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Digital Transformation of the Healthcare Supply Chain: A Clinical Safety Evaluation Model

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Abstract

The Healthcare Supply Chain (HSC) plays a key role in the safety and quality of healthcare services. A growing awareness of the complexities of the HSC has highlighted the potential usefulness of digital systems to deliver efficiencies which may lead to improved clinical safety. The business benefits of digital transformation of the HSC have been identified however there has been no clear methodology proposed to the author's knowledge to measure the clinical safety benefits. This study will examine the performance of a Clinical Safety Evaluation Model (CSEM) created to provide healthcare organisations a measure of clinical safety through digital transformation of their supply chain. The CSEM uses an adaptation of the DeLone and McLean Information Success Model blended with proven clinical safety criterion within the healthcare supply chain sphere. The study will provide measures on both the effectiveness of the model and the potential for use of the CSEM in industry application to improve clinical safety.

Keywords Clinical Safety, Evaluation Model, Digital Supply Chains, Digital Transformation

Introduction

The SARS Cov2 (COVID 19) pandemic has exposed many shortcomings that exist within healthcare supply chains (HSC) such as failures in supply of Personal, Protective Equipment (PPE), vaccines and Rapid Antigen test kits. However, fundamental issues within the HSC pre-existed the COVID 19 outbreak. The literature revealed a number of complexities which are unique, in their entirety, to the HSC including the large number of stakeholders, minimal use of information systems and complex product requirements (Duque et al. 2019; Kritchanchai et al. 2019; Rakovska and Stratieva 2018). Some aspects of the HSC have been improved through the utilisation of digital solutions however, these have not been adopted in a universal manner in the Healthcare sector (Abdulsalam et al. 2015). The business costs of supply chain failure have been the focus of significant research both in general and more specifically to healthcare (Rakovska and Stratieva 2018). However, the impact of the HSC on clinical safety has not been addressed in empirical research to date in any meaningful way and hence there is an important gap in the knowledge that is worthy of in-depth investigation (Smith et al. 2017). Some researchers have identified key considerations though many papers still recommend further study is required (Buyurgan and Farrokhvar 2015; Farrokhvar 2013; Senna et al. 2019; Supeekit et al. 2015).

Research Aims

The aim of this research is to examine the success of digital transformation of the healthcare supply chain including impact on clinical safety through SME healthcare providers use of a digital platform supporting electronic procurement. Through the development and implementation of a novel clinical safety measurement methodology, the authors seek to create an industry useful artefact as well as the findings to determine the successful use of the model. The research will provide a foundational element for clinical safety measurement in the healthcare supply chain and a basis for further research.

The measurement of clinical safety is possible if viewed from the position of "an absence or minimisation of risk" in some instances (Farrokhvar 2013). There are also a number of models which enable the measurement of the impact of Information Systems (IS) such as the DeLone & McLean Information System Success Model (DeLone and McLean 2014). This study adapted the DeLone & McLean model with key HSC related concepts within the Australian Commission for Safety and Quality in Health Care hospital standards. These are extracted from Standard 1: Clinical Governance in the National Safety and Quality Health Service Standards (Edition 2) (Australian Commission on Safety and Quality in Health Care 2017). These standards govern clinical practice in Australia and provide a structured and proven application to clinical safety. Combined with the highly regarded DeLone & McLean Information Systems Success (ISS) model and utilising the design proposed by Zaied (2012) a Clinical Safety Evaluation Model (CSEM) was developed as a research artifact in this study.

This research aims to measure the impact of digital transformation on the healthcare supply chain. This will be achieved through the implementation and evaluation of the CSEM as a potential industry application. The study will focus on small to medium healthcare providers such as General Practices (GPs), however, the key findings of this study will have greater applicability more broadly within the Healthcare industry. The research entails an intervention consisting of the implementation and use of a digital platform providing basic digital procurement and inventory capability. The research questions to be addressed are: *RQ1 How can digital transformation of a Healthcare Supply Chain to improve Clinical Safety be conceptualised?* and

RQ2 How can digital transformation of a Healthcare Supply Chain to improve Clinical Safety be evaluated?

Methodology

Design Science Research (DSR) was adopted as the research methodology since DSR enables key concepts in several different realms to be analysed in comparison. The methodology provides not only a contribution to the knowledge base but also a potentially useful mechanism for applying the knowledge generated in academic research in a practical setting (Hevner 2004). DSR provides a process to address both design research and behavioural research (Hevner and Chatterjee 2010). Figure 1 outlines the modified DSR Model for this study (Hevner et al. 2004).

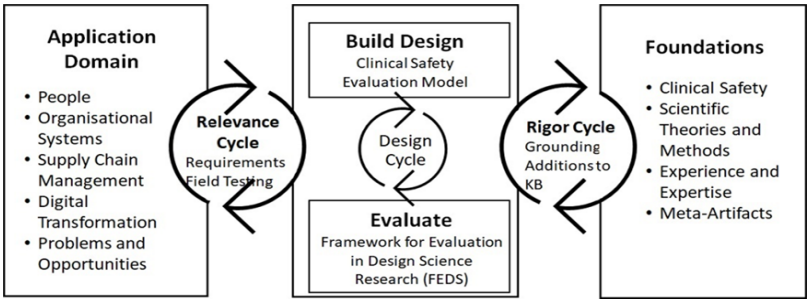

Figure 1: Design Science Research Model (adapted) (Hevner 2004)

The literature provides growing evidence of the successful use of DSR within a critical realism paradigm. Hodgkinson and Starkey (2012) advocate for this approach as a method of enhancing outcomes. Carlsson (2010) and Uppström (2017) identify the complementary nature of the paradigm and methodology, particularly when studying information systems. Uppström (2017) goes further to suggest that critical realism widens the usefulness of DSR and provides a relevant methodology to meet the aims of this study.

A DSR approach requires the development and implementation of an artifact (Hevner et al., 2004). In this study the proposed artifact is the CSEM. The artifact is designed to evaluate how clinical safety can be

measured and whether clinical safety is improved in a healthcare supply chain that has been digitally transformed. This approach will be consistently applied across all selected case study organisations. If an SME Healthcare provider is already using a digital platform that supports electronic procurement, then they will be excluded from the study. In this research project, the initial version of the CSEM has been designed and will be further developed and implemented to measure the impact of digital transformation of the healthcare supply chain on clinical safety. The CSEM will be measured across six (6) conceptual Categories with twenty-six (26) Elements and fifty-two (52) Statements.

The theoretical model used in this research is based on the DeLone and McLean Information System Success Model (modified) (DeLone and McLean 2014). The nature of the research is based on an information system approach to solving a social problem. The proven use of the DeLone and McLean Model shows usefulness in both general supply chain and healthcare. The ability to both extract as well as add to the model aims to provide a focus on clinical safety. The existing six conceptual categories of the DeLone and McLean Model are retained. The key categories of Information Quality, System Quality, Services Quality, System Use and User Satisfaction have been curated to focus on HSC and safety and quality elements. Intention to Use has been omitted due to the nature of the system. The Net Benefits concept has been adapted to reflect four key HSC and clinical safety related standards extracted from the National Safety and Quality Health Service Standards (2nd Edition) (Australian Commission on Safety and Quality in Health Care 2017). The Elements break the categories into subsections and there are two Statements reflecting each Element. The Elements and Statements utilise the structures proposed by Zaied (2012) however we have omitted elements which are not suitable for inclusion in this study such as the focus on administration and public service.

The digital platform to be used in this research project is a universal electronic trading system (UETS) that supports healthcare providers with a tool to engage in the electronic procurement process with their suppliers. The UETS has been designed to meet key healthcare supply chain standards in Australia following the reforms implemented through the National eHealth Transition Authority (Brommeyer 2014). These reforms included the introduction of unique product and location identifiers, a standardised National Product Catalogue and e-Procurement messaging standards. The UETS provides a crucial piece of infrastructure for small to medium-sized organisations in the HSC such as GPs in a minimalist and cost-effective manner. The UETS has been previously developed by one of the authors and a third-party software developer in a professional capacity with full rights for use, modification and support for research purposes.

This study will collect data on (1) clinical safety and HSC data from application of the CSEM to evaluate the UETS implemented in five to ten participating organisation and from (2) subsequent semi structured interviews with the end-user of the UETS, the key procurement manager in each participant practice (Table 1). The study will examine the status of each participant organisation before the implementation of the UETS to establish a baseline prior to digital transformation of each organisation's HSC. The same evaluations will be conducted 3 months post-implementation of the UETS.

Data Point	Action	Aim	Data type	Timeframe
Data Point 1	CSEM	Baseline model data; Use and design feedback	Quan	Month 0
Data Point 2	Semi structured Interviews	Baseline study data; Category and Element verification	Qual	Month 0
Intervention	Digital Platform implementation (UETS)			Month 0-3
Data Point 3	CSEM	Post intervention data	Quan	Month 4
Data Point 4	Semi Structured Interviews	Post intervention data	Qual	Month 4

Table 1: Data Points for Research Proposal

The interview transcripts for each procurement manager will be analysed for key themes and terms of significance using NVivo. The thematic coding and analysis of the interviews will be guided in part by organisational and substantive categories of the IS Success Model adapted to the HSC (Bickman et al. 2009). Concurrently, an examination will be conducted on the CSEM itself to assess design and performance utilising the Framework for Evaluation in Design Science Research (FEDS) (Venable et al. 2016). This work will inform the iterative nature of DSR to create a refined and robust version of the Clinical Safety Evaluation Model (Table 2).

While the CSEM is being utilised to measure digital transformation within the HSC, the nature of the model provides for "system" measurement which enables evaluation of procurement systems which may be manual, digital or a combination of both. This feature provides greater utility across industry at the same time as providing a manner in which to measure progress as digital transformation is planned and implemented. The UETS in this study provides a relatively simple manner to access many of the benefits of electronic procurement. This function could be filled by appropriate functionality within some Enterprise Resource Platforms (such as the procurement module within Oracle or SAP) or by proprietary procurement software. The cost and complexity of these solutions are not currently within the capability of most small to medium sized healthcare organisations, hence the use of the UETS as a basic model to address their electronic procurement requirements.

Data Point	Analysis	Expected Outcome	Expected Use
Data Point 1	FEDS	Design Iteration	Industry Application
Data Point 3			
Data Point 2	NVivo	Study Findings, Discussion, Recommendations	Publication
Data Point 4			

Table 2: Use of Data Points

The Semi-structured interviews are based on a series of ten main questions. Five questions are based on the first five concepts of the DeLone and McLean Model (namely; Information Quality, System Quality, Services Quality, Usage Intention/ System Use and User Satisfaction) (DeLone & McLean, 2014) and four questions are based on Net Benefit. These four questions are derived from the extracted National Safety and Quality Health Service Standards data (Australian Commission on Safety and Quality in Health Care 2017); Clinical Incident, Environment, Identifiers and Systems. The tenth question offers the opportunity for any additional feedback or observations. The questions align with the categories within the CSEM to provide both consistency and categorisation.

The study relies on a purposeful sampling approach to ensure the participants have the appropriate user expertise, that is, holding a leading role in procurement within the organisation. The research will examine the organisational and substantive categories of the CSEM applied in healthcare supply chain and identify connecting strategies (Bickman et al. 2009). Potential bias and reactivity will be addressed using validity testing through the interview protocol refinement (IPR) framework developed by Castillo-Montoya (2016). The study aims to pilot the CSEM and Semi-structured Interviews in one site to enable refinement of the interview protocol and specific questions to evaluate the CSEM underpinned by DeLone & McLean's IS Success Model (2014). The pilot will inform the study of optimal and maximum participant samples.

The suitability of this research methodology in answering the study research questions: RQ1 and RQ2 is twofold; (1) producing an evaluation model to adapt, build on, or utilise for improved clinical safety; and (2) capturing the empirical evidence to measure both the effectiveness of the artifact and its design (Beinke et al. 2019). The intent is also to provide a rigorous and documented way of implementing the artifact in the context of digital transformation of the HSC to measure the benefit of improved clinical safety.

Research often leads to improvements in human endeavour, and healthcare research has the potential to improve many lives. The ability to identify a problem, design a solution, and evaluate that solution are the key meta steps of the DSR methodology (Peffers et al. 2007). As suggested by Holmström et al. (2009), the significant challenge of applying academic research into practice can be addressed by using a DSR approach. Holmström et al. (2009) go further to state that DSR provides evidence that problem-solving research and theory-oriented academic research can complement each other.

Proposed Contribution to the Field of Research

Following the DSR iterative design process (Baskerville et al. 2018), the findings are expected to drive further revisions that will improve the robustness of the CSEM for greater use across a broad selection of healthcare providers. The use of the CSEM artifact is expected to provide a mechanism to enable healthcare providers to baseline current supply chain processes, identify deficiencies and determine improvements that can be achieved through digital transformation of the HSC that in turn improves clinical safety.

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