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Digitalization of the healthcare supply chain:

A roadmap to generate benefits and effectively support healthcare delivery

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Abstract

The healthcare supply chain lags far behind supply chains in other industries in terms of performance and the deployment of best practices. Managers could bridge this gap and improve the performance of the healthcare supply chain by implementing digitalization initiatives. However, the erratic, disconnected digitalization of practices already deployed in the healthcare sector makes it difficult to maximize the potential of these initiatives. In order to generate the greatest benefits from digitalization while improving healthcare delivery, this article sets out a roadmap for implementing technologies. Unlike previous studies that focused on the entire supply chain or had been limited to patient flow, this study adopts the perspective of the hospital as a central launching point for digitalization initiatives. The roadmap, which involves both internal and external digitalization trajectories, is based on a research methodology that combines observations with an umbrella review of literature. This methodology enables us to capture the research challenges associated with the healthcare supply chain and show how digitalization initiatives can address them. The digitalization proposals put forward are structured in terms of priority and centered on hospitals. These proposals can help managers make improvements to the supply chain and also clinical flows.

Keywords: supply chain, digital supply chain, logistics, healthcare delivery, benefits, technology

1. Introduction

The digitalization of the supply chain (SC) is emerging as a key phenomenon in the transformation of organizations (Wang and Wang, 2020) and is increasingly studied within academic circles and different industries (Büyükoçkan and Göçer, 2018; Hennelly et al., 2020; Stank et al., 2019). However, the different facets of SC digitalization and its implications for organizations have not yet been clearly identified (Queiroz et al., 2019). The digitalization of the SC can be defined as the exploitation of the capacities of traditional information systems and the implementation of new advanced technologies (e.g., the Internet of Things (IoT), big data, augmented reality, unmanned aerial vehicles, and blockchain) in order to make the different activities of the SC more flexible and efficient.

In principle, the efficiency and flexibility of SC must be improved in all sectors, including healthcare, which needs to evolve to respond to long-term demographic trends and sporadic phenomena while controlling costs (Hermann et al., 2018). Although flexibility and cost reduction are also required in the healthcare sector (Yoon et al., 2016), experience has shown that this area has had difficulties in integrating cutting-edge practices in supply chain management (Su et al., 2011). In 1999, Rickles affirmed that the healthcare sector's SC was 20 years behind other sectors like food and retailing. Supply chain initiatives in the healthcare sector have often focused on managing supplies and reducing the cost of purchases (Parker and Delay, 2008).

Two decades on, this observation still appears to hold true, since various surveys indicate higher logistics costs for the healthcare sector than for other industries (Ebel et al., 2013; Kwon et al., 2016), which gives healthcare one of the most expensive supply chains (Beaulieu et Roy, 2019). These observations tend to confirm that the healthcare sector's SC continues to lag behind and risks doing the same in terms of digitalization. In fact, hospital top management often shows only a marginal strategic interest in SC management, demonstrated by a lack of support for hospital supply managers that limits the human and technological investments necessary for fostering SC practices (Elmuti et al., 2013; Landry et al., 2016; Yoon et al., 2016). This delay more generally encompasses the deployment of digitalization technologies through the entire sector (Gandhi et al., 2016).

The impact of digitization on SC processes and performance remains under-explored in theory and practice (Ageron et al., 2020). The healthcare sector is no exception to this trend. Digitization initiatives in hospitals focus mainly on the implementation of classic technologies such as enterprise resource programs (ERP) and electronic data interchange (EDI) for the integration of the supply chain (Bentahar and Benzidia, 2019). Despite these efforts, studies highlight the fragmentation of information systems in this sector and the poor collaboration between internal and external SC players (Schneller, 2018). In addition, recent studies show the benefits generated through the adoption in hospitals of new, advanced technologies such as radio frequency identification (RFID), automated guided vehicles (AGVs), and the IoT (Bechtsis et al., 2017; Morenza-Cinos et al., 2019), but rarely from the perspective of supply chain management. However, these technologies may have a limited impact in view of surveys demonstrating the difficulties faced by SC managers in the healthcare sector in using data in their decision-making processes (Kowalski and Sheehan, 2016).

Despite the weaknesses of the healthcare SC, the situation would be less dramatic if the delay could be remedied by progressive, structured digital transformation. Hartley and Sawaya (2019) suggest anticipating an ordered, unhurried digital transformation of the SC in order to take full advantage of the benefits generated by digitalization. Gothelf and Seiden (2017) move in the same direction when they suggest that managers focus on the target results rather than on immediate technological choices, especially since the concept of digitalization includes a great range of possibilities (Haddud and Khare, 2020). In this context, the aim of this article is to set out a roadmap for digitalization initiatives in the healthcare SC that could generate significant benefits for this sector. A roadmap becomes a guide to facilitate the success of such initiatives

(de Sousa Jabbour et al. 2018). Thus, our main research question is: What initiatives should be promoted to maximize the digitalization of the healthcare SC? This first question is followed by a second question: In what order should these initiatives be deployed to maximize the benefits?

The hospital is the starting point of our analysis. This perspective distinguishes this study from other research studies that either explore digitalization by simultaneously embracing all links in the supply chain (Markarian, 2019) or are limited only to the movement of patients in the hospital (Rubbio et al., 2019). The hospital is the central point of consumption and the ultimate point of uncertainty in the healthcare SC (Forrester, 1958; Christopher, 1998). The challenges of this uncertainty have drawn the attention of many researchers who have studied the phenomenon in different industries (Lee et al., 1997; Chen and Lee, 2012) and proposed mitigation strategies centered on information sharing (Chen and Lee, 2009), as well as collaborative strategies (Holström et al., 2002; Jonsson and Mattsson, 2013). This article contributes to the extension of earlier research by proposing digitalization initiatives in the context of the healthcare SC.

The article is organized as follows. The next section attempts to define the concept of the digitalization of the SC. At the same time, it presents the main distinctive characteristics of the healthcare SC compared to other sectors of activity in order to explain the particular digitalization challenges it faces. The third section details the methodology of the study, explaining the information sources selected and the analyses carried out in order to identify initiatives for digitalizing and improving the SC. The fourth section presents the results. The fifth section includes a discussion of the results and prioritizes digitalization initiatives that should be implemented to ensure that they achieve their full potential. The final section proposes avenues for future research that would foster the successful digitalization of the healthcare SC.

2. Literature review

The first part of the literature review discusses various aspects of the concept of SC digitalization and its benefits to organizations. The second part highlights the characteristics of the healthcare SC. The third part discusses current trends in the digitalization of healthcare SC.

2.1 The supply chain and digitalization

A SC can be defined as a set of organizations that, from the extraction of resources up to the delivery of products or services, coordinates purchase, production, and distribution activities with the aim of creating added value for the final customer (Christopher, 1998). A SC is based on the flow of information between different actors to improve the management of physical flows (Ehie and Ferreira, 2019). Thus, in its very essence, the SC contains the basic elements of its digitalization. Since the early 1970s, a variety of SC-integration technologies have been put forward, including ERP, distribution resource planning (DRP), electronic data interchange (EDI) (Poirier and Reiter, 1996 ; Bentahar et al. 2016), and, more recently, flowcasting (Doherty and Landry, 2019). These various initiatives feature the sharing of information within an organization or between different organizations in the SC in order to reduce uncertainty at the main level: demand at the point of sale (Forrester, 1958). Such uncertainty generates significant SC inefficiencies, such as overstocking, stock shortages, excess production, and poor customer service.

Some authors view digitalization as an emerging concept (Stank et al., 2019), which could explain why its definition remains unclear. The terms “digital supply chain” and “Supply Chain 4.0” have been used interchangeably in the literature, often with similar theoretical underpinnings (Frederico et al., 2020). Digitalization is based on developments in the field of information and communication technologies (Queiroz et al., 2019; Wang and Wang, 2020), including the IoT, which connects organizations (Frederico et al., 2020; Haddud and Khare, 2020; Stank et al., 2019). The concept of SC digitalization is still in its early stages and few studies have analyzed its impacts (Hennelly et al., 2020). Due to the fragmented nature of the literature on SC digitalization, several definitions have emerged (Büyüközkan and Göçer, 2018). These different definitions of the concept of SC digitalization make it difficult for the logistics and supply chain management community to reach a common understanding and thus accumulate knowledge.

The concept of SC digitalization can include traditional technologies that have been well established for decades, such as EDI, electronic catalogs, and, recently, elaborate technologies like cloud computing, the IoT, big data analytics, 3D printing (Kosmol et al., 2019), blockchain (Chang et al., 2019), and artificial intelligence (Ehie and Ferreira, 2019). Even here, the concept of big data, for example, still requires a common definition (Addo-Tenkorang and Helo, 2016; Nguyen et al., 2018). Among the traditional technologies that are now integrated under the concept of digitalization are RFID and AGVs (Bechtsis et al., 2017; Morenza-Cinos et al., 2019).

Such technologies could be employed to improve the historical benefits of supply chain management, that is, the real-time synchronization of flows of matter with information flows, highly personalized production (Büyüközkan and Göçer, 2018; Zangiacomini et al., 2020), and flexibility and agility (Seyedghorban et al., 2020). Nevertheless, these new technologies would require restructuring the roles of the different actors in the SC (Holmström et al., 2019; Wang and Wang, 2020). Digitalization would also require that SC actors recruit or develop sufficient skills to master the new tools and analyze the mass of data (Kittipanya-Ngam and Tan, 2020; Benzidia et al. 2020). In this area, Hartley and Sawaya (2019) suggest that organizations should develop deployment plans for these new technologies rather than hurry to acquire them before being in a position to fully benefit from their potential.

2.2 Characteristics of the healthcare supply chain

From a SC point of view, hospitals bring together a range of products (medication, cleaning products, bed linen, etc.) in support of the organization’s everyday operations. These products come from diverse suppliers (manufacturers and distributors) that, together, can be referred to as the external SC (Rivard-Royer et al., 2002; Landry and Beaulieu, 2013). We define *healthcare supply chain management as the strategic management and the digitalization of the external supply chain network and internal supply chain of flows, including patients, material, pharmaceutical and medical supplies, laundry items, catering, and waste with the aim of creating sustainable value for stakeholders.*

To illustrate internal SC in the healthcare sector, medical flow provides a good example. Medical supplies, such as needles, syringes, medical gloves, and so on, constitute a key group because

these items are critical for delivering medical care (Rossetti et al., 2012). Each healthcare unit in a hospital is equipped with a storeroom that uses between 150 and 400 codes for different products, solely in the category of medical supplies (Bélanger et al., 2018). These storerooms are replenished from a central warehouse located in the hospital. This warehouse generally manages 1,500 to 2,000 stock keeping units (SKUs) of different products (Beaulieu et al., 2018). This number is often a fraction of all of the medical supplies consumed in a healthcare facility. One facility can consume up to 8,000 or 9,000 different SKUs, still for medical supplies alone (Beaulieu et al., 2018). The articles that represent the difference between the total number of product codes and those kept in the central warehouse are managed per item by the user service, which fills in a request forwarded to the purchasing department, which then places an order with the supplier. Thus, two inventory management processes are involved: stock items and non-stock items.

Medical supplies differ from pharmaceutical products in two ways. Firstly, inventory management for medication is more automated than for medical equipment (Falasca and Kros, 2018). Secondly, unlike drugs, where products are defined by their molecular formulas, in the category of medical supplies, a wide variety of products can satisfy the same needs. For example, the catalogue of a single supplier can contain 140 different product codes for an item like compresses (Beaulieu et al., 2018). Healthcare professionals have a very strong influence on the choice of product (Laczniak, 1979) and it can be extremely difficult to convince them to alter their preferences, especially surgeons (Montgomery and Schneller, 2008). In fact, healthcare professionals (e.g., doctors and nurses) take an autonomous approach to personalized patient-focused care, while healthcare managers (e.g., logistics managers, quality managers and IT managers) generally adopt an approach centered on efficiency and the standardization of patient care (Meijboom et al., 2011). This difference in approach often creates organizational tension that can have a negative impact on initiatives to digitalize the SC and lead to the failure of technology-driven projects (De Vries and Huijsman, 2011; Landry et al. 2016).

The variety of flows and products and the strong influence of a professional approach to healthcare can explain why studies periodically conclude that the logistics costs of healthcare are eight to 20 times higher than for other industries (Dooley, 2009; Ebel et al., 2013; Ageron et al. 2018). This kind of result may seem surprising given that studies dating from the mid-1990s have identified a series of measures devised to upgrade the performance of the SC in this activity sector (CSC Consulting, 1996). Nevertheless, surveys produced in the late 2000s indicate a stagnation in the performance of the different links within the healthcare sector's logistics chain (Kwon et al., 2016; Nachtmann and Pohl, 2009). In 2017, a survey by the firm AT Kearney concluded that the logistics costs of the healthcare sector amounted to 16% of revenue (AT Kearney, 2017), or 60% more than the average activity sector, and, in particular, almost the same as in 1996 (CSC Consulting, 1996).

2.3 The state of digitalization in healthcare SC

Hospitals' various experiments with digitalization include classics like information systems (e.g., ERP), EDI, and new advanced technologies like AGVs and RFID. However, there is still some doubt whether these initiatives have reached their full potential. For example, over 15 years ago,

Rivard-Royer et al. (2003) wrote about the clinical chain, linking the traditional SC and healthcare services. More recently, O'Connor (2011) outlined a fragmentation of information systems in which financial, clinical, and logistics information were still poorly integrated.

AGV has a proven track record. It has reached maturity in the industrial sector and has the capacity to manage logistics and transport systems in warehouses, container terminals, e-commerce distribution centers, and so on. The benefits of AGVs have been demonstrated in the industrial sector and we observe that several public and private hospitals have started to implement them in the healthcare sector. Regarding the implementation of AGVs in pioneer hospitals, we can confirm that these technologies are effective in reducing the cost of labor and improving the management of hospital flows, including pharmaceuticals and medical supplies, laundry, catering, and waste. A United States hospital with 1,100 beds estimated that the use of AGVs led to savings of 58 full-time equivalents (Birk, 2007).

Regarding inventory management in the care unit, over 40 years ago Housley (1977) underlined the importance of regularly reviewing decisions concerning replenishment thresholds and the choice of products to be kept in the care unit. In reality, observations show that hospitals rarely modify these parameters. At best, they do so annually (Beaulieu et Roy, 2015) and sometimes only when stock shortages become too frequent.

Surveys show that information technologies have a positive influence on the integration of the supply chain (Chen et al., 2013; Mandal et al., 2018). In addition to improving SC performance, technologies like RFID and EDI are even considered to have positive long-term effects on clinical performance (Bradley et al., 2018). These benefits may be of limited scope, as surveys show that logistics departments in healthcare facilities have difficulty in obtaining the type of data required to manage supply chain performance (Kowalski and Sheehan, 2016). The integration of the internal or external SC remains an ongoing challenge in several hospitals (Schneller, 2018).

These examples tend to demonstrate the stagnation in logistics performance of health organizations. This situation arises from the use of deficient practices or technologies to manage stocks and the internal or external SC. Supply managers often do not have the support of top management regarding the necessary investments required to improve the performance of their activities (Callender and Grasman, 2010; Elmuti et al., 2013).

Supply managers must therefore develop their political skills to obtain the necessary levers for implementing these upgrading initiatives (Landry et al., 2016). Yoon et al. (2016) have shown that leadership has a positive impact on the deployment of logistical practices in hospitals. In terms of digitalization, these investments are not always easy to justify. For example, the implementation of AGVs requires significant investment but provides long-term benefits to companies in terms of optimization, flexibility, and customer service quality while reducing levels of staff needed for tasks with low added value (Ventura et al. 2015; Fazlollahtabar and Saidi-Mehrabad, 2015; Benzidia et al., 2019). These benefits can exceed economic criteria and integrate a sustainable dimension that is often neglected in practice (Rico and Oruezabala, 2012; Bechtsis et al., 2017; Kavakeb et al. 2017).

Stank et al. (2019) stipulate that further studies are needed to identify the impacts of digitalization on the SC. More specifically for the healthcare sector, this last comment reflects the view of Petrick and Echols (2004) that it is necessary to balance investments with effort required and capacity to support forthcoming initiatives. Frederico et al. (2020) consider the development of a strategic vision is a pre-condition for harnessing the full potential of digitalization technologies. A roadmap therefore offers a guide for managers to channel their resources efficiently (De Sousa Jabbour et al., 2018). This situation justifies our two research questions: “What initiatives should be promoted to maximize the digitalization of the healthcare SC?” and “In what order should these initiatives be deployed to maximize the benefits?”

3. Methodology

The above two questions can be associated with the concept of a roadmap consisting of “a detailed plan to guide progress toward a goal” and involving an “extended look at the future” (Moretto et al., 2018). This roadmap can be used to identify the gaps that managers need to fill or that require additional research (Santos et al., 2017). To produce the roadmap, we draw from our own knowledge, accumulated through 20 years of experience as researchers, and observers of the healthcare SC. This kind of approach is invaluable for understanding the studied phenomenon, but insufficient on its own to build a foundation from which to justify our proposals. The risk is that we might be prisoners of the environment that we are studying or of the time horizon in which our observations have been carried out. To overcome these obstacles and reduce the limitations of observation, we employ a methodology similar to that used by Santos et al. (2017) in order to suggest strategic industry 4.0 orientations. This approach is based on a literature review. A literature review can take different forms (Grant and Booth, 2009). One form commonly used by researchers is the systematic review, which involves a replicable, scientific, and transparent process (Tranfield et al. 2003). This type of review presents an overview of existing research in a specific field, identifies key patterns, and provides the foundation for integrating knowledge and makes a relevant scientific contribution on a specific topic (Pittaway et al. 2014; Sashi et al. 2019; Contobeli et al. 2019). In our paper, however, we chose to conduct an umbrella review in order to achieve a comprehensive integration between generic and specific concerns and issues. An umbrella review differs from a systematic review in that it takes stock of existing reviews rather than undertaking a search of primary studies. According to Grant and Booth (2009, p. 95), “*the umbrella review refers to compiling evidence from multiple reviews into one accessible and usable document. Focuses on broad condition or problem for which there are competing interventions and highlights reviews that address these interventions and their results.*” In this sense, the umbrella review represents a potential solution to the dilemma that often arises for researchers regarding “lumping” versus “splitting” (Grant and Booth, 2009). Salleh et al. (2017) used this methodology to study the use of modeling tools in the healthcare sector. We consider that the healthcare SC lends itself to such an exercise in view of the challenges involved in its digitalization.

3.1 Identification of a literature review

Periodically, literature reviews on the healthcare SC are produced. By making use of this material, it is possible to accelerate the process of identifying digitalization initiatives that could be applied to the SC; rather than undertaking a new full-scale literature review, we tap into observations that have already been made. We judge that it would be difficult to obtain better quality results, given that some lists focus on specific themes related to the healthcare SC. To identify published articles on this topic, we employed the following keywords: literature review, supply chain, logistics, and healthcare. Five databases were investigated: Emerald Insight, ScienceDirect (Elsevier/Scopus), Web of Science, ABI/INFORM Collection (Proquest) and Business Source Complete (EBSCO). The first three databases comprise reviews that publish articles on different spheres of the field of supply chain management. The last two cross-reference multiple publishers and include journals that do not appear in the first two databases. Using these five databases guarantees the widest possible coverage of publications on our theme.

The search for articles was based on the following keywords: *literature review*, *healthcare*, *supply chain*, *logistics*, and *hospital*. The table shows the number of articles identified in each database. This number totals the results from all the keyword combinations used. Thus, there may be duplicate articles. From these initial identifications, we made a first round of exclusions based on the following criteria: the article is not written in English; it is not an article but conference proceedings; the article crossed the concept of healthcare SC with a more distant concept not of interest to our article, which could make the exploration of digitalization more difficult (for example, several articles dealt with reverse logistics or sustainability). Through this process, after an analysis of the summaries, 15 articles were retained to inform our reflections.

-----Table 1-----

-----**Table 2**-----

The articles are listed in Table 2. It should be noted, however, that the themes shown in Table 2 can be directly associated with SC management. The publications may have introduced other concepts, such as strategies in the service sector, system design in service organizations, lean management or quality challenges, and examples as discussed by Dobrzykowski et al. (2014). This does not mean that these themes might not relate to SC management, but the way that they have been developed limits their potential for integration.

3.2 Identification of digitalization initiatives

The previous section identifies three main areas of intervention by means of digitalization: inventory management, integration of the internal supply chain, and integration of the external supply chain. These themes center on hospitals, which, being the real point of uncertainty, constitute the first entity in which initiatives to improve the SC are launched (Christopher, 1998; Forrester, 1958; Landry et al., 2016; Beaulieu et al., 2018). However, from an overview analysis of the selected articles, Ahmadi et al. (2019) examine inventory management in the very specific context of the supply of surgical instruments for operating rooms. In this context, we split the inventory management component into two: one for general medical supplies and a second for specialty products in the operating room. For each of these axes we will cross some of the future research to be conducted with our observations from the field. This approach will allow us to identify digitalization initiatives.

To identify the digitization initiatives for our roadmap, we first analyze the identified articles (Table 2). Through the themes of Table 2, we can observe synergies between the articles. On the basis of these synergies, we crossed the elements constituting future directions of research and identified the consensus emerging from these literature reviews. The analysis and processing of consensus led to the selection of those that fit with the main areas of digitization identified previously. Finally, we have enriched the results from our experiences, our observations and knowledge of the field.

4. Results

The identification of health SC digitalization initiatives will be structured around the four axes described in the methodology. Although our discussion will be built around the articles from the literature review, we will also refer to other sources that justify the suggested initiative.

4.1 *Managing stocks in healthcare units*

Volland et al. (2017, p. 68) consider that “one major obstacle for a better integration of hospitals and their supplies is the unpredictable nature of hospital demand.” For medical supplies used in healthcare units, inventory management systems are reactive. Moons et al. (2019, p. 209) describe the broad outlines of this system as follows: “Traditional inventory replenishment models at medical units determine when to order (i.e., reorder point) and how much to order (i.e., reorder quantity) (Saha and Ray, 2019).” These are standard decisions in inventory management. Another difference in the healthcare sector is the difficulty of applying tried and tested management tools, like economic order quantities. The latter attempts to determine the stock cost, the order cost, and the shortage cost. However, in an area like healthcare, the cost of a

shortage is disproportionate given that a patient's life may be put at risk (Misic and Pecakis, 2020). Under these circumstances, the different links of the internal chain will attempt to overstock in order to deal with fluctuations in demand (Saha and Ray, 2019).

As indicated by the literature review, these decisions take the form of two major strategies: one for stock items and one for non-stock items. Stock items are stored in healthcare unit storerooms. Non-stock items, in contrast, are not kept in stock, but instead the healthcare unit sends a purchase request to the supply department, which then orders the items from a supplier. While these strategies are ostensibly simple, a periodic revision of the decision parameters is required: Are we stocking the right articles? What is the appropriate frequency for restocking units? Are the restocking thresholds adequate? While several authors suggest forecasting models (Saha and Ray, 2019; Volland et al., 2017), such tools are potentially unnecessary, given that the items being stocked (syringes, needles, cotton balls, and compresses, etc.) are inexpensive. It could be better to invest in the development of indicators to alert the manager to modify certain management parameters. Indicators such as the velocity and frequency of stock shortages and the rate of stock rotation could be used. Thus, instead of having two inventory management strategies (stock items and non-stock items), these strategies could be more nuanced. For example, in some hospitals, certain non-stock-items are kept in stock only at the healthcare unit and not at the central warehouse, as a way of managing the risk of shortage (Bélanger et al., 2018). To make this kind of decision, variables such as consumption velocity, variability of demand, predictability of demand, time required to receive stocks from the supplier, and supplier's level of service should be taken into account. **Initiative #1: Make inventory policies for healthcare units more dynamic.**

Facilities have equipped themselves with a double-bin system to replenish stocks of medical supplies in healthcare units, a process that can be associated with a Kanban system and lean management (Borges et al., 2019). Landry and Beaulieu (2010, p. 88) describe this system as follows: "When the first of the two bins or compartments is empty, nursing staff remove the label (and its holder) identifying the product from the front of the bin and fix it to a wall-mounted rail. These labels then trigger replenishment at regular, predetermined intervals. The replenishment information is transferred to an information system that generates a pick list for items stored in the central warehouse. The medical supplies are delivered to the ward and put away in the empty bins by a storekeeper." This system has been refined with the integration of RFID technology (Khorasani et al., 2020; Wamba et al., 2010). In the latter case, labels containing an RFID chip are placed on a rail equipped with an antenna that automatically retransmits the information. Currently, this technology is used mainly to reduce costs associated with the replenishment process by eliminating the activity of counting articles. However, RFID technology brings access to demand almost in real time rather than at the point when the storekeeper goes around reading the labels on the rail. By combining the information coming from the consumption of medical supplies with certain clinical data, it could be possible to discern the emergence of phenomena (influenza or gastroenteritis episodes) before they have reached a truly visible proportion and then develop contingency plans to ensure that sufficient quantities of articles are in stock to meet the increased demand. This kind of capability would

allow for a more proactive approach than simply reacting to events as they occur. **Initiative #2: Develop demand predictors to implement more proactive inventory management.**

4.2 Managing medical supplies in operating rooms

The operating room SC is different from the healthcare unit SC because it includes a sterilization unit to reprocess the instruments that are necessary for particular operations (Fredendall et al., 2009), which makes the internal SC more complex. Operating room stocks are different from healthcare unit stocks in three ways. Firstly, they are very expensive (Robinson, 2008) as medical supplies for operating rooms represent 60% of purchases for this group of products (Burns et al., 2018). Next, several of these supplies are specific to a precise surgical procedure, and sometimes even to a particular physician. Lastly, some of these items can be used again following sterilization (Ahmadi et al., 2019). This applies to small surgical instruments used to carry out particular surgical procedures. These articles are grouped into containers that are referred to as trays (Ahmadi et al., 2019, p. 139). The appropriate trays for the surgery due to take place are then taken into the operating room. “Once the tray is opened in the operating room, all items in the tray must go through every step in the sterile processing department (SPD), even if an item was not used,” (Ahmadi et al., 2019, p. 139). These trays also have an expiry date. Once this date has past, the entire contents must be sterilized again, whether or not they have been used.

These characteristics make the management challenges more complex. For single-use medical supplies, Moons et al. (2019) note that the management practices are often very basic. Observations in the field lead to similar conclusions, since inventory management processes are rarely automated and depend on the intervention and knowledge of healthcare staff (Beaulieu et al., 2018a; 2018b). For sterile surgical instruments, the challenge is to determine the right number to meet demand. Since these articles are very expensive, making the correct choice is particularly crucial. This involves managing the capacity of the SPD. Our observations show, for example, that SPD managers use the FIFO (first in first out) method to organize tray sterilization cycles. The problem with this strategy is that it can lead to sterilizing a tray that will not be used for several weeks before a tray that could meet a more pressing need. Naturally, this strategy has an impact on inventory management, because it requires maintaining more of the trays for which the demand is high. Thus, making the best decisions on sterilization priority involves improving the visibility of forthcoming operations.

Ahmadi et al. (2019) have identified in the literature two different models of inventory management for the operating room: deterministic and stochastic. Dobrzykowski et al. (2014), Saha and Ray (2019), and Volland et al. (2017) tackle the question of developing forecasting models. In principle, these models are more robust if they are built on a large volume of data associated with big data. While Volland et al. (2017) underline that the absence of forecasting makes supply chain management of the healthcare sector more complex, the operating room constitutes an environment in which this forecasting approach can be applied, or at least where a planning horizon can be anticipated. In fact, operating rooms often have to manage waiting lists of several days up to several months. Giving greater visibility on the development of the operating schedule to those who manage medical supplies, whether reusable or not, would help

them make better inventory management decisions. This is not a new idea, since it was experimented with 40 years ago by Steinberg et al. (1982), who viewed the operating schedule as similar to a factory's manufacturing schedule. Improving the visibility of the operating schedule would not only be beneficial for inventory management; it would also upgrade the general practice of the operating room by making it easier to choose between the different options. Beaulieu et al. (2018b) have already mentioned that improving the performance of inventory management for the operating room involves improving the management practices of the theater itself.

Improving the performance of the operating room is not a secondary benefit, because it could lead to reductions in the time that patients wait for surgery (Marques and Captivo, 2017) while ensuring better coordination of the facility's core resources (Bail et al., 2018). Achieving these results is not simple, however, since it requires the reconciliation of numerous variables (Testi and Tanfani, 2009) whose weightings vary depending on the nature of the actors, (e.g., surgeons or nurses) (Xie and Peng, 2012). Data analysis would make it possible to develop an operating schedule on a longer horizon that includes the probability, based on historical data, that certain operations will take place. Thus, instead of working in an environment of certainty, but with a very short-term horizon, hospitals could improve their visibility by weighting a longer-horizon schedule with the probability that certain events will take place. **Initiative #3: Make the operating schedule more dynamic.**

4.3 Improve the internal supply chain

Berges et al. (2019) identify four main flows in a hospital: process, materials, patients, and medicine. Too often these flows are managed independently without any real concerted effort at interaction between these flows and consequently generate losses (Khorasani et al., 2020). The lack of an integrated view of flows can be identified through literature reviews, with some reviews focusing on a specific type of product, such as drugs (Narayana et al. 2012; 2014), or a specific flow, such as patient travel (Misic and Pecakis, 2020).

We refer above to the use of RFID technology combined with a double-bin system to manage the replenishment of healthcare units' medical supply stocks. By transmitting the state of the consumption of healthcare units in real time, the frequency of replenishment could be made more dynamic in line with consumption. Currently, this frequency is fixed and often determined by past practices rather than by detailed analysis (Bélanger et al., 2018).

Similarly, patient flow traceability can be implemented at hospital sites. Connected mobile applications already exist to coordinate the management of patient transportation between hospital porters and medical staff (Kim et al. 2016; Karra et al. 2016; Chikul et al. 2017). The digitalization of patient flows would make it possible to connect this data with data on equipment management or materials and medicine. Thus, if a patient suffering from a particular condition is put into a medical unit that is not equipped for his or her condition, then the connection in the data would ensure that the equipment required to care for that patient's health will follow, creating a continuous flow environment (Borges et al., 2020).

As discussed earlier, RFID can be combined with other technologies such as AGVs (Morenza-Cinos et al., 2019). Beyond the reduction of operations costs, the improvement of the organization of hospital flows via AGVs relieves care staff of logistical tasks and allows them to concentrate on their core responsibility, patient care, thus increasing the level of patient service. The combination of these different technologies should contribute to making the healthcare chain safer and improve the sustainable performance of the healthcare SC (Kumar and Rahman 2014). In particular, the use of technology like AGVs would encourage the facility to standardize these processes in order to reduce the human mechanisms that impede the full potential of the technology. **Initiative #4: Implement logistics automation technologies to better link the flows within the facility.**

4.4 Making logistics networks more dynamic

If the previous direction was centered on hospitals, this flexibility could be sought for the entire SC. Narayana et al. (2012; 2014) and Marques et al. (2020) emphasize the complexity of supply networks in the healthcare sector, targeting the behavior of actors in the supply chain (Narayana et al., 2012). Some authors (Berges et al., 2020) have proposed the implementation of strategies that have been proven in other industries, such as vendor-managed inventory (VMI). These proposals converge with the conclusions of studies by Chen et al. (2013) and Mandal (2018).

These solutions cannot be considered sufficient, however, because this complexity is unlikely to decrease, given that two phenomena tend to come together in healthcare delivery. The first of these relates to the dispersal of healthcare facilities: clinics, rehabilitation centers, centers specializing in certain types of surgery, and so on. This dispersal is based on demographic trends in which healthcare network managers pursue measures to make it easier for people to stay in their homes, which involves health services being delivered closer to patients (Garagiola et al., 2020). Thus, new information technologies put an emphasis on, for example, telemedicine, which involves a physical disconnection between the patient and the doctor. With the new generation of telemedicine, basic vital signs can be checked remotely, making long-distance diagnosis possible. This kind of technology is established in workplaces, creating yet another dispersal of healthcare providers. However, this dispersal of healthcare services should be accompanied by greater flexibility in the SC to distribute the pharmaceutical products and medical supplies needed by the patient following a given consultation. Experiments already exist. A Canadian healthcare facility for instance, entrusted a supplier with the task of distributing medical supplies to the home of a vulnerable client (limited mobility, intellectual disability). For the supplier, this meant equipping itself with a logistics infrastructure better suited to distribution in small batches rather than through bulk deliveries, and included a pick-up zone for unit collections, a more appropriately sized delivery fleet, and a customer service more adapted to answering specific questions. This particular chain has to coordinate new clinical partners that are not generally included in the traditional logistics chain (Beaulieu et al., 2019). This example has its limitations, given that the hospital controls the patients that can access this type of service. The supply network develops organically. The multiplication of healthcare delivery sites could lead to a constant reshaping of supply networks, similar to what has been

seen in electronic commerce. **Initiative #5: Make the external supply chain more dynamic to adapt to the evolution of care activities.**

5. Discussion

As already mentioned, the healthcare SC is significantly more expensive than the supply chains of other industries (Kwon et al., 2016). These costs result partly from the natural complexity of the healthcare sector (Bourlakis et al., 2011; Bentahar, 2018; Beaulieu et al., 2018), but they are also due in part to the difficulty of implementing exemplary practices that have been proven to work in other sectors (Su et al., 2011). In this situation, it is easy to imagine that the SC may be lagging behind in implementing digital solutions.

In addition, it would be also easy to see in some of the suggested initiatives the prelude to significant investment in digitalizing the healthcare SC; after all, technologies like RFID and AGVs can be considered manifestations of digitalization. However, observations indicate that the implementation of RFID or AGVs involves organizational and technological obstacles that require change management, training of operational teams, and the involvement of top management (Baker and Halim, 2007; Papadopoulos et al. 2011). This observation supports the arguments made by Gothelf and Seiden (2017), who call for going beyond a simple collection of technologies and reflecting on the objectives pursued.

Moreover, it corresponds to the recommendations made by Hartley and Sawaya (2019), who suggest that a delay in digitalization can be remedied if judicious initiatives are put in place. The previous section identifies several of these potential initiatives. In addition, this article aims to put forward a roadmap for initiatives that could be pursued to digitalize the SC in the healthcare sector. These initiatives should not be carried out in a random way but rather organized progressively. Figure 1 represents the positioning of digital initiatives and serves as a basis for the discussion of possible trajectories for implementation. To support this sequence of initiatives, we have opted for a classic effort–impact matrix. At this stage in the thought process, the simplicity of the tool allows for a visualization of the different initiatives and how they are positioned in relation to one another. This visual representation is useful for understanding the potential interconnections among these different initiatives or their independence (Killen and Kjaer, 2012).

What is the explanation for the positions of the different initiatives in Figure 1? Firstly, regarding the impacts, greater benefits have been ascribed to initiatives that can generate benefits beyond the SC. Thus, a more dynamic operating schedule generates clinical benefits due to the potential reduction of patient waiting times for surgery. Similarly, making external supply networks more dynamic can improve the services on offer to patients, who could, for example, receive their prescriptions at home following a remote consultation. The research work of Bradley et al. (2018) demonstrates that the use of EDI and RFID technologies improves logistics performance and ultimately clinical performance.

The most visible representation of efforts on digital initiatives is in the form of costs. While AGVs require significant financial investments and the involvement of actors, they can generate a considerable impact by optimizing flow management, improving the transparency of the

healthcare chain, and improving working conditions for employees and patient service quality. In fact, most studies on AGVs concern the industrial sector and focus on issues of optimizing processes and reducing delivery times based on mathematical models (Ventura et al. 2015; Kovakeb et al. 2017). In hospitals, AGVs load trolleys and transport products prepared by logistics operators in the central warehouse to healthcare units using lifts. The hospital agents working on different floors alongside healthcare units deliver the various products to medical staff and put the trolleys back in the floor stations to return via the AGVs to the central warehouse.

In addition, the “efforts” aspect can be used to approach the themes presented in Table 2 that have not been discussed up to now, including organizational barriers and information technologies (Table 2). Concerning information technologies, several literature reviews identify the limitations of numerous systems for managing equipment used in the healthcare sector (Dixit et al., 2019; Dobrzykowski et al., 2014; Kim and Kwon, 2015). Thus, initiatives that require a connection between two information systems (clinical and logistics) are judged to require more effort, which would take the form of employee training, change management, and ensuring employee ownership of technology (O’Conner, 2011). The next developments justify the position in the matrix and hence the suggested trajectories for making adjustments.

-----**Figure 1**-----

The development of a more dynamic inventory management policy could reduce the level of stock in the hospital and the losses arising from obsolete products. In return, once the configuration phase has been completed, the hospital’s effort will be directed mainly toward the allocation of resources that ensure the updating of these policies. The development of predictors will require greater effort, as it will be necessary to cross-check different databases and identify phenomena that seem to interact. A real big-data analytics effort will be involved. The benefits of this approach will be indirect, supporting other initiatives.

The last three initiatives generate the greatest impact, but at the same time they require the greatest degree of effort. This positioning can be explained by their impact, which will go beyond logistics performance to generate clinical benefits. In return, they will require collaboration with stakeholders outside the traditional scope of hospital supply chain management.

In this situation, which initiative would be the best choice to launch the digitalization of the healthcare SC? We think that it should involve improving the dynamics of inventory policies. One of the organizational barriers to be overcome is the indifference of top management to SC activities (Callender and Grasman, 2010; Elmuti et al., 2013), which they consider to be far from their core business. This barrier inevitably affects all the proposed initiatives. By carrying out a project that will impact all the healthcare units in the hospital, supply managers can develop allies that will support their initiatives in the hospital or with external partners. This

improvement does not so much require technological developments as a review of skills related to the access to a much greater mass of data (Holmström et al., 2019; Kittipanya-Ngam and Tan, 2020). These skills are no longer restricted to SC expertise. They should also integrate organizational and relational skills. Several researchers have underlined the importance of integrating these skills to tackle the challenge of the digital transformation of the SC (Mangan and Christopher, 2005; Derwik et al. 2016). Thus, once these skills are developed, they could be used again to consolidate other initiatives.

Moving on from this first choice, which initiatives should be implemented next? We suggest two development trajectories. One is an internal trajectory in which the next logical step would be to make the operating schedule more dynamic; this would involve working on a section that is at the heart of hospital activities. A second option would be an external trajectory aimed at making the distribution routes more dynamic.

6. Conclusion

The digitalization of the SC opens up such possibilities that this article could have been even more forward-looking in terms of projecting their impacts on the healthcare sector. At the same time, we have been observing this sector for many years and objective data on the performance of this SC (Beaulieu and Roy, 2019; Kwon et al., 2016; Nachtmann and Pohl, 2009) reveal a major difficulty in overturning established paradigms. From perspective, we have opted to suggest initiatives that can be implemented relatively easily. Some of these proposals are not particularly new, since they were put forward as many as 40 years ago (Housley, 1997; Steinberg et al., 1982). One observation that underlines our point concerns a degree of conservatism in supply practices in the healthcare sector. We have therefore targeted initiatives that start off in hospitals at the point of consumption, the point of uncertainty in all supply chains (Christopher, 1998; Forrester, 1958). In addition, some of the proposed initiatives promise to improve not only supply chains but also clinical practices, as in the example of dynamic operating schedules.

Our paper offers two main implications for managers. First, it proposes digitalization initiatives that can help managers significantly improve the hospital supply chain. Second, the article adopts a political perspective, emphasizing that supply chain managers are largely under-recognized as key actors in hospitals and that top management should better consider their function and support them in their initiatives and investment decisions. Therefore, the paper offers supply chain managers a new framework for thinking about their roles.

Thus, the suggested initiatives are inspired by the state of scientific knowledge in healthcare SC management as well as existing logistics practices in this field. Since our proposals center on hospitals, it could be worth carrying out studies on how digitalization impacts all partners involved in the healthcare SC. After all, reducing uncertainty at the point of consumption has its limits: uncertainty will always exist and a certain level of stock will be necessary to deal with it. The presence of stock is all the more important because the cost of shortages is disproportionate in the healthcare sector compared to other fields, given that human lives are at stake. It will be

necessary to identify the practices and decision criteria in order to determine the best actor in the SC to take on this risk.

This study has limitations. Although the initiatives proposed overlap with the observations made in different literature reviews combined with our own experience in the field, it would be appropriate to go back to the decision-makers in the field in order to validate the conclusions represented in Figure 1. A World Café session could directly confront the point of view of hospital supply chain managers (Pulles et al., 2016). Such an exercise could identify new initiatives or map these initiatives in a different way according to the effort–impact matrix and thus suggest a new roadmap.

Furthermore, the suggested roadmap has a universal character, whereas De Sousa Jabbour et al. (2018) emphasize that such an exercise is often linked to the specific culture of the organization. Thus, the research opens an interesting perspective on the topic. One avenue of future research could be to investigate organizational characteristics that accelerate the implementation of digitalization initiatives and that go beyond the support of top management. Moreover, in the same perspective, are there countries whose health networks have a more pronounced level of digital maturity? An international comparative study would help answer this question.

Our proposal thus centers on the movement of materials. Digitalization could equally be applied to the movement of patients or equipment. Technologies already exist to this end. For example, we have observed that in hospitals, the implementation of mobile technology (e.g., iPods) connected to electronic patient records (EPRs) and WIFI can be used to trace patient transportation between the sites in a hospital in real time. It would thus be worth exploring how data from information systems relating to patients and equipment could be linked to those of equipment management systems. The concept of digitalization tends to put the spotlight on concepts associated with managing the SC that the healthcare sector would benefit from implementing. This last avenue of research would complete the vision formulated in this paper. The challenge relates to deploying digitalization technologies to improve logistics performance and the overall performance of the entire hospital by integrating all its flows (Berges et al., 2019).

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Figure 1: Digital initiatives positioning grid

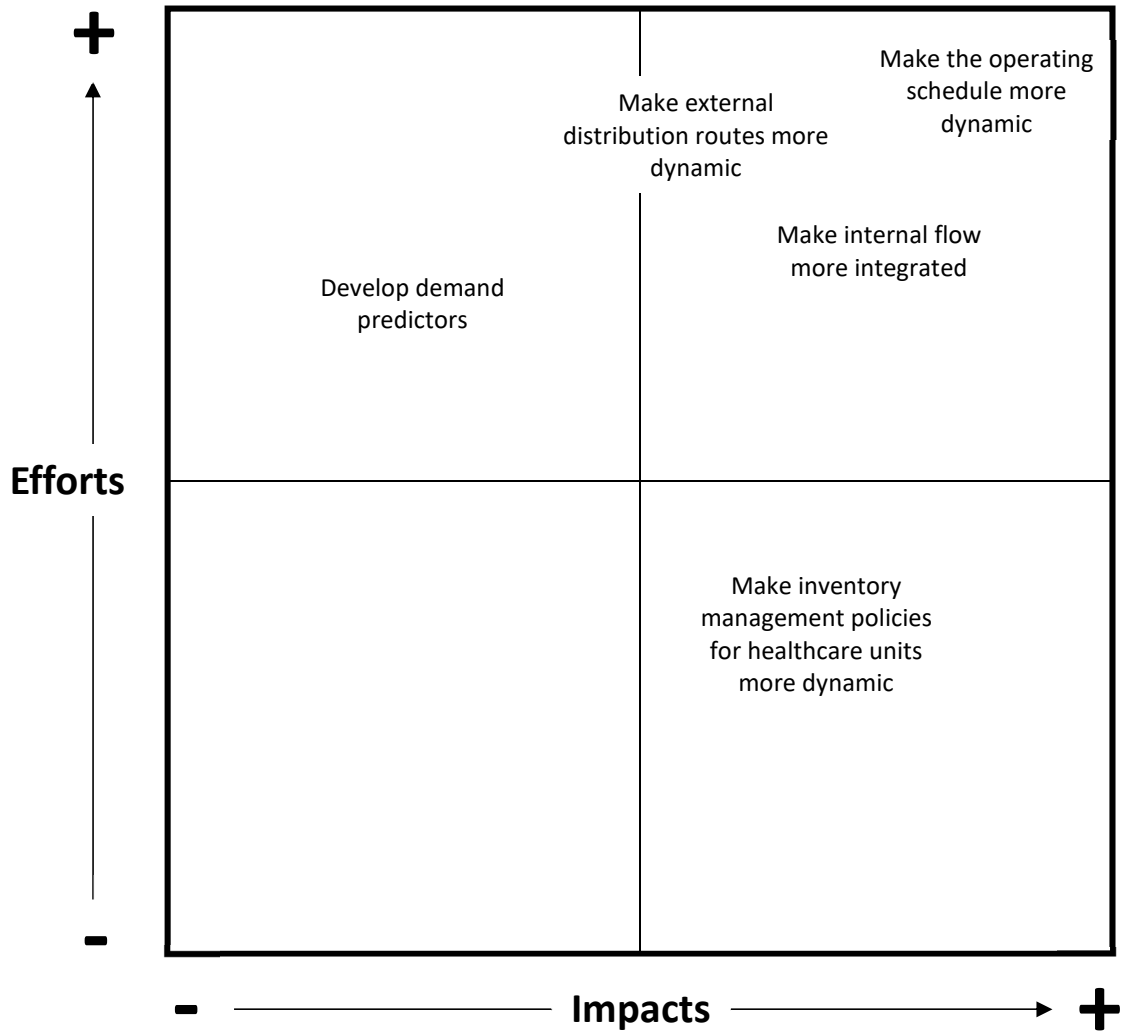


Table 1 – Articles retrieved from databases

Databases	Identified articles	Analyzed articles
Emerald Insight	8	8
ScienceDirect (Elsevier/Scopus)	39	10
Web of Science	110	17
ABI/INFORM Collection (Proquest)	20	12
Business Source Complete (EBSCO)	29	12

Table 2 – Research themes resulting from the list of publications on the healthcare SC

Year	Authors	Themes					
		Technological information	Organizational barriers	Planning, scheduling, forecasting	Inventory management	Internal distribution	External networks
2012	Narayana et al.						✓
2014	Dobrzykowski et al.	✓	✓	✓			
2014	Narayana et al.		✓				✓
2015	Kim and Kwon	✓	✓				
2017	Volland et al.			✓	✓	✓	
2018	Mathur et al.		✓		✓		
2019	Moons et al.				✓	✓	
2019	Dixit et al.	✓	✓		✓	✓	
2019	Ahmadi et al.				✓		
2019	Berges et al.				✓	✓	✓
2019	Saha and Ray	✓		✓	✓		
2020	Misic and Perakis				✓		
2020	Kharasani et al.		✓			✓	✓
2020	Garagiola et al.						✓
2020	Marques et al.						✓