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Digital Transformation of Health Services Value Streams

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Abstract

This research proposes the use of value stream mapping to guide the choice of Healthcare 4.0 (H4.0) digital applications that are more prone to support the enhancement of value flows in health services. A three-step approach is developed, beginning with mapping the current and future state of the value streams, identifying improvement kaizen bursts, and finally evaluating H4.0 digital applications that best underpin improvements and comply with attributes that characterize well-succeeded technological innovations. This method is illustrated through a case study in the sterilization unit of a large university hospital. With the advent of Industry 4.0, the accelerated pace at which digital transformation has been conducted challenges healthcare organisations to prioritise the digital applications with the largest positive impact in their operations assertively. Our propositions provide means to integrate H4.0 into healthcare towards more effective health services values streams.

Keywords Digital transformation, Healthcare, Value stream map, Industry 4.0, Healthcare 4.0.

1 Introduction

Catalysed by the Fourth Industrial Revolution's advent, the digital transformation of organizations has been recognized as a growing trend in the search for higher competitiveness. Supported by the integration of disruptive information and communication technologies (ICTs), the digitalization of processes, products, and services is expected to lead organizations to superior performance levels (Frank et al., 2019). Such positive impact is envisioned at a macro level, such as the supply chain, and at a local level, in the organization or its workstations, including several industries, e.g., manufacturing, construction, and healthcare.

In the healthcare industry, digitalization efforts are long-dated. In the 1960s, healthcare professionals started to use computers to standardize and share medical data (VertitechIT, 2019). In the late 1970s, desktop personal computers ushered the modern age of ICTs, offering new solutions to the healthcare sector (Dehe and Bamford, 2017). In the 1990s, the importance of ICTs was significantly enhanced by the introduction of the Internet (Aceto et al., 2020). Nowadays, healthcare organizations are entering the Fourth Industrial Revolution era, whose technological advances allow higher interconnectivity that benefits therapeutic strategies and supporting processes (Tortorella et al., 2020a), giving rise to the term Healthcare 4.0 (H4.0) (Thuemmler and Bai, 2017).

Despite the digital frenzy, researchers such as Tortorella and Fettermann (2018) and Chiarini and Kumar (2020) pointed out that integrating new ICTs into ill-structured processes is unlikely to result in significant improvements, potentially frustrating managers. The integration of new ICTs should be viewed as a process improvement opportunity, with benefits recognized by those involved. Process improvement approaches such as Lean Healthcare (LH) provide the analytical tools to investigate processes in the light of potential digitization (Ker et al., 2014). LH is a systematic approach for continuously improving healthcare organizations through employees' active involvement (Costa and Godinho Filho, 2016). Derived from Lean Manufacturing, LH adapts the principles and practices originally conceived in the manufacturing context to healthcare, enabling waste elimination and enhancing value flow (Tlapa et al., 2020). A successful LH implementation improves processes and services and fosters the proper mindset and behaviours in healthcare organizations (Tortorella et al., 2019), establishing a favourable environment for their digital transformation. Nevertheless, there is a lack of propositions in the literature regarding the systemic integration of H4.0 digital applications into LH towards flow improvements.

This study aims at examining the integration of H4.0 digital applications into healthcare value streams to promote continuous improvement grounded on digitization. For that, we proposed a method that uses value stream mapping (VSM) as the primary input. VSM is one of the most widely used lean practices, and its applicability in the analysis of healthcare value streams is recognized in the literature. The proposed method will be illustrated through a case study in the materials' sterilization unit (SU) of a Brazilian public hospital.

2 Background

2.1 Lean healthcare

Health services face continuous pressure to increase efficiency and reduce waste (Leite et al., 2020). Operational efficiency in health services means rapid access to care, minimum waiting time, and delivering defect free quality care at the minimum cost (Yaduvanshi and Sharma, 2017). To increase efficiency, hospitals have implemented LH, focusing on waste elimination and increasing the value to patients (Crema and Verbano, 2015). In this sense, LH is a management approach that can change the way health services are organized and structured (Fogliatto et al., 2019). Although the integration of lean principles and practices into health services initiated in the early 2000s (Costa and Godinho Filho, 2016), about 70% of hospitals in USA have been implementing LH (Shortell et al., 2018). Further, successful initiatives of LH implementation have been reported in different hospital departments and services, such as emergency department, materials' SU, cardiac catheterization, gynecologic oncology clinics, pharmacy, laboratories, among others.

Despite the variety of LH practices, most studies applying LH used VSM as a means to represent both the current and future states of patient flow, identifying systemic improvement opportunities that can truly impact the health service (Zepeda-Lugo et al., 2020). This indicates the relevance and usefulness of VSM to systematically implement LH across health services (Henrique and Godinho Filho, 2020). Additionally, the National Health Service in the UK highlighted that VSM is a key practice to enhance the patient journey and, hence, it must be extensively applied as part of the continuous improvement initiatives of a hospital (Westwood et al., 2007).

2.2 Digital transformation of healthcare

The denomination for the digitalization of healthcare varies from e-Health (Scarpato et al., 2017), Health 4.0 (Thuemmler and Bai, 2017), Healthcare 4.0 (Tortorella et al., 2020b), Care 4.0 (Chute and French, 2019), Smart Health (Demirkan, 2013), among others. Despite the differences in terminology, Aceto et al. (2020) mentioned that H4.0 is characterized by the combined adoption of three main ICTs: IoT, big data, and cloud computing. Those ICTs provide the basis to different digital applications that can be used in both healthcare treatments and supporting processes (Javaid and Haleem, 2019).

Because the adoption of disruptive ICTs usually requires high levels of capital expenditure and skilled labor, the digitalization level of health services may vary according to the contextual characteristics of the hospital (Tortorella et al., 2020c). Moreover, as suggested by Pan et al. (2019), the extensive digitalization of health services impact the work routine of caregivers. Hence, if not properly managed, such digitalization can generate resistance among employees, impairing the achievement of the envisioned benefits. Hospitals' abilities to cope with major disruptions is also likely to be affected by the adoption of H4.0 digital applications. In fact, Tortorella et al. (2021a) indicated that technologies can reduce over-reliance on human adaptive skills while at the same time offering new and expanded opportunities for resilient performance in healthcare.

Depending on the focus of these digital applications across the healthcare value chain, they can be classified in four categories: (*i*) patient diagnosis, (*ii*) patient treatment, (*iii*) patient follow-up, and (*iv*) healthcare supply chain (Tortorella et al., 2021b). Specifically in terms of healthcare supply chain, these applications help to enhancing healthcare supply chain management considering both internal and external value streams (Demirkan, 2013). Based on the findings from Wang et al. (2019), for instance, the adoption of these applications is likely to enhance the material and information flows in the healthcare supply chain, which may lead to more flexible processes and shorter lead times. Nevertheless, the combination between those digital applications and LH practices is still poorly explored in the literature.

3 Proposed method

The proposed method consists of three steps. In the first step, the current state of the healthcare value stream is mapped. The current state map enables the identification of the modus operandi of the value stream, supporting the identification of wastes and improvement needs of the future state (Tortorella et al., 2017). For that, products and services included in the healthcare value stream under analysis are analysed in order to group them according to their process similarities and determine families, simplifying the subsequent mapping activities (Duggan, 2012). Preliminary data on the value stream is initially gathered, such as historical demand, quality and productivity indicators. To complete the drawing of the current state map, six 4-hour meetings are carried out, in addition to several *gemba* walks in the department's shop floor to visualize the processes in loco.

The second step encompasses the design of the future state map of the value stream. The future state map enables the clear definition of improvement opportunities that lead to waste elimination, iterative improvement, and sustained benefits (Womack and Jones, 1996). Through a team-based, systemic approach, problems are more easily identified, and waste eliminated (Larson, 2013). Following Rother and Shook (2003), four design principles are applied to design the future state map; they are: (*i*) increase system's flexibility to allow rapid adaptation to changes in demand; (*ii*) eliminate waste; (*iii*) minimize inventories producing only when required; and (*iv*) increase efficiency of materials and information flows. To ensure the practical feasibility of improvement actions, also denoted as kaizen bursts (KBs), we determine a one-year implementation horizon. Those KBs are then assessed to check their criticality for the value stream improvement. Due to the large amount of identified KBs and to avoid integrating highly costly digital technologies into opportunities that are not as relevant, a prioritization is performed. The top five KBs that most impacted waste reduction on the lead time of the value stream under analysis (Duggan, 2012) are prioritized.

In the third step, following Aqlan et al. (2017), we apply the multi-criteria method Multi Attribute Utility Theory (MAUT), which measures the attractiveness of alternatives (i.e., kaizen bursts) with respect to multiple attributes (see Table 1). Seven H4.0 digital applications derived from Tortorella et al. (2021b) are scored regarding (*i*) their potential impacts on KBs, and (*ii*) their compliance with the five attributes that characterize successful technological innovations, following the Diffusion of Innovation Theory (DIT) by Rogers (1995).

	Kaizen bursts			Attributes of DIT					
H4.0 digital applications	kb_1	…	kb_5	Relative advantage	Compatibility	Complexity	Trialability	Observability	Final score
	w_1	…	w_5	x_1	x_2	x_3	x_4	x_5	
Automated monitoring of vendor managed inventory									
Remote and real-time inventory control									
Radio frequency identification device (RFID) for materials' and products' traceability									
Upstream/downstream integration through a common Enterprise Resource Planning (ERP)		a_{im}				b_{in}			f_i
Automated scheduling and control of materials									
Real-time demand forecast based on cloud									
Interconnected internal material distribution									

Table 1. MAUT for H4.0 digital applications prioritization

Leaders of the value stream under analysis are interviewed to assign weights w_m (m=1,…,5) and x_n (n=1,…,5), ranging from 0 – 'no important' to 10 – 'highly important') to KBs and DIT's attributes, respectively. Then, those leaders are asked to indicate values to each pairwise relationship between H4.0 digital applications and KBs and DIT's attributes (a_{im} and b_{in}, respectively) varying from 1 (weak) to 3 (strong). The final criticality score f_i for each H4.0 digital application is given by the expression:

$$f_i = \frac{\sum_{m=1}^{5} a_{im} \times w_m + \sum_{n=1}^{5} b_{in} \times x_n}{\sum_{m=1}^{5} w_m + \sum_{n=1}^{5} x_n},\ i=1,\ldots,7 \quad (1)$$

To determine the most critical H4.0 digital application, f_i values are standardized. H4.0 applications whose standardized values are greater than 1.0 are considered extremely critical (Tortorella and Fogliatto, 2014) and, hence, have their integration into the value stream prioritised.

4 Results

The case study will be carried out in a public teaching hospital located in Brazil. Because this hospital is deemed as a reference in management practices in the Brazilian public healthcare system, its readiness level offers the adequate context for this case study investigation. Although randomly implemented across the hospital, the pervasiveness of lean practices and digital applications is observed in many departments, such as emergency, surgical centre, pharmacy, and materials' SU. Specifically regarding the SU, hospital senior managers have faced recurrent episodes of shortage of surgical instruments in both the surgical centre and clinics, which justifies the selection of this value stream in our study.

Sterile services departments deliver a high variety of outputs based on intensive manual labour (Fogliatto et al., 2018), which is evidenced by the approximately 80 employees distributed in five teams that alternatively work three shifts during the seven days of the week. This value stream supplies material to 36 surgery/procedure rooms in the hospital, sterilizing approximately 23,600 instruments per day, which are grouped in package kits with an average of 50 parts. Currently, only 75% of the order requests are met in right time and quantity. To conduct this case study, in addition to the SU personnel, a cross-functional team will be assembled with members from other departments identified as internal customers and/or suppliers. Finally, we envision the application of the proposed method during the period between July and September 2021, whose results will be compiled and analysed throughout the following months.

5 Conclusion

This study proposes a three-step method that uses VSM as the primary input to prioritize the integration of H4.0 digital applications. The proposed method will be illustrated through a case study in the materials' SU of a Brazilian public hospital. Through this case study, we will verify the proposed method's implications within a real and contemporary context. Even though a single case study may be more subject to bias, this research design was chosen due to its valuable utilization in contexts where authors seek to make a contribution by the illustration of a proposed method, as observed in previous studies with similar approach (e.g., Tortorella et al., 2017). Besides the theoretical contributions, this study provides managers guidelines to catalyse their continuous improvement initiatives, already addressed by LH, through the integration of H4.0 digital applications. The proposition of a method that systemically combines H4.0 and LH to improve the flow of value enables more assertive decisions regarding digital transformation, which could significantly impact the bottom line of healthcare organizations.

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