Critical Value Factors in Business Intelligence Systems Implementations

Abstract

Business Intelligence (BI) systems have been rated as a leading technology for the last several years. However, organizations have struggled to ensure that high quality information is provided to and from BI systems. This suggests that organizations have recognized the value of information and the potential opportunities available but are challenged by the lack of success in Business Intelligence Systems Implementation (BISI). Therefore, our research addresses the preponderance of failed BI system projects, promulgated by a lack of attention to Systems Quality (SQ) and Information Quality (IQ) in BISI. The main purpose of this study is to determine how an organization may gain benefits by uncovering the antecedents and critical value factors (CVFs) of SQ and IQ necessary to derive greater BISI success. We approached these issues through adopting 'critical value factors' (CVF) as a conceptual 'lens'. Following an initial pilot study, we undertook an empirical analysis of 1,300 survey invitations to BI analysts. We used exploratory factor analysis (EFA) techniques to uncover the CVFs of SQ and IQ of BISI. Our study demonstrates that there is a significant effect in the relationships of perceived IQ of BISI to perceived user information satisfaction thereby confirming the importance BI system users place on information and the output produced. Our study also reported that there is a significant effect in the relationships of perceived IQ of BISI to perceived user information and SQ satisfaction thereby confirming the importance BI system users place on information and the system output produced. We believe our research will be of benefit to both academics and practitioners in attempting to ensure BI systems implementation success

Introduction

Research evidence shows that only 20% of users having access to BI tools used them on a regular basis (Clark, Jones, & Armstrong, 2007). In addition, Yeoh and Koronios (2010), report spending on BI systems has comprised one of the largest and fastest growing areas of IT expenditures. In spite of these investments, only 24% of 513 companies surveyed in a study conducted by Howson (2008), considered their BI implementations to be very successful. Furthermore, Marshall and de la Harpe (2009), noted 80% of the time spent in BI support involves investigating and resolving IQ issues which if inadequately addressed, will severely affect organizations through decreased productivity, regulatory problems, and reputational issues.

It is apparent that pre-implementation activities for BI projects, particularly addressing system quality (SQ) and information quality (IQ) requirements are of paramount importance to BISI success (Howson, 2008; Marshall & de la Harpe, 2009; Negash & Gray, 2008; Power, 2008; Watson et al. 2002). Moreover, there has been a significant body of research that seeks to determine the role of SQ and IQ in IS success (DeLone & McLean, 2003; Petter & McLean, 2009). However, very little attention has been given in the literature to addressing the role of SQ and IQ in the success of BISI (Arnott & Prevan, 2008; Ryu, Park, & Park, 2006; Nelson et al. 2005). Also, little attention has been given to the user's perceived value of SQ and IQ characteristics that have an impact on BISI success (Nelson et al. 2005; Popovic et al. 2009). Wixom and Watson (2001) investigated the SQ and IQ factors that affected BI success in a data warehouse environment and acknowledged that there were important factors associated with data quality that were not included in their research. Furthermore, Nelson et al. (2005) acknowledged the importance of identifying the appropriate SQ and IQ factors for BI success and stated that "some factors are more important than others in the data warehousing context and it is not clear if these results will be stable across technologies or applications" (p.220). Researchers in BI success have also suggested constructs and associated measurement items that consider the decision support environment and its maturity in BISI success (Dinter, Schieder, & Gluchowski, 2011; Isik, Jones, & Sidorova, 2013). However, few empirical studies have sought to uncover SQ and IQ characteristics that are of value to users of BI systems, as measured by user satisfaction from BISI.

The relationships between the constructs of user perceived value (level of importance) and user satisfaction in the context of understanding the SQ and IQ necessary for BISI success have also received little attention in the literature. Research has been limited to studies that rely only on specific SQ and IQ factors for BI that are based on prior research, not on the universal set of antecedents for SQ and IQ that had been subjected to empirical analysis (Nelson et al. 2005). Thus, in the context of emerging technologies such as BI, it is important to focus on objectives and decisions that are of value, often requiring the exposure of underlying or hidden values that allow researchers and practitioners to be proactive and hence create more alternatives instead of being limited by available choices (Dhillon, Bardacino, & Hackney, 2002; Keeney, 1999). According to Sheng, Siau, and Nah (2010), it is important to elicit and organize values in "developing constructs in relatively new and under-studied areas" (p. 40). Therefore, our research addresses the preponderance of failed BI system projects, promulgated by a lack of attention to SQ and IQ in BISI (Arnott & Prevan, 2008; Jourdan, Kelly, & Marshall, 2008). As noted, the main purpose of this study is to determine how an organization may gain benefits in the context of BISI by uncovering the antecedents and critical value factors (CVFs) of SQ and IQ necessary to derive greater BISI success.

Theoretical background

Value theory

In cognitive value theory, value refers to the individual's perceived level of importance (Rokeach, 1969). According to Rokeach (1973), a value is "an enduring belief that a specific mode of conduct or end-state of existence is personally or socially preferable to an opposite or converse mode of conduct or end-state of existence" (p. 5). The concept of value is often referenced in various fields of social research but mainly in the context of economic value, thereby neglecting the applications of user perceived cognitive value (Levy, 2006). According to Levy (2008), "several scholars have suggested that although it is important to investigate the nature of attitudes and opinions, it is more fundamental to investigate the nature of value since attitudes and opinions can often change based on experience, while value remains relatively stable over time" (p.161). Keeney (1992) stated that values are what one desires to achieve. Bailey and Pearson (1983) measured the value (or level of importance) of information system (IS) characteristics using a scale featuring the semantic differential pair, important to unimportant (Levy, 2003). These measures provided a deeper understanding of satisfaction with the IS (Etezandi-Amoli & Farhoomand, 1991; Levy, 2003; Sethi & King, 1999). Levy (2009) defined user perceived value as a "belief about the level of importance that users hold for IS characteristics" (p. 94). Moreover, user perceived value has been recognized as relevant to the understanding of user satisfaction and user-perceived effectiveness (Bailey & Pearson, 1983; Levy, 2009).

In the context of BI, as a large number of projects are considered to be failures because organizations do not see tangible business value, it is necessary to understand the value factors that are needed to benefit from BI investments (Todd, 2009). Value based exploration techniques have been applied in many research areas such as value-focused assessment of privacy and security (Dhillon & Torkzadeh, 2001; Dhillon et al. 2002), value-focused assessment of trust in mobile commerce (Siau, Nah, & Sheng, 2004), and assessing the values of mobile applications (Nah, Siau, & Sheng, 2005; Sheng et al. 2005). Levy (2008), in a study of online learning activities, used Critical Value Factors (CVFs) to investigate and uncover issues related to learners' perceived value. When considering new or emerging technologies, it is often necessary to uncover hidden attributes that are valued or important to users in their measurement of IS success. Value theory has been established to uncover hidden attributes that users find important to IS success (Dhillon et al. 2002; Keeney, 1999; Sheng et al. 2010). However, there has been little attention paid to ask the questions regarding what characteristics users find important in business intelligence systems implementations (BISI). Furthermore, less is known about the CVF's that may lead to IS success in BISI. Therefore, this study investigated issues related to the perceived value of IQ and SQ in BISI by uncovering CVFs as identified by users of BI analytical systems. CVFs are the factors that organizations should pay attention to in order to increase the BI systems perceived value, which in turn may lead to improved BISI success. In this context, the CVFs for SQ and IQ have been identified and discovered using a process whereby a number of SQ and IQ characteristics form clusters that provided an understanding of the factors that users of BI analytical systems find important or of value in BISI (Mertler & Vannatta, 2001). This is particularly important in an emerging technology such as BI where it is not a conventional application-based IT project but a complex undertaking (Yeoh & Koronios, 2010).

IS success theory

The measurement of IS success has been a top concern of researchers and practitioners. Several models have been proposed to define and identify the causes of IS success. However, a universally agreed definition of IS success has not emerged due to differences in the needs of stakeholders who assess IS success in an organization (Urbach, Smolnik, & Riempp, 2009). The need for a general but comprehensive definition of IS success was recognized by DeLone and McLean (1992) in their review of existing definitions of IS success and their associated measures. This led to the multidimensional and interdependent model that classified the six major categories of system quality, information quality, user satisfaction, use, individual impact, and organizational impact. Since the publication of the DeLone and McLean (1992) IS success model, many researchers have treated IS success as a multidimensional construct (Urbach et al. 2009). Subsequent to the publication of the original DeLone and McLean (1992) IS success model, many researchers had suggested that it be extended or re-specified to include additional dimensions (Seddon, 1997). As a result, DeLone and McLean (2003) published an updated IS success model to include the addition of service quality and intention to use as constructs, as depicted in Figure 1. They also collapsed the individual and organizational impact constructs into the net benefits construct to measure the positive and negative influence of user satisfaction and use on an IS.

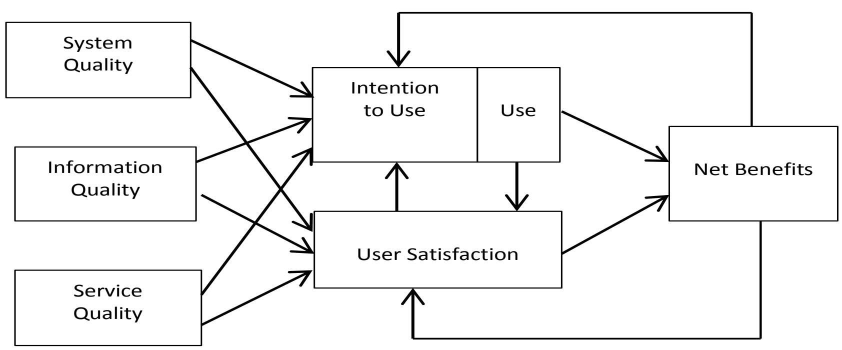

Figure 1. DeLone & McLean (2003) IS Success Model

According to Urbach et al. (2009) "the majority of studies of IS success use the DeLone and McLean IS success model (1992; 2003) in combination with other theoretical models as a basis for deriving new research models that are applicable to the specific requirements of the corresponding problem domains" (p. 9). However, researchers have argued that certain constructs of the DeLone and McLean model do not significantly correlate with IS effectiveness. According to Levy et al. (2009), "IS usage has been demonstrated to have mixed results as a predictor of IS effectiveness" (p. 99). Moreover, according to Petter, DeLone, and McLean (2013), "while the service quality construct in the updated DeLone and McLean IS success model is an important dimension of IS success, they did not find any studies that considered the determinants of this construct. The few studies that did identify the determinants of service quality considered the overall quality of service provided by the IS department for all applications and services rather than for a specific IS" (p. 30). Furthermore, there is mixed support for the determinants of the construct 'Intension to Use' as an insufficient number of studies have investigated the relationship to IS success (Petter et al., 2013). Gatian (1994), in a study of 39 organizations found that there was a close relationship between user satisfaction, decision performance, and user efficiency. However, researchers had also recognized the complicated nature of establishing the dependent variable in IS success (DeLone & McLean, 1992; 2003; Iivari, 2005; Seddon, 1997). According to Seddon "in the long run, it is people's observations of the outcomes of use and the impacts that determine their satisfaction with the system" (p. 243).

Dinter et al. (2011) suggested alternatives for establishing BI specific success models to assist organizations in understanding the maturity of their BI decision environment by taking into consideration their BI capacity and capabilities. For instance, an organization may use the report writing and query capability of the BI implementation more than the analytical functionality in their implementation while another organization may use the analytical features of the BI system, such as predictive analytics, as their primary reason for implementing the BI system. In essence, BI success will be measured differently depending on the BI maturity level of the organization. Recognizing the differences in BI system maturity, Dinter et al. (2011) adopted and extended the updated DeLone and McLean (2003) IS success model in the BI domain thereby broadening the scope of the DeLone and McLean (2003) IS success model by adding additional constructs and items that have a causal relationship to the existing constructs in the BI decision environment.

Isik et al. (2013) examined the maturity of the required decision environment of BI to assess what capabilities of BI are necessary to achieve success. They suggested technical, functional, and organizational elements of the decision environment that could lead to BI system implementation success. Moreover, Isik et al. (2013) concluded that the technical capabilities of the system represented a necessary foundation for BI success without regard to the decision environment but organizational capabilities that support flexibility in decision making should be managed in relation to the decision environment in which the BI is employed.

Despite some weaknesses, the DeLone and McLean (1992; 2003) success model has become the dominant model for measuring IS success (Urbach et al. 2009). According to DeLone and McLean (1992), the importance of IS success is imperative and "the evaluation of IS practice, policies and procedures requires an IS success measure against which various strategies can be tested. Without such a measure, much of IS research is purely speculative" (p. 61). Clark et al. (2007) followed the guidance of the DeLone and McLean IS success model (1992; 2003) to study the underlying threads of commonality with BISI success. Their study suggested that BISI success was theoretically grounded in IS success research. While much attention has been paid to IQ, SQ, and user satisfaction in IS success literature, little research has focused on the constructs of IS success in the domain of BISI. This may be related to a lack of understanding of BI technologies caused, in part, by the multifaceted nature of BI which combines a nonconventional application-based set of systems with infrastructure related projects (e.g. ERP and CRM) in an analytical user based decision support environment.

For the purpose of our study, it is assumed that user satisfaction may be a reasonably good surrogate for net benefits if measures are confined to decision performance (Iivari, 2005). Therefore, the underlying theory of the DeLone and McLean (2003) model was explored with emphasis on the user satisfaction construct as the dependent variable for IS success (Iivari, 2005). Moreover, the BISI was considered effective when users perceived the characteristics of SQ and IQ to be of value or highly important and were also highly satisfied with these same characteristics. Thus, this study uncovered the SQ and IQ characteristics that are of value in BISI as measured by user satisfaction. This study limited the scope of assessment to a model that considered multidimensional functional and technological implementation success constructs that used measures that were empirically confirmed. Participants in the study implemented BI analytical systems which represent a higher level of organizational BI system maturity in comparison to those who primarily perform report and query generation.

Nelson et al. (2005) addressed a gap in the literature in their research model involving confusion in differentiating between SQ and IQ factors in the context of user satisfaction when using BI analytical tools in a data warehouse environment. Their model studied factors of SQ and IQ identified in the literature and their relationships with the constructs of system satisfaction and information satisfaction. The results of the Nelson et al. (2005) study suggested that "crossover or interaction effects may exist between the two constructs" (p. 207). They found that while the crossover effects of SQ on information satisfaction was significant within the context of BI analysis tools, the path leading from IQ to information satisfaction in the same context was surprisingly not significant. They concluded that future research was necessary to understand the characteristics of BI that led to the user perception that IQ did not strongly influence information satisfaction in the BI analytics domain. Nelson et al. (2005) expressed concern regarding this finding and offered the explanation that, from the user's perspective, it may be difficult to differentiate the BI system from the output it produces, leading to potential over-reliance on the system for IQ while ignoring the responsibility for user interaction with the interface and the generation of output.

Extending those notions, Nelson et al. (2005) derived a model, depicted in Figure 2, that identified, integrated, and assessed the dimensions of SQ and IQ as antecedents of the constructs of perceived user systems satisfaction and perceived user information satisfaction in their model titled "Determinants of information and system quality" (p. 208). Moreover, Nelson et al. (2005) extended the DeLone and McLean (1992) model of IS success, expanding the user satisfaction construct and suggesting that user perceived system satisfaction and user perceived information satisfaction could be considered as dependent variables and as a combined surrogate for user satisfaction. Therefore, this study tested a proposed BI SQ and IQ research model which was based on the DeLone and McLean (1992; 2003) IS success model as extended by Nelson et al. (2005). The study specifically tested the influence of SQ and IQ in BISI with user satisfaction from BISI in a decision support environment that leveraged BI analytics to improve and optimize decisions.

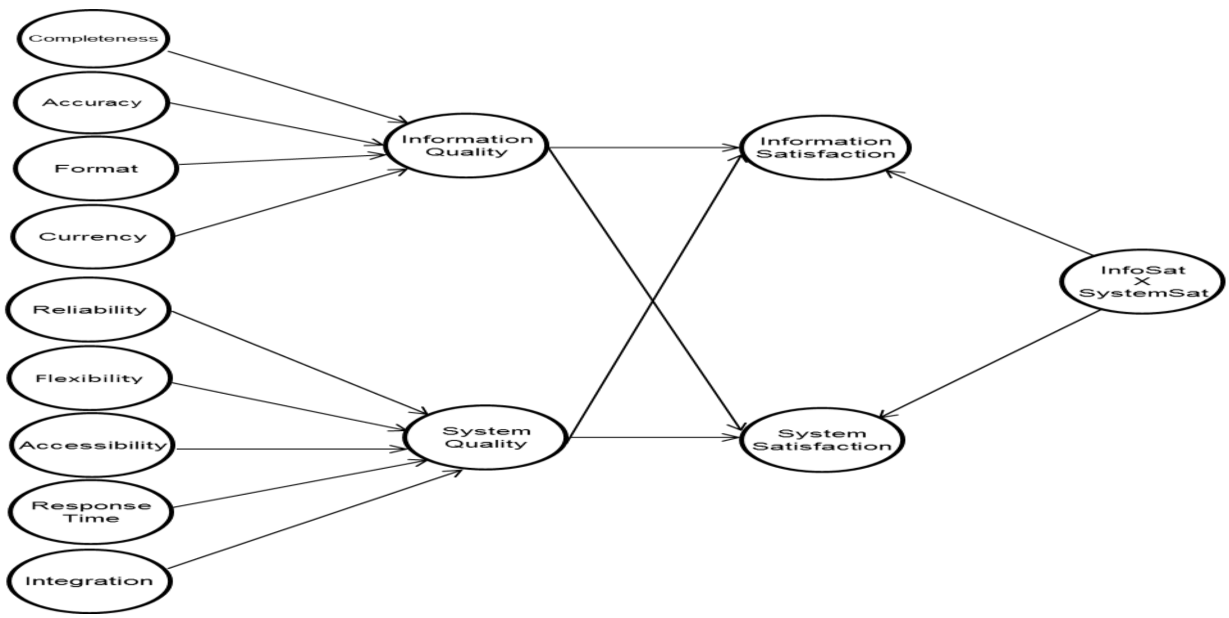

Figure 2. Nelson et al. (2005) Determinants of Information and System Quality

Various frameworks have been developed for categorizing and measuring IQ, SQ, and user satisfaction leading to IS success. The framework for IQ developed by Lee et al. (2002), for instance, provided four different categories used to assess IQ in IS. These categories were based on an empirical study of characteristics of a group of conventional IS. Moreover, Nelson et al. (2005) suggested a framework for the measurement of SQ for BI system satisfaction based on five dimensions of system quality.

Nelson et al. (2005) studied the possibility that more complex relationships may exist between quality and satisfaction in the context of BI success. According to Nelson et al. (2005), the literature suggested that system factors may influence a user's perception of satisfaction with the information provided by the system. Moreover, past confusion in differentiating SQ from IQ factors suggested that crossover or interaction effects may exist between the two constructs leading Nelson et al. (2005) to explore the possibility that more complex quality/satisfaction relationships may exist. Thus, Nelson et al. (2005) studied the determinants of SQ and IQ which included the study of crossover relationships from quality (information and systems) to satisfaction (systems and information) as well as the interaction effect of information satisfaction and systems satisfaction. They suggested that future research should explore the relationship of SQ, IQ and perceived user satisfaction in the context of BI analytical systems to address the surprising results of their empirical analysis that indicated that the influence of SQ on user perceived IQ satisfaction was stronger than the influence of IQ on user perceived IQ satisfaction. Nelson et al. (2005) also acknowledged that some factors in their study of BI systems success were more aligned with data warehousing, contributing to the possibility of instability across technologies and applications that may have altered the strength of relationships in their conceptual model. It was, therefore, necessary to understand what dominant SQ and IQ characteristics are deemed important in BI to guide the design of

BI systems and distinguish the system from its output. This study used the BI SQ and IQ research model based on DeLone and McLean (1992; 2003) IS Success Model as extended by Nelson et al. (2005) as depicted in Figure 3. This study has furthered the research of Nelson et al. (2005) by empirically assessing the universal set of characteristics for SQ and IQ to determine the CVFs for SQ and IQ of BISI for the purpose of exploring what CVFs of BISI lead to BISI success and addresses the user perceived ambiguity between a BI system and its output.

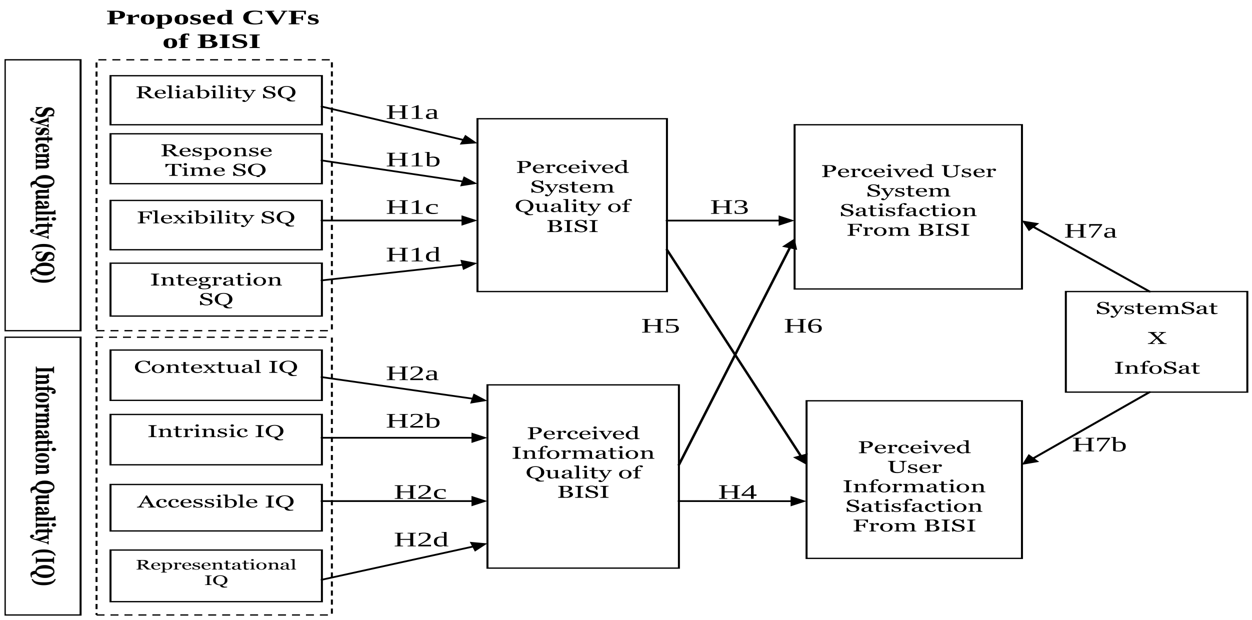

Figure 3. BI SQ and IQ research model based on DeLone and McLean (1992) IS Success Model as extended by Nelson et al. (2005).

The first specific goal of our research, following Keeney's (1992) methodology, was to gather a list of user perceived SQ and IQ characteristics from literature and augment it with input from an expert panel. The second research aim was to use the SQ and IQ characteristics to uncover the CVFs of SQ and IQ associated with BISI. The third specific goal of this research was to test the impact of the CVFs of SQ on perceived SQ of BISI and the CVFs of IQ on perceived IQ of BISI. The fourth research goal was to test the impact of perceived SQ of BISI on perceived user system satisfaction from BISI and perceived SQ of BISI on perceived user information satisfaction from BISI. The impact of perceived IQ of BISI on perceived user information satisfaction and perceived IQ of BISI on perceived user system satisfaction from BISI was also tested using the BI SQ and IQ research model based on the DeLone and McLean (1992; 2003) model for IS success as extended by Nelson et al. (2005).

Methodology

Our study used a mixed method approach following the work of Keeney (1999), utilizing both qualitative and quantitative research methods. Using value theory and IS success theory, the study validated empirically a model for IS success that investigated how an organization may gain user satisfaction in the context of BISI by uncovering the CVFs of SQ and IQ necessary to derive BISI success. Hanson, Plano-Clark, Petska, Creswell, and Creswell (2005) stated that quantitative and qualitative data could be complementary when variances are uncovered that would not have been found by a single method. Qualitative research could be used to discover and uncover evidence, while quantitative methods are often used to verify the results, thereby improving the integrity of the findings of the study (Shank, 2006). Additionally, both qualitative and quantitative methods each carry their own capabilities to uncover the underlying meaning of phenomena in research (Straub, 1989).

Phase I: Expert Panel and Open-Ended Questionnaire

The qualitative process (Phase I) began with the creation and distribution of an open-ended questionnaire designed to elicit SQ and IQ characteristics considered to be important in BISI. Development of the instrument followed the process proposed by Straub (1989). The open-ended questionnaire was developed to uncover new characteristics of SQ and IQ for BISI. An expert panel was formed, consisting of a small group of six individuals with experience in business analytics. The expert panel members had an average of 20 years' experience implementing business analytics systems in large organizations. Four experts were Business Analysts with leading financial institutions in banking, pension finance, and brokerage services. Two of these experts have also managed departments devoted to analytics. The remaining two experts, in addition to implementing business analytics systems were also responsible for BI system infrastructure and implementation services for organizations providing systems services. All experts have performed business analyst functions and have been responsible for decision making using BI system output. SQ and IQ characteristics drawn from the expert panel's responses to the open-ended questionnaire and the literature review of validated sources (Arazy & Kopak, 2011; Goodhue, 1995; Jarke & Vassiliou, 1997; Lee et al., 2002; Nelson et al., 2005; Wand & Wang, 1996; Wang & Strong, 1996) were analyzed using Keeney's (1999) approach. Similar SQ and IQ characteristics identified from literature as well as responses from the expert panel were grouped into the four main proposed SQ categories of reliability SQ, response time SQ, flexibility SQ, and integration SQ, as well as the proposed four high level IQ categories of intrinsic IQ, contextual IQ, representational IQ, and accessibility IQ. These SQ and IQ characteristics were evaluated for inclusion in an updated list of SQ and IQ items. Items that did not appear to relate to any category were investigated for inclusion in a new SQ or IQ category. After considering the grouping of similar responses as well as the feedback from the expert panel using Keeney's (1999) approach there were 33 SQ and IQ characteristics identified, consisting of 16 SQ items and 17 IQ items identified and grouped under the appropriate SQ and IQ category. This included nine SQ and IQ items identified by the expert panel that did not correspond with any of the initial sources of BI success identified in the literature. As a result, the following nine measurement items were added to the survey instrument: functionality and features of the BI system are dependable, frequency of data generation and refresh in the BI system are flexible, the BI system accommodates remote access, the BI system is scalable, the BI system has an intuitive user interface, the BI system provides appropriate navigation to obtainable information, the BI system provides portability of data and data sources including import and export features, the source of BI information is traceable and verifiable, information is reproducible in the BISI.

Phase II: Instrument, Data Collection, and Exploratory Factor Analysis

The quantitative process (Phase II) began with the development of a two part quantitative survey instrument to collect data. This preliminary survey instrument was based on the results of phase I. The quantitative assessment of the SQ and IQ characteristics found in literature, augmented by additional SQ and IQ characteristics uncovered in phase I of the study was performed using value theory under Keeney's (1999) methodology. After a further review by the expert panel, an instrument was developed that had content validity, construct validity, and reliability. The feedback from the expert panel was used to adjust the proposed instrument and included the removal of unnecessary items and the modification of questions, language, and the layout of the instrument (Straub, 1989). The final survey instrument emerged from this process which was distributed to a larger group of users of BI systems to assess the perceived value attributed to the items using a 7-point Lickert scale ranging from not important to highly important. Our study used the revised quantitative survey instrument to collect data in order to empirically determine the CVFs of SQ and IQ for BISI success. Hair, Teo, and Wong (1998) suggested 15 to 20 observations for each variable for the results of a study to be generalizable. This study targeted 250 participants as an appropriate sample size (Schumacker & Lomax, 2010). Approximately 1300 survey invitations were sent to analysts through a service of SurveyMonkey to achieve the response rate necessary to reach the targeted sample size of 250 participants. After completion of pre-analysis data screening, 257 responses were available for analysis for a 20.8% response rate with 176 or 68.5% completed by females and 31.5% completed by males. Analysis of the ages of respondents indicated that 217 or 84.4% were above the age of 30. Additionally, 55 or 21.4% of the respondents considered themselves novices in the use of BI systems, 115 or 44.7% considered themselves average users, 77 or 30% considered themselves advanced users and only 10 or 3.9% considered themselves expert users.

Respondents with graduate degrees comprised 35% of the subject population. Overall, 198 respondents or 77% had a university degree.

The study used exploratory factor analysis (EFA) techniques to uncover the CVFs of SQ and IQ of BISI. Factorial validity assessed whether the measurement items corresponded to the theoretically anticipated CVFs of SQ and IQ in a successful BISI. Principal component analysis (PCA) was used as the extraction method to provide variances of underlying factors (Mertler & Vannatta, 2001). The perceived SQ and IQ CVFs of BISI were identified by conducting EFA via PCA using Varimax rotation. PCA was used to extract as many factors as indicated by the data.

Phase III: Confirmatory Factor Analysis (CFA)

In phase III, hypotheses were tested to validate the proposed BI SQ and IQ research model based on IS success theory and the DeLone and McLean (1992; 2003) IS success model as extended by Nelson et al. (2005). This study then gathered data regarding the perceived SQ and IQ of BISI as it relates to perceived user system satisfaction and perceived user information satisfaction from BISI. Since SQ and IQ can separately influence user satisfaction, after determining the CVFs for SQ and IQ of BISI, this study tested each construct of the proposed BI SQ and IQ research model for reliability followed by the testing of the entire model. In addition to the data analysis performed in phase II of the study that established the CVFs for SQ and IQ of BISI, data was also analyzed in Phase III for the conceptual model constructs of perceived system quality of BISI, perceived information quality of BISI, perceived user system satisfaction from BISI, and perceived user information satisfaction from BISI.

Data Analysis and Results

SQ - Exploratory Factor Analysis - PCA

After conducting EFA via PCA using Varimax rotation, the Kaiser criteria was applied to the SQ factor analysis. Based on the Kaiser criterion, the results of the PCA factor analysis suggested that two SQ factors with a cumulative variance of 61.9% should be retained. Using the factor loadings, survey items were scrutinized for low loadings (< .4) or for medium to high loadings (~.4 to .6) on more than one factor. The results of this review indicated that five items could be eliminated from further analysis. Furthermore, the Cronbach Alpha analysis indicated that all remaining items supported the reliability of the items and the factors. Moreover, the Cronbach's Alpha of each factor was 0.83 or higher, indicating very high reliability. As a further test of reliability, the Cronbach's Alpha "if item is deleted" was calculated to test the reliability of the items for all SQ factors. Based on an analysis of the results it was concluded that the appropriate number of SQ factors for extraction were two as represented in Table 1 and were comprised of 12 items.

Factor Name	Item	1	2	Factor's Alpha if Item is Deleted
Integration Flexibility SQ	SQI3	.797	.060	.888
	SQI1	.770	.291	.879
	SQI2	.758	.260	.883
	SQF2	.730	.348	.878
	SQF3	.707	.356	.881
	SQI4	.662	.295	.889
	SQF4	.621	.318	.891
	SQF1	.610	.369	.889
Reliability SQ	SQR2	.203	.851	.765
	SQR3	.328	.795	.761
	SQR1	.217	.735	.827
	SQR4	.376	.663	.814
Cronbach's Alpha		.898	.837	

Table 1. SQ CVFs of BISI Resulting from PCA

As a result of the analysis, integration flexibility SQ was found to explain the largest variance in the SQ data collected and consisted of characteristics that addressed the ability of the BI system to combine information using compatible systems that supported integrated communications and transmissions among a variety of systems and the associated data in various functional areas. The new factor of integration flexibility SQ was also comprised of the BISI SQ characteristics of extendibility, expandability, modularity, and configurability, as well as adaptability and scalability with an intuitive user interface. In particular the characteristic of data portability was considered to be very important to BI users. It is clear that flexibility in integrated systems is important to BISI success. Reliability SQ explained the remaining variance in the data collected and represented a combination of the characteristics of system dependability, recoverability, and low downtime. In essence, BI users found the technical quality of the system to be important. The list of SQ characteristics of BISI is provided in Table 2.

Item	CVF	Perceived SQ Items
SQI3	Integration flexibility SQ	The ability of the BI system to communicate and transmit a variety of data between other systems servicing different functional areas.
SQI1		The ability of the BI system to combine information with other information and deliver to the user.
SQI2		The compatibility of BI system software with other software and hardware
SQF2		The BI system is extendible, expandable, modular, and configurable
SQF3		The BI system is scalable (e.g. hardware, software, memory)
SQI4		The BI system provides portability of data and data sources including import and export features
SQF4		The BI system has an intuitive user interface (UI)
SQF1		The BI system is adaptable to user needs
SQR2	Reliability SQ	The BI system has a low percentage of hardware and software downtime.
SQR3		The BI system can easily recover from malfunctioning equipment and restore data
SQR1		The functionality and features of the BI system are dependable
SQR4		The BI system is of high technical quality

Table 2. SQ characteristics of BISI

IQ - Exploratory Factor Analysis - PCA

The results of the IQ EFA under PCA using Varimax rotation and the Kaiser criteria suggested that three IQ factors with a cumulative variance of 75.3% should be retained. Using the factor loadings, survey items were scrutinized for low loadings (< .4) or for medium to high loadings (~.4 to .6) on more than one factor. The results of this review indicated that three items could be eliminated from further analysis. The Cronbach's Alpha's of the individual factors provided high reliability: representation IQ - 0.896, intrinsic IQ - 0.957, accessibility IQ – 0.852. Based on an analysis of the results it was concluded that the appropriate number of SQ factors for extraction were three, as represented in Table 3 and were comprised of 14 items.

Factor Name	Item	1	2	3	Factor's Alpha if Item is Deleted
Representation IQ	IQR3	.848	.171	.144	.873
	IQR4	.798	.296	.002	.883
	IQR5	.733	.143	.335	.876
	IQR1	.703	.290	.381	.871
	IQR2	.693	.078	.400	.883
	IQC4	.604	.320	.334	.884
Intrinsic IQ	IQI1	.176	.914	.196	.937
	IQI3	.223	.905	.231	.932
	IQI4	.211	.877	.214	.949
	IQI2	.249	.864	.178	.953
Accessibility IQ	IQA3	.358	.255	.765	.772
	IQA2	.048	.304	.764	.873
	IQA4	.476	.158	.720	.784
	IQA1	.527	.160	.615	.816
Cronbach's Alpha		.896	.957	.852	

Table 3. IQ CVFs of BISI Resulting from PCA

Representation IQ was found to explain the largest variance in the IQ data collected and consisted of characteristics that addressed the representation of information in BI systems which rely on the user to ensure that IQ is retained as information from various sources are joined, aggregated, updated, configured, manipulated, and mapped into suitable representations and formats. The item IQC4 "traceability and verifiability of the source of information in BISI" loaded high on the CVF of representation IQ. Accessibility IQ explained the next largest variance in the data collected and included items representing a combination of ease of access to locatable, obtainable, and searchable information. In essence, BI users found interactive information access for the purpose of improving information content quality important in their BI IQ work. The IQ CVF of BISI with the third highest variance belonged to intrinsic IQ and consisted of the items of information accuracy, consistency, reliability, and correctness. The list of IQ characteristics of BISI is provided in Table 4.

Item	CVF	IQ Items
IQR3	Representation IQ	Information is easily joined, aggregated, updated, configured, and manipulated in BISI
IQR4		Information is reproducible in the BISI
IQR5		Information is mapped into suitable representations at the user level in the BISI
IQR1		Understandability of Information in BISI
IQR2		Format of information in BISI
IQC4		Traceability and verifiability of the source of information in BISI
IQI1	Representational IQ	Accuracy of information in BISI
IQI3		Reliability of information in BISI
IQI4		Correctness of information in BISI
IQI2		Consistency of information in BISI
IQA3	Accessibility IQ	Accessibility to locatable and searchable information in BISI
IQA2		Security of accessed information in BISI
IQA4		Appropriate navigation to obtainable information in BISI
IQA1		Ease of accessing information in BISI

Table 4. IQ characteristics of BISI

Confirmatory Factor Analysis

The strength and direction of the hypothesized relationships (Figure 4) in the conceptual model were validated using the partial least squares (PLS) method, a subtype of structured equation modeling (SEM) used in performing confirmatory factor analysis (CFA). The bootstrapping resampling method (5,000 samples) was also employed. As a result of Phase II factor analysis, the hypothesized paths from the two empirically assessed CVFs of SQ to the perceived SQ of BISI have been named H1.1 and H1.2. Likewise, the hypothesized paths from the three empirically assessed CVFs of IQ to the perceived IQ of BISI have been named H2.1, H2.2, and H2.3. Furthermore, the paths from user perceived SQ and user perceived IQ of BISI to perceived user system satisfaction and perceived user information satisfaction from BISI as hypothesized in the proposed BI SQ and IQ research model, based on the Delone and McLean IS success model (2003) as extended by Nelson et al. (2005) were tested in the overall context of BISI success. PLS was used to empirically test the conceptual model path coefficients to determine the significance of the relationships. As indicated in the conceptual model in Figure 4, all CVFs of BISI for SQ and IQ have significant positive impacts on the perceived SQ and IQ of BISI.

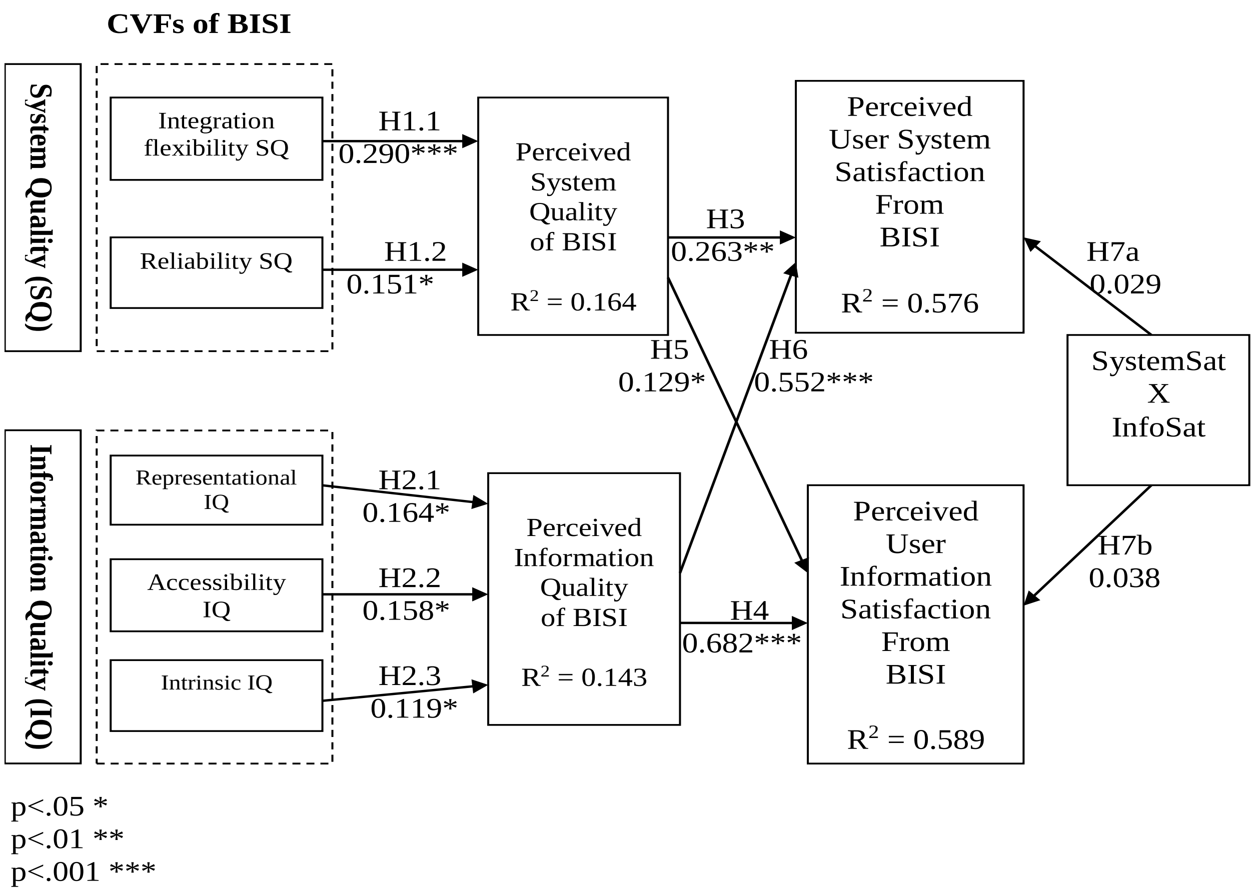

Figure 4. Structural Equation Model Testing Results of Conceptual Model

Findings

The results of the testing of the hypotheses clearly indicate support for the empirically determined CVFs of SQ and IQ of BISI as depicted in Table 5. Moreover, these results provided evidence that many of the antecedents uncovered in the literature and by the expert panel in the qualitative phase of the study were highly valued by BI users and contributed to the strength of the relationships between the CVFs of BISI and perceived SQ and IQ of BISI. Furthermore, seven of nine items recommended for inclusion in the survey by the expert panel were reliable and grouped accordingly within the retained CVFs.

The results confirm that there is a significant positive impact between perceived SQ and perceived user system satisfaction as well as a significant positive impact between perceived IQ and perceived user information satisfaction. The results also provided confirmation that there is a significant positive impact in the crossover relationships between the perceived SQ and IQ of BISI and the perceived user system satisfaction and perceived information satisfaction from BISI. It is also noted that the interaction effect did not have a significant positive impact on either perceived user information satisfaction from BISI or perceived user system satisfaction from BISI. These results were shared with members of the expert panel who expressed their agreement and support of the findings.

Hypotheses	Results
H1.1 and H1.2: The CVFs of integration flexibility SQ and reliability SQ will have a positive significant impact on SQ for BISI success.	Supported
H2.1-3: The CVFs of representational IQ, accessibility IQ, and intrinsic IQ will have a positive significant impact on IQ for BISI success.	Supported
H3: The perceived SQ of BISI will have a positive significant impact on perceived user system satisfaction from BISI.	Supported
H4: The perceived IQ of BISI will have a positive significant impact on perceived user information satisfaction from BISI.	Supported
H5: The perceived SQ of BISI will have a positive significant impact on perceived user information satisfaction from BISI.	Supported
H6: The perceived IQ of BISI will have a positive significant impact on perceived user system satisfaction from BISI.	Supported
H7a: The interactions of perceived user system satisfaction from BISI and the perceived user information satisfaction from BISI will have a positive significant impact on perceived user system satisfaction from BISI.	Not Supported
H7b: The interactions of perceived user system satisfaction from BISI and the perceived user information satisfaction from BISI will have a positive significant impact on perceived user information satisfaction.	Not Supported

Table 5. Summary of Hypotheses Results

Discussion

The main goal of this study was to validate empirically a model for IS success that investigated user satisfaction in the context of BISI by uncovering the CVFs of SQ and IQ necessary to derive BISI success. The study found that a BISI project should place emphasis on the CVFs of integration flexibility SQ and reliability SQ as the primary drivers for SQ of BISI success. Emphasis should also be placed on the CVFs for IQ of representational IQ, intrinsic IQ, and accessible IQ, as the primary drivers for IQ of BISI success.

The CVF of integration flexibility SQ had the most significant effect on the SQ of BISI as greater emphasis was placed on the capability of the BI system to easily combine information from multiple sources while retaining compatibility with other software and hardware. This is important to users of BI as the ability of the BI system to communicate and transmit a variety of data between other systems supporting different functional areas is necessary for BISI success. This had previously been understood to be merely a relevant attribute and expected in BI systems that leveraged data warehouse technologies (Nelson et al., 2005). The results of this study also confirm the importance of integration flexibility SQ to facilitate integration of changing information from various sources to support business decisions. The system must be flexible in supporting ad hoc and unplanned requests for information in various representations. Reliability SQ was also considered as an important CVF as system dependability, recoverability, and low downtime are valued by BI users. On the other hand, the SQ CVF of response time SQ was not a reliable CVF in BISI success. It may be that response time for BISI was considered less important as a separate CVF but was assumed to be available in reliable and flexible BI systems. It might also be possible that due to the analytical nature of BI systems, response time does not carry the same level of importance as would be necessary in a transaction based system.

The CVF of representation IQ had the most significant effect on IQ as the representation of information in BI systems, as with most analytical based applications, relies on the user to ensure that IQ is retained as information from various users and sources are joined, aggregated, updated, configured, manipulated, and mapped into suitable representations and formats. Of particular interest was the high level of importance placed on the traceability, verifiability, and ability to reproduce information in BISI. This may point to user recognition of the need for accountability for the output produced by the user in BI systems. The CVF of accessibility IQ was also considered important in successful BISI as emphasis was placed on the importance of ease of access to locatable, obtainable and searchable information as well as the security of the accessed information and the ability to navigate within the BI system. Intrinsic IQ was also a reliable CVF as information accuracy, consistency, reliability, and correctness have generally been a cornerstone to BI success. The CVF of contextual IQ, however, was not a reliable CVF of perceived IQ of BISI. This may be due to the nature of BI systems which often rely on historical data to perform analytics and, as with response time expectations and assumptions, the contextual characteristics of currency, timeliness, sufficiency, and relevancy of information may be assumed to be of less importance than in systems that are more time dependent and transaction oriented.

The effects of perceived SQ on perceived user system and information satisfaction as well as the effects to perceived IQ of BISI on perceived user system and perceived user information satisfaction were also of particular interest in the study. The perceived IQ of BISI had a significant positive impact on perceived user information satisfaction from BISI. Perceived IQ of BISI also had a significant positive impact on perceived user system satisfaction from BISI. While the perceived SQ of BISI had a significant positive impact on perceived user system satisfaction from BISI there was less of an impact on perceived user information satisfaction from BISI, thereby highlighting the differences between the BI system and the information produced. It is apparent that BI systems provided functionality that features advanced interfacing capabilities that may influence the users' perception that the interaction with the interface has an impact on the output produced thereby making it difficult to differentiate between the interface and the user's responsibility for the quality of the output. This study also confirms that while the empirically determined CVFs of SQ and IQ of BISI and their crossover effects are perceived to be important to user perceived SQ and IQ user satisfaction from BISI, the strength of the impact of IQ on the system corresponds to the importance users place on the output in analytical BISI. Moreover, this finding emphasizes the differences between the BI system tools and the output that is produced as well as the need for BI system implementers to accept responsibility for IQ. The results of this study and particularly the crossover effects found in the research model shed light on our understanding of quality and highlight a continuum of interactivity in BISI that distinguishes SQ and IQ characteristics and their effect on output and user perceived satisfaction.

Contributions of the Study

Our study has several implications in the field of IS. First, it contributes to the body of knowledge by empirically identifying the CVFs and characteristics of SQ and IQ that users find important in successful BISI. Secondly, this study empirically addressed the relationship between the qualities of the BI system (SQ) and its output (IQ). The study determined that there was a significant positive impact from perceived SQ and IQ of BISI on perceived user system and information satisfaction from BISI. Previous studies in BISI placed emphasis on the use of a data warehouse within the BISI domain and there had been ambiguity between the system (SQ) and its output (IQ) whereby the strength of the relationship between SQ and information satisfaction was stronger than the relationship between IQ and information satisfaction. The empirically developed findings of this study are in line with expectations for system success as theorized in the BI SQ and IQ research model, based on the DeLone and McLean IS success model (1992; 2003) as extended by Nelson et al. (2005). Lastly, this study identified characteristics of SQ and IQ that are valued or important in BISI, thereby assisting researchers and practitioners in determining the best areas of focus for BISI success. This study represents the first empirical analysis of CVFs that affects SQ and IQ for BISI success and has uncovered important factors and characteristics for BISI success that will enable BI stakeholders to better optimize scarce resources.

Limitations and Suggestions for Future Research

The primary limitation of this study surrounds the possibility that participants may have varying degrees of exposure to analytical BI systems. While BI systems are associated with decision making, the complexity of the implemented system and the interpretation of its output could require skill levels that may not be consistent among all participants. It is, therefore, assumed for the purposes of this study that participants had, at a minimum, BI or analytical system implementation experience. Another limitation of this study is that it may not be representative of the entire BI analytical user population. Participants in this study were selected on a random basis and their experience levels varied. The gender differences among BI users may also be examined more closely, possibly as a limitation, as there were twice as many females that participated in the survey than males. Another limitation surrounds the lack of consistency in the BI technologies used. For example, one participant may have experienced BI using the IBM Cognos tool. Another participant may have experienced BI using systems that were integrated in an ERP system. Another limitation is that the survey instrument was distributed via email to BI system users. This raises the possibility that BI system users may have ignored the invitation based on email overload and the associated lack of time to review and respond to a multitude of messages.

Our study provided a solid theoretical foundation from which future studies can originate. Firstly, it was designed to empirically validate a model for IS success for user satisfaction in the context of BISI and although the individual CVFs of SQ and IQ necessary to derive BISI success were significant, future studies may be warranted to examine and assess other constructs and items that are important to BI systems users that lead to BISI success such as governance and service quality. Moreover, BI systems are expected to accommodate the big data phenomenon which represents additional, unusual, and complex sources of data in BISI (Wixom, Ariyachandra, Douglas, Goul, Gupta, Babita, Iyer, Kulkarni, Mooney, Phillips-Wren, & Turetken, 2014). Furthermore, future research could assess the needs of BISI in a big data environment whereby information is often unstructured. With more attempts to manipulate input streams, many issues have been raised in the field of big data, accompanied by a wide variety of potential failures. There have been few attempts to actually apply big data analytics to the validation of big data, particularly in the analysis of data streams (Wixom et al. 2014). Social media for instance is open to a wider range of validation techniques. This could explain, in part, the high degree of importance placed by BI users in this study on validity of data sources. This finding may also point to the need to establish tailored systems development methodologies with emphasis on testing and verification for the delivery of BI systems in the future.

Conclusion

This study provided further evidence that the antecedents of integration flexibility SQ and reliability SQ are important to BISI success. Moreover, it also demonstrated compelling evidence that the antecedents of representation IQ, accessibility IQ, and intrinsic IQ are important to successful BISI. These findings confirm the widely held view that BISI is not a conventional application-based IT project but a complex undertaking requiring an appropriate infrastructure over a lengthy period of time. The findings also confirm that successful BISI require a robust and easy to use interface for user-driven information representation in an analytical user-based decision support system context from multiple integrated heterogeneous sources (Yeoh & Koronios, 2010; Goodhue & Thompson, 1995). Our study also reported that there is a significant effect in the relationships of perceived IQ of BISI to perceived user information and system satisfaction thereby confirming the importance BI system users place on information and the system output produced.

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