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Better and more Efficient Treatment: The Individual and Organizational Impacts of Business Intelligence Use in Health Care Organizations

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Abstract. This study investigates the critical success factors for individuals' use of business intelligence (BI) in health care organizations. We also examine the organizational impact of BI. We develop a model that expands DeLone and McLean's IS success model to include task characteristics. To analyze the model, we used a mixed-method approach. First, a questionnaire was sent to BI users, which was completed by 746 respondents. In this step, we found that the expansion of the IS success model enhances the degree of explanation, such that user satisfaction and individual impact are better explained. Second, we investigated the organizational impact through semi-structured interviews. We identified two user types—system users and information users—and we found that BI is used for financial reporting, improving patient progress, and enhancing learning in hospitals. Future research should focus on the impact of tasks on IS success.

Keywords: Business intelligence success, public health care sector, task

1 Introduction

Organizations relying on data-driven decision making have 5-6% higher productivity than other organizations, according to research on information technology usage and other investments [1]. Business intelligence (BI) "is an umbrella term that is commonly used to describe the technologies, applications, and processes for gathering, storing, accessing, and analyzing data to help users make better decisions" [2]. Research focused on BI has shown that this technology has numerous impacts on organizations. For example, it can help minimize the mistargeting of customers [3], enrich organizational intelligence [4], support the development or improvement of products and services [5], and transform business processes [3]. However, the literature also indicates that a significant number of organizations fail to realize the expected benefits of BI [6–8]. Therefore, the question of how to ensure BI success is of great interest to both researchers and practitioners. The terms "success," "benefit," "worth," and "value" are used interchangeably in this regard, and these concepts tend to overlap [9].

There are several definitions of information systems (IS) success and different measures have been used to evaluate it. In this study, we adopt DeLone and McLean's success model [10], which is one of the most widely used models. DeLone and McLean explain IS success as a multidimensional construct [11]. Their model consists of six dimensions: system quality, information quality, use, user satisfaction, individual impact, and organizational impact. When using the IS success model in relation to BI, one challenge is the fact that BI covers technologies and applications, as well as processes. The latter are not captured by the model. Many organizations implement IS to support the completion of certain tasks [12]. Often, IS is used to automate or infomate tasks [13]. By incorporating task characteristics into the IS success model, the relationship between task and technology can be measured. According to Petter, DeLone, and Mclean [14], few researchers have investigated task characteristics using the IS success model.

The public sector is generally characterized by a high volumes of data and high levels of complexity [15]. In Denmark, the health care sector is part of the public sector and financed through taxes. Notably, the implementation and use of BI in the health care sector is relatively new. This is because all data in Denmark have only recently been digitized and because of challenges in terms of data quality [16]. Public hospitals in Denmark use BI in conjunction with several underlying data sources, such as electronic patient records, accounting systems, and payroll systems. Many different employee groups have access to BI, including medical secretaries, doctors, nurses, administrative staff, and management. A study by Parente and Dunbar indicates that health care organizations using IS have a higher overall margin and higher operating margins than their peers that do not use IS [17].

In general, the evaluation of IS differs between public and private organizations [18]. The public sector is the most significant investor in and user of IT worldwide [19], but most IS-focused research centers on private organizations [18]. However, public and private organizations have distinct differences in objectives, governance modes, and management structures. Therefore, not all concepts and methods can be transferred between the two [19]. Tona et al. [20] highlight that few IS evaluations studies focus on IS in e-government or health care.

Therefore, our research questions are as follows:

- What critical success factors affect individual impact of BI in public organizations?
- What impact does BI have at the organizational level in public organizations?

In this study, we use mixed methods to investigate the links among BI quality, task characteristics, and individual and organizational impacts. The first three are examined with the help of a survey of BI users. Semi-structured interviews were also conducted to allow us to investigate the organizational impact of BI use in public hospitals.

The remainder of the paper is organized as follows. Section 2 presents the research model used in the study. It is followed by a description of our mixed methods in Section 3. Section 4 covers the results of the study, which is followed by the discussion in Section 5. The conclusions are presented in Section 6.

2 Research model

In 1980, Keen asked the following questions: “What is the dependent variable? How should the researchers within the IS field understand the term “information”? How should IS success be measured?” [21] In 1992, DeLone and McLean contributed the IS success model to the discussion [10]. The theoretical foundations for the model were Shannon and Weaver’s [22] three levels of information, and Manson’s [23] extension of the effectiveness or influence level. In their previous research, DeLone and McLean had identified over 100 measures used in more than 180 studies [10]. In their 1992 paper, the authors introduced a six-factor taxonomy covering the IS success dimensions in the studies they had reviewed: system quality, information quality, use, user satisfaction, individual impact, and organizational impact. As all of the factors in the model were presented as interrelated, the model was deemed a satisfactory answer to Keen's questions. Not only did the model relate to a theoretical understanding of information but it also brought previous research together under a single umbrella [10]. Moreover, the model related the categories to each other [24, 25].

From 1992 to 2003, several researchers conducted empirical investigations of the multidimensional relationships among the IS success constructs (e.g., [25, 26]). In 2003, DeLone and McLean proposed a revised model—the updated D&M IS success model—which contained three changes from the original model. The authors added a "net benefit" construct consisting of individual and organizational impact. In addition, they added “intended use” and “service quality” as new constructs.

DeLone and McLean's 1992 article was entitled “Information Systems Success: The quest for the dependent variable.” However, the question of what the independent variables were remained unanswered until 2013. Constructs such as “user involvement” and “top management support” were suggested, but no systematic research was undertaken. Petter, DeLone, and McLean contributed to the answer with a literature review covering more than 140 studies in which 43 different variables were identified [14]. In this review, the authors called for studies of interactions among different success factors. In particular, they highlighted the lack of research on the relationship between task characteristics and IS success [14]. Another literature review confirmed that this was true for the relationship between task characteristics and BI success [27]. The current paper responds to Peter et al.’s [14] call for tests of the relationship between task characteristics (e.g., task compatibility, task difficulty, task interdependence, task significance, and task specificity) and the IS success model, as depicted in Figure 1. In this study, we use DeLone and McLean’s IS success model because, in that model, the use of IS is mandated. We are not interested in the user’s “intent to use” the system. Furthermore, we are interested in the effects of BI use, especially the impact it has on users’ daily work. Therefore, we measure the individual impact of BI separately from the organizational impact. As it can be challenging to capture the organizational impact, we utilized qualitative methods.

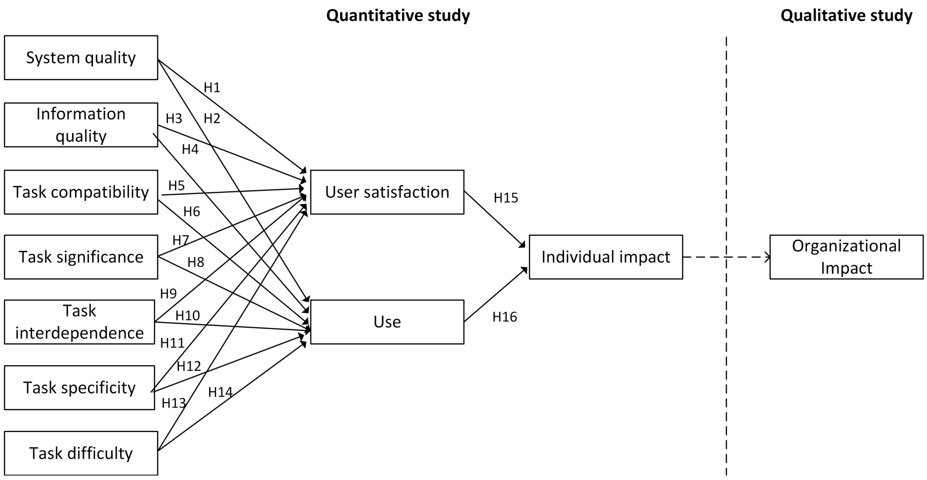

Fig. 1. Modified DeLone and Mclean IS success model [10] with task characteristics
* The figure indicates where the quantitative and a qualitative studies were performed.

The two papers on the IS success model do not offer guidance on how to measure each construct. Instead, for each dimension, they highlight the distinct types of subdimensions found in the research [10, 28]. The questions in the survey were based on the original work of DeLone and Mclean, and on studies that use some of the dimensions included in the model. The appendix contains an overview of all the questions as well as information on their origins, while each construct is explained in the next section.

Petter et al.'s [12] task characteristics include task compatibility, task interdependence, task significance, task difficulty, and task specificity. The fit between the BI user's task and BI is referred to as task compatibility [14]. Task interdependence reflects whether the completion of a BI-related task depends on others , while the importance of the task is characterized as task significance [14]. The extent to which a user believes a task has been resolved by BI is task difficulty [14]. Finally, task specificity is the level of clarity of the task supported by BI [14].

Ease of use, data quality, and maintenance of the BI system are referred to as system quality [25], while the quality of the output from BI is known as information quality [25]. As use is related to the system's yield, it is measured in terms of time needed for use [25]. The use of information systems for certain tasks is often mandated. Therefore, user satisfaction is measured in relation to the particular system [29]. In this study, the user's overall satisfaction with BI is measured. The two impact measures—individual impact and organizational impact—are based on DeLone and McLean's definitions. Individual impact is defined 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" [10]. Organizational impact is understood as the effect of the individual impact on the organization [10].

Our hypotheses are shown in Figure 1. We expect all relationships to be positive. The dotted line between individual impact and organizational impact indicates the split between the qualitative and quantitative studies. We investigated the organizational impact using a qualitative method, as studies have shown that there is no statistical correlation between individual impact and organizational impact [24].

3 Research design and method

The research design consisted of a questionnaire followed by semi-structured interviews. To research the factors critical for BI success, we used a questionnaire [30, 31]. Our sample covered a wide range of health care professionals (e.g., nurses and doctors), economists, and administrative staff at 12 public hospitals in Denmark. These professionals used BI for reporting and various kinds of analyses. The users filtered the data, and the information was visualized with charts or tables. If the data were at an aggregated level, the users could "drill down" into the information.

Our data-collection process followed the guidelines introduced by Dillmann [32]. First, potential respondents received emails from their organizations' management encouraging them to participate in the study. Then the potential respondents received a personalized invitation with a personal link to the survey. In total, 4,232 invitations were distributed by email. The respondents received an adapted questionnaire depending on whether they BI users and the extent of their usage. A reminder was sent after two weeks. The overall response rate was 32%, with 1,351 BI users completing the questionnaire. 605 were not users of BI and were therefore not included in the analysis. Hence, 746 respondents were used for the statistical analysis. We conducted a test of non-response bias by dividing the answers into early responders and late responders, as late responders are likely to resemble non-responders [33].

The research model was tested using partial least squares (PLS), which is a structural equation modeling technique. The purpose was to model the structural and measurement paths [34]. The hypotheses were tested using Smart-PLS 3.2.7. Before testing the relationships in the model, the validity of the measurement model must be evaluated [35]. The Cronbach's alpha and composite reliability must be above 0.7 [36]. Moreover, the variance of a construct must be greater than the error, which is measured in terms of the average variance extracted (AVE; AVE must be greater than 0.5 [35]). To examine discriminant validity, we calculated the heterotrait-monotrait ratio (HTMT). The ratio did not include the number 1 [34]. Therefore, the discriminant validity is high. All outer loadings on the constructs were significant ($p < 0.001$). The results of the calculations are presented in Table 1.

Table 1. Structural model of outer loadings, internal consistency, convergent, and discriminant validity of items

Construct	Item	Outer	Cronbach's	Composite	AVE

		loading	Alpha	reliability	
Information quality	InfQua01	0.716			
	InfQua02	0.883	0.774	0.851	0.657
	InfQua03	0.827			
System quality	SysQua01	0.901			
	SysQua02	0.933	0.826	0.898	0.748
	SysQua03	0.745			
User Satisfaction	UseSat01	0.853			
	UseSat02	0.907	0.882	0.927	0.809
	UseSat03	0.809			
Individual Impact	IndImp01	0.911			
	IndImp02	0.877	0.844	0.906	0.762
	IndImp03	0.825			
Task compatibility	TaskCom01	0.843			
	TaskCom02	0.817	0.817	0.875	0.638
	TaskCom03	0.699			
	TaskCom04	0.828			
Task significance	TaskSig01	0.826			
	TaskSig02	0.770			
	TaskSig03	0.767	0.776	0.844	0.529
	TaskSig04	0.772			
	TaskSig05	0.431			

The second part of the research design involved a qualitative study aimed at obtaining more contextual information in order to understand the organizational impact of BI systems. This study involved interviewing BI users. To ensure the inclusion of a wide range of BI users, we took one BI user from each segment, which we identified using PLS-FIMIX [37] and a Kruskal-Wallis test in combination with a Bonferroni post hoc test [38]. The interviews served as an excellent supplement to questionnaires for three reasons. First, interview data is better able to establish the context of the BI system’s use and impact. Second, such data enables us to check whether the users agree or disagree with the findings from the survey. Third, qualitative data can help explain complex survey results [39]. A profound form of triangulation is to mix survey data with interview data. Quantitative data provide a broader view, while qualitative data provide greater depth. The two methods, when used together, should allow for more accurate inferences [40].

Three face-to-face, semi-structured interviews were conducted in public hospitals. All interviews lasted between 45 minutes and 1 hour. Afterwards, the interviews were transcribed and analyzed in Nvivo [41]. Deductive coding was applied to the interview transcripts in order to find examples of organizational impact.

In the next two sections, the findings of the quantitative study and the qualitative study are presented. In the final section, the findings of the quantitative and qualitative studies are integrated.

4 Quantitative research findings

Table 2 presents the results obtained from the PLS analysis. The table includes the hypotheses, coefficients, p-values, and results.

Table 2. Results from the tests of the hypotheses. The cut-off for results is $p < 0.05$.

Hypothesis		Coeff.	P-value	Results
H1	System quality -> User satisfaction	0.492	0.000	Significant
H2	System quality -> Use	0.165	0.000	Significant
H3	Information quality -> User satisfaction	0.074	0.031	Significant
H4	Information quality -> Use	-0.066	0.140	Insignificant
H5	Task compatibility -> User satisfaction	0.238	0.000	Significant
H6	Task compatibility -> Use	0.017	0.723	Insignificant
H7	Task significance -> User satisfaction	0.060	0.034	Significant
H8	Task significance -> Use	0.278	0.000	Significant
H9	Task interdependence -> User satisfaction	-0.039	0.195	Insignificant
H10	Task interdependence -> Use	0.063	0.084	Insignificant
H11	Task specificity -> User satisfaction	0.006	0.823	Insignificant
H12	Task specificity -> Use	0.026	0.455	Insignificant
H13	Task difficulty -> User satisfaction	0.135	0.000	Significant
H14	Task difficulty -> Use	0.020	0.629	Insignificant
H15	User satisfaction -> Individual impact	0.746	0.000	Significant
H16	Use -> Individual impact	0.014	0.525	Insignificant

The results indicate that system quality, information quality, task compatibility, and task difficulty are positively and significantly related to user satisfaction ($p < 0.001$). Furthermore, there is a positive and significant relationship between task significance and user satisfaction ($p < 0.05$). These findings suggest, for example, that users who feel that BI supports the tasks that they perform are likely to be more satisfied. Similarly, users who perform difficult and/or important tasks are likely to exhibit greater satisfaction. System quality and task significance are both positively and significantly related to use ($p < 0.001$). Therefore, users who view their tasks as significant or who view the system quality as high are more likely to use the system. Finally, we find a positive and significant relationship between user satisfaction and individual impact ($p < 0.001$). In other words, the more satisfied a user is with BI, the higher the individual impact. However, we find no relation between use and individual impact. In other words, if usage increases, the individual impact remains unchanged.

The R^2 is 0.56 for individual impact, 0.59 for user satisfaction, and 0.143 for use. The model SRMR is 0.06, which is below the threshold of 0.08 [34] and indicates a good fit.

When surveys are used, complex social and technical phenomena are reduced to numbers. Consequently, surveys cannot offer in-depth insights into the context of organizational impacts on different stakeholders. Therefore, we conducted a number of interviews. The results of the interviews are presented in the section below.

5 Qualitative research findings

The addition of qualitative data to the survey results provides a more complete understanding of the organizational impact of BI success. The interviews also allow for the detection of stakeholder groups that influence the organizational impact. We interviewed three different users of BI. All three users stated that they delivered BI-based reports to either doctors or their immediate managers. In this regard, BI users can be divided into two types: those who directly use the BI system to solve daily tasks and those who do not necessarily have access to the system but use information from the system to solve tasks (e.g., follow up on KPIs, reports for decision support). The respondents used two types of reporting: standard reporting with specific frequencies, such as daily, monthly, or quarterly; and ad-hoc reporting.

We also identified three types of BI usage that had different impacts. The first type was traditional KPI-related reporting (e.g., bed-occupancy rates, days of hospitalization, sickness-related employee absenteeism, provision of medicine to the patients). The organizational impact of this type of use related to hospital efficiency. For example, one respondent stated that BI could be used to identify the number and types of needles used, thereby allowing for savings on purchases. Another example given was that the schedule could be optimized because information on bed-occupancy rates and hospitalization times was available.

Another type of BI use related to increasing the quality of cancer patients' care. The amount of time that passes from diagnosis to treatment may be crucial for the prospects of some cancer patients. As public hospitals in Denmark had combined data, the responsible nurses could identify patients for whom there was no flow in the course of treatment. More specifically, they could identify errors in treatment or errors in the data found in the health care information systems that resulted in the patient not receiving treatment. In this way, problems in the course of treatment could be identified before they became critical for the patient, and the quality and flow of the patient’s course of treatment were enhanced.

The last type of BI use in the health care sector related to learning. One respondent stated that the BI data were used to reduce the number of hospitalization days for patients receiving antibiotics. The data could be used to identify relevant patient pathways. Consequently, patients could quickly progress from intravenous antibiotic treatment to oral treatment, thereby saving hospitalization days. Quality was affected by the fact that those using BI could identify whether the patients were hospitalized again after short time. In addition to reducing costs, patient safety was improved, as there is always a risk of infection when patients are hospitalized. Another example related to the inappropriate patient pathways that could be identified through BI. Such pathways were discussed in meetings and continually reviewed, and new guidelines were introduced to prevent future mistakes. As one respondent stated, the organizational impact of BI is "more effective and safer treatment of the patients."

6 Discussion, implications, and conclusions

The first question focused on which critical success factors contribute to the individual impact of BI use in public organizations. We found little discussion in the literature regarding the relationship between task characteristics and BI success. The second question addressed the impact of BI at the organizational level in public organizations. Our extensive survey provided us with information on the relations among different constructs [42–44]. Our contribution goes beyond our earlier publications on this topic in that this paper expands DeLone and McLean's IS success model to encompass constructs related to task characteristics.

More specifically, we extended the modified IS success model [10] to include five task characteristics: task compatibility, task significance, task interdependence, task specificity, and task difficulty. One of our previous articles [42] assessed the modified IS success model and showed that the adjusted R^2 for user satisfaction increased from 0.56 to 0.59. Furthermore, the adjusted R^2 for the use construct increased from 0.02 to 0.143. The R^2 for individual impact was similar. The addition of task characteristics improves the model's ability to explain user satisfaction and use relative to the modified IS success model in which organizational impact is omitted. The significant and positive relationships in the model indicate that there are no changes. Therefore, the enhanced explanatory power of the model can be ascribed to the expansion of the model to include task characteristics. System quality, information quality, task compatibility, task significance, and task difficulty are positively related to user satisfaction, while task significance and system quality are positively related to use. Two studies that measure the relationship at the individual level are Iivari [45] and McGill et al. [24], but the hypothesized relationship was found to be insignificant in both studies. Several studies find no significant relationship between use and individual impact [24, 45].

In terms of organizational impact, one significant finding is the presence of two types of users of BI: system users and information users. This was uncovered in the interviews when the interviewees were asked to describe the organizational impact. When BI was used to follow up on KPIs, system users acted as suppliers of information while others made decisions based on that information. Therefore, a BI user may have a perception of a low individual impact, but the organizational impact of the work can be high. We also found that BI can have organizational impacts in public health organizations related to KPI reporting, quality improvement, and learning. Therefore, measurements of organizational impact should include more than performance.

This study has several theoretical implications. First, the IS success model's explanatory ability is higher when using mandated systems and including task characteristics. In particular, use can be better explained. Second, the organizational impact must be measured using more than just performance measures—quality and learning in the organization should be considered as well. Third, there is a difference between system users and information users. In terms of the methodological implications of this study, Petter, DeLone, and McLean [14] argued that few studies included task characteristics. In this study, these characteristics were operationalized so that they could be examined across different tasks. The practical implications of this study are that certain task characteristics increase either user satisfaction or BI use, which should be considered when implementing BI in an organization. Moreover, in relation to user involvement in the BI system, it is essential to distinguish between system and information users.

One limitation of this study is that the number of interviews was relatively low,but covers the three calculated usertypes identified with latent class analysis. Finally, there is abundant room for further progress in determining the relationship between task characteristics and IS success given various IS systems and settings. For example, an examination of the role of mandated versus voluntary use in relation to tasks would be beneficial. Future research could also address how organizational impact can be measured in ways that do not involve performance in order to develop a deeper understanding of BI's impact on organizations. In conclusion, the relationships between individual and organizational performance and between system and information users should be explored.

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Appendix: Questionnaire

Construct	Item	Question	Reference
Use	Use01	What is the approximate share of the total work you have used BI to solve in the past month?	[10]
User satisfaction	UseSat01	BI has all the functions and capabilities I expect it to have.	[46]
	UseSat02	If a colleague asked, then I would recommend BI.	[47]
	UseSat03	Overall, how satisfied are you with BI?	[46]
System quality	SysQua01	BI is easy to learn.	[48]
	SysQua02	BI is easy to use.	[46]
	SysQua03	The information in BI is easy to understand.	[49]
Information quality	InfQua01	Data are displayed in a consistent format in BI.	[49]
	InfQua02	The data in BI have high validity.	[49]
	InfQua03	Other employees in the region also think the data in BI have a high validity.	[49]
Individual impact	IndImp01	I can effectively make my reports using BI.	[48]
	IndImp02	I can complete my reports quickly using BI.	[48]
	IndImp03	I can complete my reports using BI.	[48]
Task compatibility	TaskCom01	This information is useful for my tasks.	[49]
	TaskCom02	This information is complete for my needs.	[49]
	TaskCom03	This information is relevant to my tasks.	[49]
	TaskCom04	This information is sufficiently up to date for my tasks.	[49]
Task difficulty	TaskDif01	BI makes it possible to complete complicated tasks.	[50]
	TaskDif02	The tasks I complete in BI require specialized knowledge.	[50]
	TaskDif03	The tasks I solve in BI, have I never met before	[50]
Task Interdependence	TaskInt01	If I do not complete my tasks in BI, one or more employees in the organization cannot complete their tasks.	[50]
	TaskInt02	In BI, I can only do tasks if	[50]

		one or more employees have completed another task first.	
	TaskInt03	I am independent of other employees to prepare tasks in BI.	[50]
Task significance	TaskSig01	The tasks I complete in BI are an important part of my tasks.	[50]
	TaskSig02	I make decisions on the basis of the tasks I complete in BI.	[50]
	TaskSig03	My tasks completed in BI are important to other employees in the organization.	[50]
	TaskSig04	Other people make decisions based on the tasks I completed in BI.	[50]
	TaskSig05	My tasks in BI are important for collaborators outside the organization.	[50]
Task specificity	TaskSpe01	My tasks are always defined before I complete them in BI.	[50]
	TaskSpe02	The tasks I complete in BI can be done in more than one way.	[51]
	TaskSpe03	Normally, I do not complete the same kinds of tasks in BI.	[50]