completeness, format, and currency. In the context of system administration, system planning, updating, and debugging are often done with only the information supplied by the system; rarely are system admins lucky enough to have system failure physically apparent and, thus, must rely on the accuracy of the information supplied to them (Barrett et al., 2004). Prior work has also reported that many system admins prefer to use a command issued through a command line interface (CLI) tool that queries and returns information in real time rather than having to refresh a graphical user interface (GUI) screen or require constant information updates, which reinforces the importance of current information (Barrett et al., 2004; Takayama & Kandogan, 2006). In addition, we found support for including two new constructs relevant to the context of system administration: verification and logging. Investigations of system administrators suggest that the ability to access and review the previous actions taken and the results of those actions are important to system admins (e.g., Barrett et al., 2004; Velasquez & Weisband, 2008). This information allows one to retrace the steps taken previously and may be relevant in other contexts when tasks are interrupted, such as online shopping (Farrimond, Knight, & Titov, 2006) and decision making (Speier, Valacich, & Vessey, 1999). Finally, system admins have reported using tools to specify the amount and format of data output (Velasquez & Weisband, 2008).

The significance of accuracy, completeness, currency, and format in a variety of studies and contexts (including data warehousing, university information systems, general computer usage, end user computing, and, now, system administration) suggests these constructs should remain in the core set of information quality characteristics (Bailey & Pearson, 1983; Baroudi & Orlikowski, 1988; Doll & Torkzadeh, 1988; Ives et al., 1983; Rai, Lang, & Welker, 2002). While the widespread application and significance of these four constructs may suggest that information quality has reached a relatively stable conceptualization across contexts, the significance of logging and verification in this study suggests that the "core" characteristics are not all inclusive. Furthermore, our findings suggest that we should investigate logging and verification in contexts that experience work interruptions and that logging and verification may be candidates for joining the "core" set of characteristics.

Similarly, all proposed system quality characteristics were important (analysis C, Table 6). The core system quality constructs found significant by WT (reliability, flexibility, integration, and accessibility) were relevant. Timeliness, which was not significant in the WT study, was also relevant. Given that a system's reliability is of the utmost importance (because downtime in a large system can cost US$500,000 per hour (Patterson, 2002)), the tools used to manage, configure, and monitor those systems need to be just as reliable. Flexibility is important because of the dynamic nature of the work system admins do and the systems they manage. For example, IT security administrators have identified the ability to change output styles or user-defined dashboards as important (Botta et al., 2007). The large number of tools used to gather small pieces of information suggests that integration could be useful to system admins; for example, system admins may consult system logs, notification systems, and knowledge repositories when completing a work task. The ability to link various data sources into a single interface would provide a streamlined information-gathering process. Accessibility to systems and the information they hold is especially important to system admins, whose work includes documenting the infrastructure and communicating system details with other stakeholders. Systems that provide easy access to information enable this aspect of system admins' work. These results provide further evidence of the applicability of the core set of system quality characteristics in a new context.

In addition to the core characteristics, context-specific system quality characteristics (credibility, scalability, scriptability, situation awareness, monitoring, and speed) were important, which supports previous qualitative research of system admins' work practices. Researchers have found a system's credibility to be an underlying factor in the user interface system admins choose (Takayama & Kandogan, 2006). In our study, we expanded credibility to include three characteristics: functionality, predictability, and helpfulness. Previous research, which reports that system admins select tools that provide functions to match their work tasks and that perform in consistent, predictable ways, supports these characteristics (Velasquez & Weisband, 2008). The large size of today's computing infrastructures presents a practical need for tools that can scale to meet the requirements of systems that continually grow and change. Because system admins can maintain systems that support a dynamic user base with variable data requirements, they need scalable tools. Other studies have also identified the need for such tools (e.g., Barrett et al., 2004; Haber & Bailey, 2007) and called out tools that don't scale as a limitation (Verdoes, 1997).

Scriptability is a large part of the work of system administration because one does much of the work using custom scripts and tools. The ability to script routines for oft-repeated or complex tasks is common among system admins, and the ability to add custom functions to existing tools would greatly enhance the usefulness of systems (Velasquez & Weisband, 2008). Researchers have identified the ability to maintain an accurate picture of complex systems as a challenge to system admins for over a decade (Hrebec & Stiber, 2001). The ability to maintain both current, tactical information about a work environment (i.e., situation awareness) and the ability to plan and anticipate the future environment (i.e., mental model) is especially relevant when maintaining complex, dynamic infrastructures.

System monitoring is a constant concern for system admins, who must ensure that storage limits and performance thresholds are not exceeded (Forsgren Velasquez, Kim, Kersten, & Humble, 2014). Without monitoring capabilities, system admins must check various aspects of system and subsystem state at regular intervals as part of their system maintenance responsibilities; monitoring capabilities allow system admins to automate alerts if thresholds are approached. Finally, the speed of start-up and execution is important in systems that system admins use because of the high-paced environments they work in; Velasquez and Weisband (2008) report preferences for tools that work quickly. In addition, scholars such as Bailey and Pearson (1983), Ives et al. (1983), and Doll and Torkzadeh (1988) have included speed as an aspect of system quality, which indicates its contextual appropriateness in a variety of settings. Speed also presents an example of why context is important when selecting information quality characteristics: users of data warehousing systems (the context studied in Wixom and Todd (2005)) query for complex information analyses that can take minutes to generate, while system admins require an immediate response from their tools as they configure and set up systems.

Overall, our results confirm that system administrators have specific needs of tools that relate to their work practices and environment. At the macro level, the WT integrated model was supported in the context of system administration, which suggests that system admins have some tool-use behaviors similar to those of computer users in previous studies. Findings also support the idea that system and information quality characteristics should be carefully chosen based on context (Galletta & Lederer, 1989). Our results also suggest that one may better model information quality and system quality as second-order constructs, whose essence is captured in their first-order constructs. The fact that all of the information quality and system quality characteristics proposed in this study were significant suggests that we need to model these two constructs as second-order constructs. Modeling them as first-order constructs could lead to falsely discarding characteristics that are indeed important.

8 Conclusion

8.1 Limitations

Before discussing this research's limitations, we note that they are subject to six limitations. First, limitations regarding the survey population exist. Although we made efforts to recruit system administrators of all specialties and experience levels, respondents may not be representative. Additionally, while we recruited respondents through organizations with primarily North American, Australian, and European membership, we had no way to ensure survey respondents were not from countries with different work cultures. We minimized these challenges by examining demographic and work information and examining the data for any outliers in response or completion time.

Second, a potential for non-response bias exists. Because system administrators self-selected into the study and did not need to complete the survey once they began it, the respondents may not represent all system administrators. For example, the survey took an average of 11 minutes to complete, which may have excluded participation from extremely busy system administrators. However, variance in respondent experience level and in the tool identified for survey responses indicate heterogeneity, which suggests that the results reported here are relatively robust. In addition, we found no significant differences between early and late respondents ($p < 0.05$ for t-test continuous variables and $\chi 2$ test for gender).

Third, we need to further develop and refine our measurement items. We used previously validated measures and newly developed measures. Most of the constructs used short scales and, though we found the measures to be reliable and valid, they could be improved.

Fourth, we focused on system administrators and the tool they used most often in their work. The findings may not be generalizable outside of the context of system administration or for tools used infrequently. However, this study does provide a test of core system and information quality characteristics in a new context and suggests new characteristics to include in future studies. If one accepts that system admins most often use tools of their choosing as Velasquez and Weisband (2008) report, our findings may not be generalizable to mandatory-use technologies. Also, one could consider additional constructs of interest to system administrators. For example, Jaferian, Botta, Raja, Hawkey, & Beznosov (2008) identify design guidelines that span general usability, technical complexity (such as providing for task prioritization and multiple levels of information abstraction), organizational complexity (such as providing for archiving and supporting collaboration), and task-specific guidelines (such as providing support for rehearsing and meaningful errors). Ross, Weill, and Robertson (2006) identify different organizational operating models that leverage enterprise architecture for organizational strategy; these models include varying levels of business process integration and standardization, which can be reflected in the information systems employed. Future research should investigate the importance of additional characteristics in the context of system administration.

Fifth, we focused on end users' perceptions of the information system being studied. However, implementing and adopting information systems can depend on much more than the end user, even when studying volitional use systems (Ross et al., 2006; Weill & Ross, 2004). Investigations of IS adoption and use among system admins that explicitly include stakeholders other than the end user would offer more insights into IS success.

Finally, our study was cross-sectional, which limits our ability to study causal effects. Future research should investigate longitudinal patterns of system use among system admins. Even with these limitations, the study provides insights into the work practices and tool use of a rarely studied and increasingly important population of users.

8.2 Implications for Research

Although the limitations above suggest caution in interpreting the results, the work presents valuable implications for future research. First, the results support our argument that one can model information quality and system quality as second-order constructs. Consistent with prior literature (MacKenzie, 2003; MacKenzie et al., 2011), we suggest modeling information quality and system quality as second-order constructs. This conceptualization allows one to more accurately measure information and system quality in each context in which one studies them. Future studies can also apply the second-order construct model proposed in this study and examine it in additional settings. We affirm the importance of the established core set of information and system characteristics in the system administration context, yet they are not a comprehensive set across all settings. As researchers apply information quality and system quality constructs to investigate additional technologies and in alternative research settings, they should take care to evaluate the unique features of these contexts to ascertain the completeness of the relevant system and information characteristics. While outside our scope here, future investigations may also include the effects of context on IS adoption and use, such as the type of IT governance that guides IS decisions (Weill & Ross, 2004), the business process being automated by the IS (Ross et al., 2006), or the impact of IT governance frameworks on IS adoption, such as COBIT.

Second, this study provides a better understanding of system characteristics influencing information and system quality in the context of system administration. Prior work states that system admins use a suite of tools to do their work (Barrett et al., 2004; Haber & Bailey, 2007; Velasquez & Weisband, 2008). Future research should examine whether our findings hold for this suite as a whole or only for particular tools in the suite.

8.3 Implications for Practice

This study also presents important implications for practice. First, the results provide designers of system administration tools guidance about characteristics important to their audience: system admins. For example, accurate information was a significant indicator of information quality. Information accuracy may be difficult to "show", but developers can account for this need through carefully programming and rigorously testing their product, or they could provide several sources of information that can be triangulated. Some significant aspects of system quality for system admins include reliability, credibility, scalability, and speed. Again, tool reliability may be difficult to show, but developers can account for this need through careful programming (e.g., being careful to avoid memory leaks, which may cause systems to hang or crash) and rigorously testing their product in many different environments. Credible tools were those with a good track record and known developers; companies with well-known and well-liked tools already on the market will benefit when introducing new applications. New companies may increase the credibility of their tools through beta testing and testimonial marketing.

Second, companies now have a way to assess information quality and system quality characteristics and have further evidence to link those characteristics to system administrator perceptions of usefulness, usability and, ultimately, use, which will allow companies to more objectively evaluate tools and identify those most useful to system administrators. For example, when considering two very similar tools, the one that is scriptable or provides an API will be better suited to system admins than ones that do not.

Lastly, our modeling of information quality and system quality can help designers of systems focus on the important characteristics in a certain context. For example, measuring information quality with indicators such as "in general, <the system> provides me with high-quality information" may not provide any useful information to practitioners in terms of what information characteristics make a certain system have high information quality. However, by modeling information and system quality as second-order constructs, practitioners can understand what characteristics are important in a certain context (e.g., timeliness in the context of this study) and can, thus, focus on these characteristics while designing systems.

8.4 Summary

While previous literature on the WT model helps explain the technology characteristics of information quality and system quality, opportunities to improve the modeling of these constructs still exist. In this study, we modeled information and system quality as second-order constructs and tested the WT model in the context of system admins. Our study makes two main contributions to the literature. First, we show that modeling information quality and system quality as second-order constructs can be more appropriate both conceptually and statistically and may resolve apparent boundary conditions with the core WT information and system quality constructs. Thus, we enhance the construct validity of information and system quality. Second, by testing an extended WT model in the context of system administration, we contribute to a deeper understanding of the characteristics of information quality and system quality that are relevant to system admins.

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Appendix A: Recent Literature Using Information and System Quality

Table A1. Recent Literature

Empirical studies	Context	Constructs used	Sub-dimensions	1st / 2nd order	Reflective / Formative
Almutairi & Subramanian (2005)	IS function in private sector organizations	Information quality	N/A	1st order[2]	Reflective
		System quality	N/A	1st order[2]	Reflective
Chen (2010)	Online system for filing income taxes	Information quality	Accuracy Timeliness Completeness	2nd order	Reflective
		System quality	Access Interactivity Ease of Use	2nd order	Reflective
Gable, Sedera, & Chan (2008)	Enterprise System	Information quality	Availability Usability Understandability Relevance Format Conciseness	1st order	Formative
		System quality	Ease of use Ease of learning User requirement System features System accuracy Flexibility Sophistication Integration Customization	1st order	Formative
Junglas, Goel, Abraham, & Ives (2013)	Second Life	Information quality	N/A	1st order[3]	Reflective
		System quality	N/A	1st order[3]	Reflective
Kim, Xu, & Koh (2004)	Internet stores	Information quality	N/A	1st order[2]	Reflective
		System quality	N/A	1st order[2]	Reflective
Lee et al. (2009)	Mobile data services	Information quality	Relevance Timeliness Timeliness Scope	2nd order	Reflective
		System quality	Access Usability Navigation	2nd order	Reflective
Medina & Chaparro (2007)	Scholar Control Information System of Higher Education Institutions	Information quality	Opportune Updated Useful Exact Complete Relevant	1st order	Reflective
		System quality	Easy to use Exact Operational Efficiency Adaptable Friendly	1st order	Reflective
Negash et al. (2003)		Information quality	Informativeness Entertainment	2nd order	Reflective

Table A1. Recent Literature

		System quality	Interactivity Access	2nd order	Reflective
Nelson et al. (2005)	Data warehouse	Information quality	Completeness Accuracy Format Currency	1st order	Reflective
		System quality	Reliability Flexibility Accessibility Response time Integration	1st order	Reflective
Pearson, Tadisina, & Griffin (2012)	e-commerce web sites	Information quality	Relevance Understandability Reliability Adequacy Scope Usefulness	2nd order[1]	Reflective
Rai et al. (2002)	Integrated student information systems	Information quality	N/A	1st order[2]	Reflective
Setia et al. (2013)	Customer service units digital design	Information quality	Completeness Accuracy Format Currency	2nd order	Formative
Teo, Srivastava, & Jiang (2008)	e-government web sites	Information quality	N/A	1st order[2]	Reflective
		System quality	N/A	1st order[2]	Reflective
Wang (2008)	e-commerce applications	Information quality	Content Accuracy Timeliness	1st order	Reflective
		System quality	Ease of use	1st order	Reflective
Wixom & Todd (2005)	Data warehouse	Information quality	Completeness Accuracy Format Currency	1st order	Reflective
		System quality	Reliability Flexibility Integration Accessibility Timeliness	1st order	Reflective
Wixom & Watson (2001)	Data warehouse	Information quality	Accuracy Comprehensiveness Consistency Completeness	1st order	Reflective
		System quality	Flexibility Integration	1st order	Reflective
Xu, Benbasat, & Cenfetelli (2013)	Consumer websites	Information quality	Completeness Accuracy Format Currency	1st order	Reflective
		System quality	Reliability Flexibility Accessibility Timeliness	1st order	Reflective

Table A1. Recent Literature

Yi, Yoon, Davis, & Lee (2013) Zheng, Zhao, & Stylianou (2013)	Websites with health information Virtual Community	Information quality	Currency Accuracy Relevancy Usefulness Completeness	1st order	Reflective
		Information quality	Reliability Objectivity Value-added Timeliness Richness Format	2nd order	Formative
		System quality	Navigation Accessibility Appearance Security Interactivity	2nd order	Formative

[1] Average scores are used for each sub-dimensions
[2] Specific items are used, but authors did not specify specific sub-dimensions.
[3] "Overall" items are used.

Appendix B: Survey Instrument

Table B1. Survey Instrument

Construct and item
Accuracy ACCU1: ____ produces correct information. ACCU2: There are few errors in the information I obtain from ____. ACCU3: The information provided by ____ is accurate.
Completeness CMP1: ____ provides me with a complete set of information. CMP2: ____ produces comprehensive information. CMP3: ____ provides me with all the information I need.
Currency CURR1: ____ provides me with the most recent information. CURR2: ____ produces the most current information. CURR3: The information from ____ is always up to date.
Format FMT1: The information provided by _____ is well laid out. FMT2: The information provided by _____ is clearly presented on the screen. FMT3: The information provided by _____ is well formatted.
Logging LOG1: ____ keeps track of previous actions so I can retrace my steps later. LOG2: ____ allows me to see and review previous actions. LOG3: ____ logs previous actions.
Verification VERI1: ____ allows me to see and review the outcomes of previous actions. VERI2: ____ makes the outcomes of previous actions available to me. VERI3: I can access the outcomes of previous commands or tasks using ____.
Information quality IQ1: Overall, I would give the information from ____ high marks. IQ2: Overall, I would give the information provided by ____ a high rating in terms of quality. IQ3: In general, ____ provides me with high-quality information.
Accessibility ACCS1: ____ allows information to be readily accessible to me. ACCS2: ____ makes information very accessible. ACCS3: ____ makes information easy to access.
Flexibility FLEX1: _____ can be adapted to meet a variety of needs. FLEX2: _____ can flexibly adjust to new demands or conditions. FLEX3: _____ is versatile in addressing needs as they arise.
Integration INTE1: ____ effectively integrates data from different areas of the company. INTE2: ____ pulls together information that used to come from different places in the company. INTE3: ____ effectively combines data from different areas of the company.
Reliability REL1: ____ operates reliably. REL2: ____ performs reliably. REL3: The operation of ____ is dependable.

Table B1. Survey Instrument

Timeliness TIM1: It takes too long for ____ to respond to my requests (RC). TIM2: ____ provides information in a timely fashion. TIM3: ____ returns answers to my requests quickly.
Credibility/trust (functionality) FUNC1: ____ has the functionality that I need. FUNC2: ____ has the features required for my work activities. FUNC3: ____ has the ability to do what I want it to do. FUNC4: ____ has the overall capabilities I need.
Credibility/trust (helpfulness) HELP1: The help function of ____ provides competent guidance (as needed). HELP2: The help function of ____ provides whatever help I need. HELP3: The help function of ____ provides very sensible and effective advice, if needed. HELP4: The help function supplies my need for help through a help function.
Credibility/trust (predictability) PRED1: ____ behaves in a predictable way. PRED2: I can forecast in advance how ____ will work. PRED3: ____ functions in the same way each time I use it. PRED4: As a work tool, ____ is very predictable.
Mental model MM1: ____ provides me with information necessary to predict future system state. MM2: ____ provides me with information necessary to plan future actions on the system. MM3: ____ helps me understand my system so that I can anticipate future events. MM4: ____ helps me “picture” my system in my head so that I can formulate plans.
Monitoring MON1: ____ allows me to monitor system state. MON2: ____ provides monitoring capabilities. MON3: I can monitor my system using ____.
Situation awareness SA1: ____ helps me to understand the current state of my environment. SA2: ____ helps me build a mental map of my current system. SA3: ____ provides information that helps me understand how my current system is operating. SA4: ____ helps me build a mental map of the system that I can use when I troubleshoot. SA5: ____ provides information that helps me respond to emergencies in my system.
Scalability SCAL1: _____ can be used in both simple and complex environments. SCAL2: _____ is scalable. SCAL3: _____ can be used in both small and large environments.
Scriptability SCRIPT1: ____ allows me to automate processes. SCRIPT2: ____ supports scripting. SCRIPT3: ____ is programmable.
Speed SPEED1: _____ executes commands quickly. SPEED2: ____ starts up rapidly. SPEED3: ____ initializes swiftly.

Table B1. Survey Instrument

System quality SQ1: In terms of system quality, I would rate ____ highly. SQ2: Overall, ____ is of high quality. SQ3: Overall, I would give the quality of ____ a high rating.
Information satisfaction ISAT1: Overall, the information I get from ____ is very satisfying. ISAT2: I am very satisfied with the information I receive from ____.
System satisfaction SSAT1: All things considered, I am very satisfied with _____. SSAT2: Overall, my interaction with _____ is very satisfying.
Usefulness USE1: Using _____ improves my ability to make good decisions. USE2: ____ allows me to get my work done more quickly. USE3: Using ____ enhances my effectiveness on the job.
Ease of use EOU1: ____ is easy to use. EOU2: It is easy to get ____ to do what I want it to do. EOU3: ____ is easy to operate.
Attitude ATT1: Using ____ is (not enjoyable/ very enjoyable). ATT2: Overall, using ____ is a (unpleasant/pleasant) experience. ATT3: My attitude toward using ____ is (very unfavorable/very favorable).
Intention INT1: I intend to use ____ as a routine part of my job over the next year. INT2: I intend to use ____ at every opportunity over the next year. INT3: I plan to increase my use of ____ over the next year.

Table B2. Descriptive Statistics and Item Loadings

Item	Mean	S.D.	AVE	CR	Loading
ACCS1	6.11	1.020			0.908
ACCS2	5.83	1.293	0.848	0.944	0.957
ACCS3	5.68	1.325			0.897
ACCU1	6.07	0.987			0.904
ACCU2	5.62	1.510	0.699	0.870	0.639
ACCU3	6.13	0.877			0.929
ATT1	5.42	1.247			0.878
ATT2	5.55	1.161	0.794	0.920	0.932
ATT3	6.06	1.054			0.861
CMP1	5.11	1.686			0.937
CMP2	5.31	1.571	0.789	0.917	0.928
CMP3	4.50	1.826			0.791
FUNC1	5.72	1.126			0.889
FUNC2	5.90	0.991	0.822	0.949	0.911
FUNC3	5.88	1.049			0.916
FUNC4	5.76	1.109			0.911

Table B2. Descriptive Statistics and Item Loadings

HELP1	4.33	1.681	0.843	0.955	0.923
HELP2	4.11	1.652			0.934
HELP3	4.03	1.620			0.939
HELP4	4.15	1.691			0.875
PRED1	6.24	0.798	0.730	0.915	0.905
PRED2	6.00	1.068			0.797
PRED3	6.29	0.807			0.805
PRED4	6.25	0.845			0.904
CURR1	6.05	1.044	0.834	0.940	0.950
CURR2	6.05	1.018			0.948
CURR3	5.83	1.190			0.849
EOU1	5.27	1.485	0.793	0.920	0.879
EOU2	5.50	1.294			0.889
EOU3	5.48	1.379			0.904
FLEX1	6.07	1.333	0.892	0.961	0.920
FLEX2	5.80	1.543			0.957
FLEX3	5.78	1.449			0.956
FMT1	5.24	1.436	0.841	0.941	0.920
FMT2	5.24	1.399			0.944
FMT3	5.46	1.323			0.885
INT1	6.50	0.758	0.643	0.842	0.793
INT2	5.94	1.289			0.880
INT3	5.31	1.404			0.723
INTEG1	4.41	1.949	0.930	0.975	0.945
INTEG2	4.44	1.990			0.971
INTEG3	4.38	1.972			0.976
ISAT1	5.58	1.271	0.941	0.969	0.969
ISAT2	5.60	1.287			0.971
IQ1	5.78	1.177	0.918	0.971	0.953
IQ2	5.88	1.142			0.959
IQ3	5.86	1.159			0.962
LOG1	4.45	2.061	0.827	0.933	0.954
LOG2	4.57	2.018			0.961
LOG3	4.78	1.977			0.799
MM1	4.59	1.765	0811	0.944	0.911
MM2	4.80	1.764			0.933
MM3	4.77	1.683			0.944
MM4	4.95	1.560			0.805
MON1	5.46	1.709	0.875	0.953	0.939
MON2	4.98	2.013			0.900
MON3	5.25	1.939			0.960
REL1	6.27	0.913	0.894	0.962	0.952
REL2	6.21	0.911			0.958

Table B2. Descriptive Statistics and Item Loadings

REL3	6.21	0.916			0.926
SA1	6.07	1.200	0.674	0.911	0.848
SA2	5.49	1.526			0.818
SA3	5.84	1.287			0.834
SA4	5.46	1.449			0.845
SA5	5.81	1.376			0.754
SCAL1	6.08	1.199	0.726	0.88	0.904
SCAL2	5.87	1.290			0.747
SCAL3	6.20	1.131			0.896
SCRIPT1	5.79	1.654	0.781	0.914	0.872
SCRIPT2	5.93	1.483			0.913
SCRIPT3	5.65	1.640			0.864
SPEED1	5.64	1.329	0.892	0.961	0.910
SPEED2	5.75	1.366			0.953
SPEED3	5.68	1.383			0.969
SSAT1	6.07	1.113	0.939	0.968	0.970
SSAT2	5.89	1.220			0.968
SQ1	6.14	1.054	0.947	0.982	0.967
SQ2	6.16	1.043			0.976
SQ3	6.15	1.051			0.977
TIM1	5.34	1.697	0.775	0.912	0.817
TIM2	5.73	1.081			0.898
TIM3	5.57	1.349			0.926
USE1	5.64	1.343	0.757	0.903	0.794
USE2	5.98	1.231			0.911
USE3	6.25	1.004			0.902
VERI1	4.28	1.914	0.847	0.943	0.906
VERI2	4.34	1.862			0.914
VERI3	4.13	1.951			0.939

Appendix C: Factor Correlations and Square Root of AVE on Diagonal

Table C1. Factor Correlations and Square Root of AVE on Diagonal

Constructs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Access	**0.92**													
2. Accuracy	0.52	**0.83**												
3. Attitude	0.54	0.45	**0.89**											
4. Completeness	0.38	0.44	0.47	**0.89**										
5. Credibility (functionality)	0.54	0.45	0.60	0.46	**0.91**									
6. Credibility (help)	0.48	0.31	0.45	0.42	0.51	**0.92**								
7. Credibility (predictability)	0.58	0.52	0.51	0.28	0.53	0.31	**0.85**							
8. Currency	0.44	0.63	0.40	0.48	0.39	0.24	0.42	**0.92**						
9. Ease of use	0.61	0.31	0.54	0.34	0.50	0.46	0.41	0.35	**0.89**					
10. Flexibility	0.40	0.42	0.46	0.29	0.45	0.30	0.33	0.29	0.21	**0.94**				
11. Format	0.64	0.46	0.43	0.35	0.46	0.49	0.38	0.39	0.55	0.28	**0.92**			
12. Info quality (first-order)	0.65	0.66	0.58	0.51	0.61	0.48	0.62	0.55	0.48	0.44	0.56	**0.96**		
13. Information satisfaction	0.64	0.57	0.59	0.47	0.60	0.51	0.56	0.42	0.46	0.40	0.62	0.85	**0.97**	
14. Integration	0.28	0.16	0.28	0.26	0.40	0.32	0.05	0.15	0.16	0.41	0.24	0.24	0.25	**0.96**
15. Intent	0.47	0.43	0.62	0.38	0.54	0.28	0.45	0.44	0.39	0.43	0.36	0.54	0.52	0.32
16. Logging	0.22	0.25	0.30	0.31	0.38	0.22	0.21	0.14	0.13	0.43	0.08	0.35	0.31	0.32
17. Mental model	0.45	0.26	0.39	0.27	0.35	0.26	0.35	0.26	0.30	0.35	0.38	0.40	0.46	0.28
18. Monitor	0.30	0.10	0.10	0.17	0.09	0.26	0.14	0.11	0.13	0.22	0.27	0.17	0.29	0.20
19. Reliability	0.62	0.53	0.50	0.32	0.51	0.37	0.71	0.35	0.43	0.34	0.36	0.58	0.54	0.02
20. Scalability	0.44	0.43	0.49	0.25	0.49	0.36	0.49	0.41	0.27	0.47	0.32	0.52	0.46	0.20
21. Scriptability	0.18	0.24	0.37	0.25	0.40	0.25	0.19	0.15	0.01	0.59	0.03	0.30	0.29	0.44
22. Situation awareness	0.51	0.37	0.44	0.30	0.37	0.29	0.49	0.33	0.30	0.34	0.41	0.50	0.51	0.26
23. Speed	0.61	0.42	0.42	0.33	0.45	0.43	0.57	0.39	0.45	0.34	0.36	0.49	0.48	0.10
24. Sys quality (first-order)	0.65	0.59	0.63	0.35	0.63	0.49	0.71	0.44	0.46	0.48	0.46	0.71	0.65	0.16
25. System satisfaction	0.66	0.54	0.70	0.45	0.71	0.54	0.63	0.47	0.56	0.47	0.51	0.74	0.70	0.22
26. Timeliness	0.58	0.49	0.50	0.36	0.49	0.41	0.59	0.42	0.47	0.35	0.41	0.61	0.57	0.10
27. Usefulness	0.59	0.50	0.70	0.34	0.62	0.39	0.53	0.37	0.49	0.55	0.48	0.65	0.64	0.36
28. Verification	0.17	0.18	0.27	0.28	0.37	0.25	0.10	0.16	0.19	0.30	0.17	0.29	0.26	0.35

	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1 Access														
2 Accuracy														
3 Attitude														
4 Completeness														
5 Credibility (functionality)														
6 Credibility (help)														
7 Credibility (predictability)														
8 Currency														
9 Ease of use														
10 Flexibility														
11 Format														
12 Info quality (first-order)														
13 Information Satisfaction														

Table C1. Factor Correlations and Square Root of AVE on Diagonal

14 Integration														
15 Intent	**0.80**													
16 Logging	0.30	**0.91**												
17 Mental model	0.40	0.24	**0.90**											
18 Monitor	0.09	-0.01	0.39	**0.93**										
19 Reliability	0.34	0.31	0.28	0.13	**0.95**									
20 Scalability	0.50	0.31	0.36	0.24	0.48	**0.85**								
21 Scriptability	0.40	0.54	0.35	0.13	0.23	0.45	**0.88**							
22 Situation awareness	0.53	0.17	0.60	0.50	0.37	0.47	0.29	**0.82**						
23 Speed	0.34	0.27	0.29	0.26	0.63	0.42	0.18	0.35	**0.94**					
24 Sys quality (first-order)	0.53	0.27	0.35	0.19	0.73	0.60	0.32	0.49	0.63	**0.97**				
25 System satisfaction	0.56	0.26	0.37	0.16	0.65	0.53	0.32	0.46	0.60	0.83	**0.97**			
26 Timeliness	0.42	0.21	0.30	0.23	0.62	0.50	0.16	0.41	0.76	0.65	0.65	**0.88**		
27 Usefulness	0.64	0.31	0.51	0.13	0.52	0.52	0.42	0.55	0.42	0.65	0.68	0.49	**0.87**	
28 Verification	0.27	0.56	0.35	0.05	0.12	0.24	0.36	0.24	0.07	0.20	0.21	0.11	0.31	**0.92**

Appendix D: Factor Correlations and Square Root of AVE on Diagonal

Table D1. VIF and Tolerances for System Characteristics when Predicting Information Quality Model

Coefficients[1]							
Model	Unstandardized coefficients		Standardized coefficients	t	Sig.	Collinearity statistics	
	B	Std. error	Beta			Tolerance	VIF
(Constant)	-2.283E-7	.000		.000	1.000		
Accuracy	.258	.001	.258	479.833	.000	.525	1.906
Completeness	.268	.000	.268	564.048	.000	.671	1.489
Currency	.281	.001	.281	532.088	.000	.545	1.834
Format	.299	.000	.299	660.097	.000	.741	1.350
Logging	.194	.000	.194	395.543	.000	.635	1.575
Verification	.187	.000	.187	389.324	.000	.662	1.511
[1] Dependent variable: IQ							

Table D2. VIF and Tolerances for System Characteristics when Predicting System Quality

Coefficients1							
Model	Unstandardized coefficients		Standardized coefficients	t	Sig.	Collinearity statistics	
	B	Std. error	Beta			Tolerance	VIF
(Constant)	-3.823E-6	.000		-.018	.986		
Accessibility	.124	.000	.124	357.187	.000	.381	2.624
Credibility (functionality)	.160	.000	.160	498.693	.000	.442	2.262
Credibility (help)	.131	.000	.131	481.380	.000	.618	1.618
Credibility (predictability)	.132	.000	.132	379.015	.000	.377	2.655
Flexibility	.097	.000	.097	326.286	.000	.518	1.929
Integration	.057	.000	.057	206.388	.000	.597	1.674
MentalModel	.104	.000	.104	364.700	.000	.559	1.790
Monitoring	.049	.000	.049	186.565	.000	.651	1.535
Reliability	.123	.000	.123	345.821	.000	.359	2.788
Scalabilty	.089	.000	.089	301.579	.000	.522	1.917
Scriptability	.063	.000	.063	207.839	.000	.501	1.994
SituationAwareness	.129	.000	.129	395.695	.000	.426	2.347
Speed	.118	.000	.118	324.333	.000	.344	2.906
Timeliness	.108	.000	.108	297.076	.000	.345	2.900
[1] Dependent variable: SQ							

Tables D1 and D2 show the variance inflation factor (VIF) and the tolerances for system characteristics when predicting IQ and SQ, respectively. Here VIF is a metric for multicollinearity, while the tolerance is an indicator of the percent of variance in the indicator that cannot be accounted for by the other indicators. Based on the results above, VIFs for all system characteristics were quite low (below 5), which indicates that multicollinearity was not an issue here. Further, the tolerances for system characteristics were all above 0.1, which indicates that each system characteristic was not redundant and deserves further investigation. To summarize, these results demonstrate that new system characteristics were highly correlated with existing characteristics from WT model (consistent with the results from measurement model) and contributed valuable information for IQ and SQ.

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