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Business Intelligence Success applied to Healthcare Information Systems

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Abstract

In this paper, DeLone and McLean's IS Success Model is empirically tested on a Business Intelligence System applied to Healthcare Information Systems at 12 public hospitals in Denmark. The purpose of the study is to investigate which factors contribute to BI Success. A total of 1351 end-users replied to the questionnaire, and the response rate was 32%. Eight relationships in the model were tested, and four relationships were found to be significant. Our results are as follows: System Quality is positively and significantly associated with Use and User Satisfaction. Information Quality is positively and significantly associated with User Satisfaction but not Use, and User Satisfaction is not significantly associated with Use and vice versa. User Satisfaction is positively and significantly associated with Individual Impact, but Use is not significantly associated with Individual Impact.

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1. Introduction

In many organisations, the IT manager's top priority is to handle the increasing amounts of data produced internally and externally and make the data available to analysts and decision makers at all levels of the organisation[1]. This development results from the management's desire to create a data-driven organisation. According to Madsen: 'Data-driven means that information must be consumable and contextual, to encourage action that will modify behaviour over time'[2].The healthcare sector has historically generated a significant amount of data, driven by the demand for record keeping, compliance, regulatory requirements and patient care[3]. Therefore, it is relevant to use Business Intelligence (BI) applied to Healthcare Information Systems (HIS). Parente and Dunbar found that healthcare organisations with Information Systems (IS) have higher total margins and operating margins than those that do not have IS[4].

BI is an umbrella term that includes applications, infrastructure, tools and best practices that enable access to and analysis of information to improve and optimise decisions and performance[5]. Obtaining BI success is complex, and this complexity carries a cost[6]. The investment in BI technologies is expensive, because the implementation includes infrastructure, software, licenses, training and wages[7]. Moreover, the literature indicates that many organisations fail to realise the expected benefits of BI[8–10].

An area with a huge amount of data and high system complexity is the public sector[11]. It is important to point out that the evaluation of IS differs between private and public organisations[12]. Still, most research on IS evaluation has been focused on the private sector[12]. In Scandinavian countries, the healthcare sector, including hospitals, is financed and run by the public sector. Health insurance and private hospitals constitute a small part of the sector. The Scandinavian welfare model is a political model that includes Denmark and other Nordic countries and was developed after the end of World War II. The basic principles of this model imply, on one hand, that all citizens of society have access to social and healthcare services without regard to their social background or origin and, on the other hand, that the benefits are not linked to insurance contributions or other forms of user payment[13]. The health sector has been late to use BI on their data from HIS because the complexity in this sector is much higher than in the private sector[2]. The public hospitals in Denmark use BI with HIS as a data source in combination with other data sources, such as the accounting and payroll system. Most professions have access to the BI system, including secretaries, doctors, care staff, management and administrative staff. Sometimes they have access to data both in the source system and in the BI system; other times the data come only from BI.

There have been many definitions of IS success and also many different measures of IS evaluation[14]. DeLone and McLean's IS Success Model consists of six constructs, including Information Quality, System Quality, User Satisfaction, Use, Individual Impact and Organisation Impact[15,16]. The model can capture the complexity of using BI in a healthcare setting. According to Iivari[17] and Tona et al.[14], it still lacks the empirical test of DeLone and McLean's model, because the author emphasises that an empirical test needs to be performed with different types of IS and in various contexts. Moreover, since there is a lack of research on IS success in a healthcare setting, it is relevant to use DeLone and McLean's model. This paper will therefore empirically test DeLone and McLeans's IS Success Model at 12 hospitals and contribute to the sub-field of 'BI success' and especially 'BI success in hospitals'. Researchers of IS evaluation are concerned with the assessment of interventions in different organisational settings. Therefore, BI serves as a critical means for accomplishing the intervention's expected goals. The remaining parts of the papers are organised as follows. In section 2 the IS Success Model is presented, followed by a explanation of the methodology employed in Section 3. Section 4 presents the results of the survey, which is followed by the discussion. In the final part, the conclusions are presented.

2. IS Success Model

In 1980, at the first International Conference on Information Systems, Peter Keen asked, 'What is the dependent variable?'[18]. To address this issue, DeLone and McLean[15] proposed the IS Success Model based on Shannon and Weaver's three levels of communication[19] and Mason's[20] information influence theory. DeLone and McLean's IS Success Model has its roots in communication theory. IS success is based on several interrelated factors. The IS Success Model consists of six constructs, including Information Quality, System Quality, Use, User Satisfaction, Individual Impact and Organisational Impact. An IS system is characterised by Information Quality and System

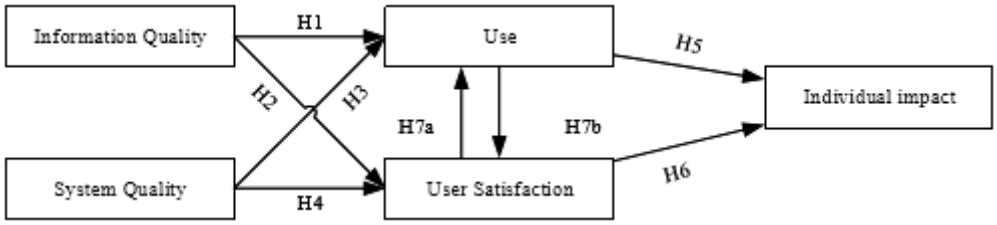
Quality. The system is operated by users, who can have different levels of satisfaction and can have individual impacts. These impacts have an effect at the organisational level. In the first version of the theory, System Quality is classified as occurring on the technical level, whereas Information Quality is semantic. The other categories assess the effectiveness of the system.[15,16]

The quality of the information produced by the system is referred to as Information Quality. It is a major factor in Information Quality that subsequent decisions be based on the output from the system.[21] System Quality is concerned with the input in the system and the quality of the Information System as a software[22]. Seddon concludes that DeLone and McLean's construct Use is related to the benefit of the system that flows from it. Therefore, Use is measured regarding time and frequency of Use.[21] Bailey and Pearson has defined User Satisfaction as: 'satisfaction in a given situation is the sum of one's feelings and attitudes toward a variety of factors affecting that situation'[23]. Individual Impact has been defined by DeLone and McLean as 'an indication that an information system has given a user a better understanding of the decision context, has improved his or her decision making productivity, has produced a change in user activity, or has changed the decision maker's perception of the importance or usefulness of the information system'[15]. The overall performance of the organisation can be measured as the impact that the use of the system has [15]. The measurement of the constructs is shown in Tabel 1.

After DeLone and McLean's IS Success Model was published, several researchers suggested improvements. In 2003, DeLone and McLean revised their work and presented an updated model[16]. The revised model included Service Quality, and it combined Individual Impact with Organisational Impact to form a Net Benefit category. This Net Benefit category was also extended to include other levels of impacts. Moreover, Use was expanded to include the Intention to Use.

To study how to obtain success with BI applied to HIS, the IS Success Model from 1992 is used. Our intention with the study is to evaluate the effects of the individual system usage and not its impacts on the organisation. Furthermore, there can be difficulties in assessing the costs and benefits related to the system, because it cannot always be expressed in monetary terms.[24] Hence, the construct Individual Impact is measured. Therefore, the absence of quantitative data excludes the Organisational Impact from our research model. A modified model is illustrated below, in which Organisational Impact is left out:

Fig. 1. Modified IS Success Model.



3. Methodology

3.1. The context of study

The BI system applied to HIS will be evaluated using the model presented in the section above. The users of BI included in this study work at 12 hospitals in a certain region. The public healthcare sector in Denmark is organised into five regions. A region has both the political and practical responsibility for hospital services and specialised institutions. It includes psychiatry, health insurance, general practitioners and specialists. The region in this study has approximately 25000 employees, more than one million citizens and a budget of over three billion euros. The hospitals are operating in an environment characterised by politically motivated priorities. Hospitals are experiencing political pressure regarding efficiency, budget compliance and shifting the allocation of resources to various diseases. In addition, they have a complex portfolio of IT systems and derived data. Therefore, BI is used to provide information to improve decision making.

The BI is created with the software Tableau, and users can access it via intranet. The BI-application is used for two primary tasks: 'view' and 'analyse'. Employees use BI to follow up on Key Performance Indicators (KPI), forecast the load on hospitals' resources, data extraction for research and other types of analysis.

A questionnaire was created to measure the constructs in the IS Success Model. The questionnaire was prepared in a survey program. First, employees from the region were sent an email encouraging them to participate in the study. Subsequently, an email was sent to individuals who were registered as users of the BI system. The first question was whether the user had used BI. If not, the questionnaire was immediately completed and the answer registered; otherwise the respondent was presented with all the questions. A reminder was sent after two weeks. A total of 4232 employees at the hospitals had access rights to the system, and 1351 users replied to the questions. The response rate was 32%. In all, 605 answered that they had not used BI, leaving us with 746 responses for statistical analysis.

3.2. The questionnaire design

The purpose of the survey was to measure the five constructs shown in Figure 1. The constructs are defined in section 2. Each construct was measured with one or more items. The questions in Table 1 were based on questionnaires that have been tested, validated and used in previous research studies. This instrument was also assessed by involving three academic colleagues who had skills, knowledge and experience in the IS research fields and applying a unidimensionality procedure[25] to ensure its validity and reliability. Finally, it was tested in a pilot study with 24 employees with various levels of experience with BI. All questions were measured on a five-point Likert scale. The author's Email address was mentioned in the cover letter, and serval participants in the survey gave voluntary qualitative comments regarding their use of the system. The data collection process was guided by Dillman[26].

Table 1. Constructs and items to be measured.

Construct	Name in PLS	Items to be measured
System Quality	SysQua01	BI is easy to learn.[27]
	SysQua02	BI is easy to use.[11]
	SysQua03	Information in BI is easy to understand.[22]
Information Quality	InfQua01	Data are displayed in a consistent format in BI.[22]
	InfQua02	In BI data have high validity.[22]
	InfQua03	Other employees in the region also think the data have a high validity in BI.[22]
Use	Use01	What is the approximate share of your total work have you used [BI] to solve for the past month?[15]
User Satisfaction	UseSat01	BI has all the functions and capabilities I expect it to have.[11]
	UseSat02	If a colleague asked, then I would recommend BI.[28]
	UseSat03	Overall, how satisfied are you with BI?[11]
Individual Impact	IndImp01	I can effectively make my reports using BI.[27]
	IndImp02	I can complete my reports quickly using BI.[27]
	IndImp03	I can complete my reports using BI.[27]

3.3. Analysis of the data

It could be argued that the appropriate statistical methodology for testing the model would be a covariance-based structural equation model (CB-SEM)[29]. However, in this dataset, the construct Use did not meet the requirement for normally distributed data measures in regard to skewness and kurtosis. Therefore, the model was tested with the SEM technique partial least squares (PLS). PLS is a widely used method, and since there were over 250 participants in the survey, there is only a small difference between the two models.[30]. The model in Figure 1 was tested using SmartPls

version 3.0. The presence of a reciprocal relationship between Use and User Satisfaction leads to testing two models. Model 1 includes User Satisfaction leading to Use, and Model 2 includes Use leading to User Satisfaction.

3.4. Estimation of measurement model

Before testing the relationships in the PLS-SEM model, the validity and reliability were evaluated[31] according to the guidelines by Hair et al. [32]. Table 2 includes all the values calculated for each construct. The convergent validity of each variable is measured by the outer loading of each variable and the average variance extracted (AVE) of each construct. The recommended threshold value for outer loadings is 0.7[32], and all the variables are above this value. Furthermore, the variance of the construct is larger than the error, because all the AVE values are above 0.5 in all the variables [31].

For measuring the internal consistency reliability, the composite reliability and Cronbach's alpha were calculated. The recommended threshold value is above 0.7 for the composite reliability and Cronbach's coefficient alpha[33]. All the constructs are above the recommended threshold value according to Cronbach's alpha and composite reliability. To examine discriminant validity, the Heterotrait-Monotrait Ratio (HTMT) was calculated. According to Hair et al.[32], this is a better measure, because the typically used cross-loadings do not allow for the reliable detection of discriminant validity issues. The HTMT interval was calculated and did not include the number 1. Therefore the discriminant validity of the constructs are acceptable. In Table 2 the results of the assessment of the different measures of validity and reliability are summarised. As shown, all the evaluation criteria have been met, which provides support for all the measures' reliability and validity.

Table 2. Results summary for reflective measurement models.

		Convergent validity		**Internal consistency reliability**		**Discriminant validity**
		Loadings	AVE	Composite reliability	Cronbach's alpha	HTMT
		>0.7	0.5<	0.7<	0.7<	Interval does not include 1
Information Quality	InfQua01	0.716				
	InfQua02	0.883	0.657	0.851	0.744	Yes
	InfQua03	0.827				
Individual Impact	IndImp01	0.911				
	IndImp02	0.877	0.762	0.906	0.844	Yes
	IndImp03	0.825				
System Quality	SysQua01	0.901				
	SysQua02	0.933	0.748	0.898	0.826	Yes
	SysQua03	0.745				
Use	Use01	1.000				Yes
User Satisfaction	UseSat01	0.853				
	UseSat02	0.907	0.809	0.927	0.882	Yes
	UseSat03	0.927				

4. Results

In this study, eight hypotheses were tested based on Delone and McLean[19]. The results from our PLS-SEM are shown in Tabel 3 and discussed in section 5.

Table 3. Results.

		Model 1		Model 2		
	Hypothesis	Coefficients	P-value	Coefficients	P-value	Results
H1	Information Quality -> Use	-0.019	0.657	-0.008	0.839	Not supported
H2	Information Quality -> User Satisfaction	0.234	0.000	0.234	0.000	Supported
H3	System Quality -> Use	0.193	0.000	0.219	0.000	Supported
H4	System Quality -> User Satisfaction	0.565	0.000	0.560	0.000	Supported
H5	Use -> Individual Impact	0.015	0.528	0.015	0.522	Not supported
H6	User Satisfaction -> Individual impact	0.746	0.000	0.746	0.000	Supported
H7a	User Satisfaction -> Use	0.045	0.331	-	-	Not supported
H7b	Use -> User Satisfaction	-	-	0.023	0.335	Not supported

In Model 1 it was tested whether User Satisfaction affects Use and in Model 2 visa versa. The variance of Individual Impact is explained 56.0% in both models, while the variance of User Satisfaction is explained 51.5% in Model 1 and 51.4% in Model 2. All the supported hypotheses in the model have a p-value below 0.001. Information Quality is positively and significantly associated with User Satisfaction ($p < 0.001$) but not with Use. System Quality is positively and significantly associated with User Satisfaction and Use ($p < 0.001$). User Satisfaction is positively and significantly associated with Individual Impact ($p < 0.001$), but the hypothesis about a relation between Use and Individual Impact is not supported. The relation between User Satisfaction and Use is not supported and visa versa. In both models, SRMR is 0.075 and is below the threshold value 0.08[34]. This value indicates a good fit.

5. Discussion

No significant relationship was found between Information Quality and Use (H1) in either Model 1 or Model 2. This indicates that higher Information Quality does not automatically lead to greater use of BI. In a BI setting in a public organisation, this result is in line with Tona et al.[14]. In another public organisation setting, Wang and Liao[11] came to the same conclusion at significance < 0.05. In other IS settings, Iivari[17] and McGill et al.[35] did not find any relationship between Information Quality and Use. There is a positive and significant relation between System Quality and Use of the System (H3). These results are similar to Tona et al.'s study[14] and the study by Iivari[17]. Therefore, if the BI system is easy to use and easy to learn, employees will use it more. Regarding the System Quality, the item 'The information in BI is easy to understand' was rated highest by the users. The users found that the system was easy to use, and in last place, it was easy to learn. The focus on System Quality is not surprising, as organisations use Tableau. The users in Gartner's Magic Quadrant survey for 2017 voted this BI system as having one of the highest ease of use.[36] Also, the region has a considerable focus on user-friendliness, for example, through user involvement and work with personas.

Several studies confirm the positive relationship between Information Quality and User Satisfaction (H2) and between System Quality and User Satisfaction (H4) (e.g. Tona[14], Seddon and Kiew[21] and Wang and Liao[11]). Several BI users later gave their response via email. Based on the user comments, the following can be summarised. One observation was that users did not comment on what they were happy with but rather on what they were dissatisfied with, which Tona et al. also experienced in their interviews. Some users found that datasets were not complete, which made it difficult to use them. Other users were unsure of the validity of the data, as they could not reproduce data from HIS and BI. This may be due both to the validity but also to the calculation methods being different in the two systems. Some users were positive about the BI system but had requested data needs that had not been met. As a result, they were not satisfied. A final type of user found that the system was difficult to use, as it was only a small part of their work, and therefore they used it only occasionally. It is essential to realise that the BI system was implemented for all employee types, from administrative staff to health professionals. Based on our statistical calculations and user

comments, it can be concluded that Information Quality and System Quality are positively associated with User Satisfaction.

Our study shows that Use and User Satisfaction are not related to each other, as neither H7a nor H7b is significant. Roldan and Leal[37] had the same issue and suggested that a predictor variable other than Use should be utilised. Another explanation may be that the system has been implemented for less than two years, and according to Pick[38], the use of the system increases user satisfaction becaure the users experience a benefit by using it. This may also support the fact that H5 is not significant; so in our study, there is no relationship between Use and Individual Impact. This finding is in line with Iivari's[17] study from 2005. In 2003, DeLone and McLean[16] found when the relationship exists when Use was, typically voluntary. The Use of the BI system applied to the HIS is not voluntary, because there are KPIs and statistics that cannot be extracted from other systems but instead should be used in daily operations and follow-up, which may be an explanation for the insignificant path. Most of the users had the same use pattern: 75% use BI in under half of their total work. This may be the reason why Use does not work as a construct.

In conclusion, there is a positive and significant relationship between User Satisfaction and Individual Impact, which supports H6. According to Tona et al.[14], as well as Iivari[17], this can be interpreted that if the BI system's capabilities support users' needs, they will experience a benefit using the BI System.

6. Conclusion

This study tested DeLone and McLean's IS Success Model[15] on BI applied to HIS. The study partly supports the model. Eight relationships were tested, four of which were significant at $p < 0.001$. Information Quality is positively associated with User Satisfaction as is System Quality. User satisfaction is also positively related to Individual Impact, and System Quality is positively associated with Use. The hypothesis about Use being positively related to User Satisfaction, and vice versa, is not confirmed. Likewise, Information Quality is not associated with Use, and Use is not related to Individual Impact. The findings from this study can be used in practice: they demonstrate the importance of high System Quality and Information Quality affecting User Satisfaction, which influences the Individual Impact.

Although the extensive procedure and the many answers have validated the IS Success Model in the context of BI applied to HIS in the public sector, some limitations can be addressed in future research. First, the validation of BI applied to HIS using an IS Success Model is a new concept. The findings and implications of this study were based on Danish public hospitals with a particular BI system and underlying source systems. To generalise these results, the model should be tested in private hospitals as well as with other BI systems in an international context. Second, the conclusion is that the construct Use is not fully explained in this model. Therefore, it may be relevant to use other predictor variables, such as task compatibility, task characteristics, experience with BI, education level and job function for inclusion in a BI success evaluation in the context of BI applied to HIS. Third, the study only measured impact at an individual level. Therefore, it would be useful to measure the effects of BI applied to HIS on an organisational level. Finally, the model was validated using quantitative data supplemented by some users' voluntary written comments. A deeper understanding of the circumstances should be investigated using qualitative methods.

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