Adapt and Flex or Die: A Systems Approach to an Unhealthy Healthcare Supply

Joshua Brodie, Gabrielle Peko(✉), and David Sundaram

The University of Auckland, Auckland 1010, New Zealand
jbro777@aucklanduni.ac.nz,
{g.peko,d.sundaram}@auckland.ac.nz

Abstract. Healthcare supply chains are becoming increasingly complex and characterized by rapid and unpredictable changes, particularly during the Covid-19 pandemic. This unpredictability means supply chains are challenged from all levels. Patients, employees and society are all sources of uncertainty resulting with the need for supply chains to be healthier. This research explores the need for healthcare supply chains to be more adaptable and flexible. A literature informed design science approach was adopted as the methodology. We propose a systems view of an adaptive and flexible healthcare supply chain. Furthermore, we build system dynamic models to illustrate an unhealthy healthcare supply chain and a healthy healthcare supply chain. Theoretical supply chain conceptual frameworks and information systems concepts were synthesized to propose models that look to solve some of the supply chain problems arising from the Covid-19 pandemic.

Keywords: Healthcare supply chains · Unhealthy healthcare supply chains · Healthy healthcare supply chains · Covid-19 pandemic

1 Introduction

The concept that a healthy future is contingent on the health and well-being of the population is not new [7]. Yet, the Covid-19 pandemic has significantly disrupted the dispensing of healthcare throughout the world. Much of this disruption can be attributed to Healthcare Supply Chains (HSC) and how they functions [19], Flexibility [21], adaptability [16], collaboration, coordination and knowledge [26], elements of a fully functional supply chain (SC) have become the key differentiators between a Healthy Healthcare Supply Chain (HHSC) and an Unhealthy Healthcare Supply Chain (UHSC). The following research's motivation comes from seeing key problems arise from the vaccine distribution across the global SC network.

This research aims to identify issues within the HSC and provide solutions using principles of e-health, SC and information systems (IS). It follows a design science research (DSR) approach. We *observed* supply chains during the Covid-19 pandemic both through academic as well as grey literature. Based on these observations and further literature review we *theorized* both the current as well as potential solutions to the current problems. This theorization included the development of high level conceptual frameworks as well as system dynamic causal loop models. Based on this theorization we have proposed a set of core *systems* as a foundation for Healthy

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Healthcare Supply Chains. These systems are already available in the technological ecosystem and can be integrated together to provide the functionality and requirements that we have proposed. The proposed concepts, models, including the system dynamic views of UHSC and HHSC, go some way to solving some of the issues identified by using modern e-care solutions, IS and traditional successful SC concepts.

Generally, the purpose of this paper is to promote resilient, health systems that are more sustainable and focus on the health and well-being of people [7]. Through simply highlighting the issues arising from an UHSC and propose requirements for its evolution to an HHSC through the utilization of different types of IS. Drawing on research that delves into the significant disruption in the HSC arising from the current global Covid-19 pandemic, several causal loop diagrams and models are presented. The following section outlines an HSC followed by what constitutes an UHSC. Different types of IS that can be utilized to transform an UHSC into an HHSC are then discussed in turn. Finally, the systems that deliver foundational elements of adaptability and flexibility are discussed.

2 Healthcare Supply Chains

2.1 Background

Sinha and Kohnke [38] suggest that an HSC can be viewed as three delineated sections labelled upstream, middle, and downstream. The upstream section refers to the part within the SC that is used to produce the different vaccines, medication, masks and equipment. The upstream section is more similar to traditional manufacturing supply chains. “The middle of the supply chain deals with financing and claims processing, and it is occupied by banks, insurance companies, and third-party administrators. These actors ensure that the developers and deliverers of care bundles are reimbursed” [38]. This part of the HSC deals with government regulations and pressure. “The downstream of the supply chain represented the health care delivery industry comprised entities such as hospitals, clinics, home-health services, and hospices” [38].

The healthcare industry’s SC is different from traditional SCs in terms of the extent to which a partner or consumer participates, degree of customization of services provided, and the inherent process uncertainty [33]. All these cause a HSC be more dynamic and complex than other SCs [14]. The HSC is defined by Mathur et al. [26] as the “backbone of healthcare delivery…due to the healthcare industry being dependent on the availability of medical supplies at the right time and in the right quantities to the patients, lack of which may create customer dissatisfaction”. Mathur et al. [27] also state that the HSC involves the flow of a variety of product types through the participation of people to fulfil patient requirements.

2.2 Motivation

The following discussion will focus on the Covid-19 vaccine distribution during the pandemic to illustrate and highlight the issues that arose within the supply chain. However, most of the identified issues apply to other SCs as well. Literature was used to highlight the key parts of an HHSC and an UHSC. Adaptable sustainable SC management operations can be best described as considering an entity towards adaptability and sustainability [4]. Each country or state has had a different response to the pandemic. In each instance, decision-makers prioritized the economic, environment, societal and cultural aspects of a country or state differently. It is implied in Fig. 1 that the HSC will often be directly correlated with a country or state approach.

An example of this is New Zealand's response to the pandemic. New Zealand was able to lock-down the country to have outstanding success in decreasing the amount of community transmitted cases [12]. This response allowed New Zealand's HSC to focus on being preventative and concentrate on vaccine distribution. Other places in the world do not have the luxury of New Zealand's geographic remoteness, which allows the country's boarders to be closed and effectively isolated it from the rest of the world. A preventative/proactive SC healthcare approach will set the standards for its processes ultimately effecting patients and employee's health (people in the area). All these key elements should be aligned, corrected, optimized and monitored through a sustainable learning flow.

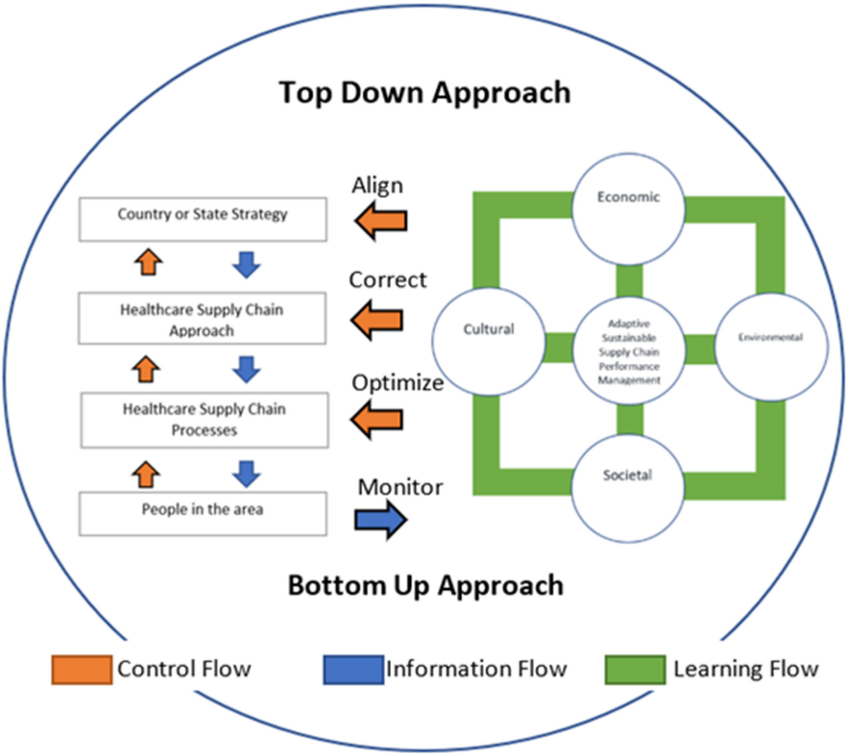

Fig. 1. Systems view of an adaptive and flexible healthcare supply chain

It is suggested by Maani and Cavana [23] that system thinking techniques are important to understanding complex systems. An HSC [24] falls under the category of a complex system considering its numerous elements. Modelling an HHSC and an UHSC needs to be done holistically rather than isolating each element of the system. This allows for relationships to be identified and variables to be highlighted. A SC model can be viewed as one system with several different elements and variables; allowing for problems to be highlighted and solutions to be provided. With all complex models, there are issues with illustrating all variables and relationships in one model. Figure 1 conceptualizes an adaptive and flexible HSC at a high level of abstraction while the Causal Loop Diagrams (CLD) in Fig. 2 and Fig. 4 are at a lower, more detailed, level of abstraction. For example, the problems that arose from the pandemic included a lack of coordination, fewer supplies available, a shortage of workers and limited capacity. The HHSC indicates that the adaptability and flexibility elements proposed (Fig. 3) are a way to solve some of these problems, highlighted in the CLDs, through IS.

3 Unhealthy Healthcare Supply Chains

Paché [30] argued that Europe's greatest HSC failure was its facemask supply. In the early stages of the pandemic, Europe could not accurately forecast how many face-masks were needed for both healthcare workers and the patients. "It is impossible to quantify the number of deaths due to the lack of face masks, but the reality of the dark side of healthcare SC management is indisputable" [30]. The lack of facemasks also allowed Covid-19 diagnosed patients to transmit the disease when moving from hospitals. If there were more IS and e-health measures in place within the SC network, Europe might have been able to better forecast how many masks would be needed. The lack of facemasks caused enormous pressure on the HSC, forcing hospitals to reach maximum capacity between March and April. The vaccine distribution in the HSC is facing similar problems throughout the world.

The model developed in Fig. 2 is used to illustrate a systems view of the current UHSC. The critical aspects in this model are the *Patients Health Deteriorating* module and the *Reactive e-health SC Measures*. As *a Lack of Coordination increases*, the *Patients' Health deteriorates* (decreases). When there are *Less Communication* and a *Lack of Coordination* between stakeholders in a supply chain, it can cost lives, particularly in the context of Covid-19 vaccine distribution. Suppose those who need the vaccine most do not receive the vaccine because of coordination failures between different elements outlined in Fig. 1. In that case, patients' overall good health might decrease, and the number of patients whose health deteriorates could increase.

The first loop is the 'employees health' loop. As the number of patients whose health deteriorates increases because of a lack of vaccine distribution, *Employee's Health* (i.e., those working in the healthcare field) worsens. Furthermore, the number of *Employees Working Overtime* increases as *Patients' Health Deteriorates*, further decreasing individual employee's health. Barnhill [3] also discusses that when *Employees Work Overtime*, it decreases the amount of *Personnel* available, increasing, a *Shortage of Workers*. Parris [32] suggests that an increase in strain on the HSC increases *Production Fluctuation* as the HSC cannot accurately forecast how many people still need the vaccine. Parris [32] claims that an increase in *Production Fluctuation* also increases *Service and Production Waste* [22]. O'Donnell [28] also suggests that this also decreases the HSC ability to *Scale Raw Materials* and distribute vaccines.

In line with Parris [32], Barnhill [3] claims that *Limited Capacity* for the vaccine increases the strain on the HSC. This further increases the amount of patients' health deteriorating due to not being unable to access the vaccine. The final loop is the relationship between *Reactive e-health SC Measures*, *Unsafe Practices* and *Production Fluctuation*. As long as the HSC continues to react to problems within the supply chain, fluctuation within the SC will increase. Decision-makers will always be on the backfoot and have less information than if they were able to engage with patients' proactively. These reactive measures will also ensure that the HSC will have to engage in *Unsafe Practices* to address these problems in the short term. Lack of Governance Risk Management and Compliance (GRC) might impact these unsafe practices, further extenuating these unhealthy SC loops. All these loops come together to increase *Work* which in turn may increase *Overall SC Waste*.

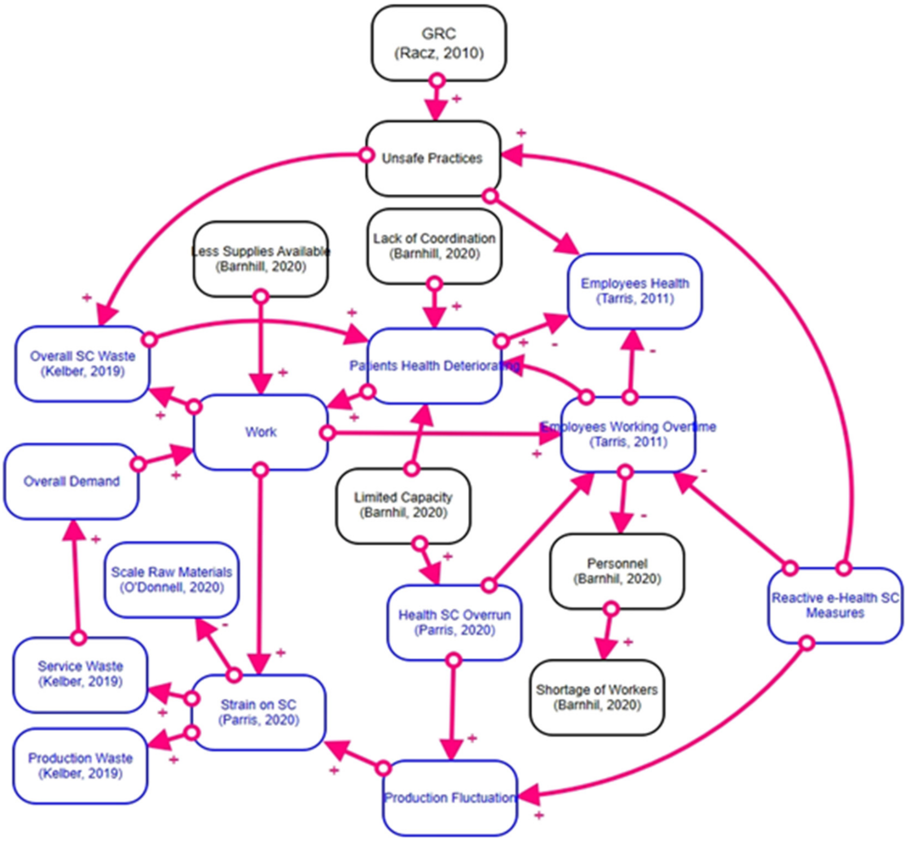

Fig. 2. Unhealthy healthcare supply chains

In summary, an UHSC Lacks Coordination which affects patient's health. An UHSC also has a Limited Capacity which increases the strain on the HSC. A Shortage of Workers, fewer Supplies Available, and Unsafe Practices are also core problems within an HSC. This paper's motivation comes from looking at these problems and finding potential solutions for them in literature. The solutions we propose will provide some basis for the HSC to transform the current way they operate. We then recommend different types of systems to help turn UHSC into an HHSC. Starting with Heinrich and Betts [16] visibility, we build our model's foundational steps.

4 Foundational Elements of Adaptability and Flexibility

A HHSC that can withstand the impacts of a global pandemic and respond effectively is one that is flexible and ultimately adaptive [40]. We propose that a certain level of education and automation can be achieved through achieving visibility, coordination, and collaboration [18]. Once education and automation are achieved, flexibility needs to be incorporated, which finally contributes to adaptability. When all these seven elements are obtained, the previous unhealthy SC will become healthier, and transformation will take place [16, 18]. These elements are illustrated in Fig. 3 and discussed in the following paragraphs.

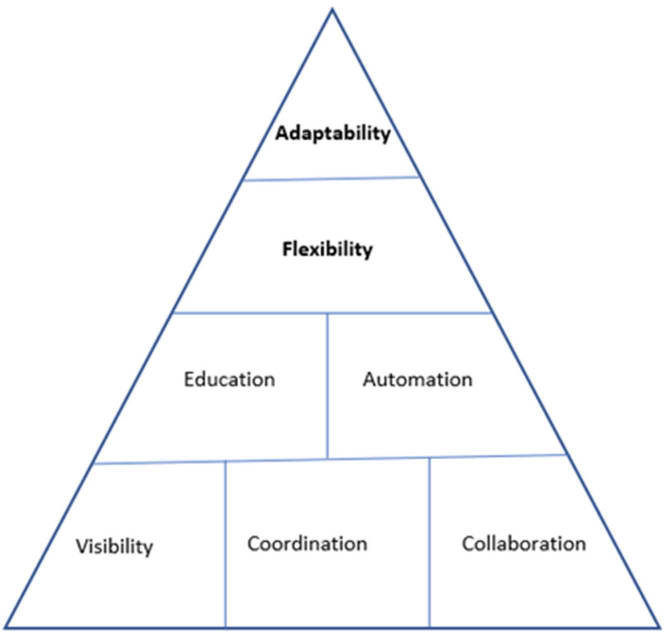

Fig. 3. Foundational elements of adaptability and flexibility

4.1 Visibility

Heinrich and Betts [16] argue that step one in achieving adaptability is visibility. The more fluctuation within the supply chain, the more significant the strain is on the overall supply chain. Heinrich and Betts [16] suggest that an increase in visibility between different partners reduces fluctuation. Heinrich and Betts [16] go on to say that "Processes are now readily visible, and achievements are measured and widely recognized when there is communication between all partners at all levels." In Heinrich and Betts [16], the recommended communication method is 'a phone call' with the frequency being a week. Briggs [6] suggests that different forms of technology should also be used within the context of increased visibility. Briggs [5] adds to Heinrich and Bett's [16] work by recommending that different forms of technology (like Zoom and Skype) could be used to increase visibility within the supply chain. This would allow partners to frequently discuss things like demand and supply, which are incredibly vital to a patient's health in the context of an HSC.

To solve the problems outlined in the descriptive model, Heinrich and Betts [16] recommend increased visibility in the SC and between all the different partners, mainly when working with partners to improve 'number accuracy'. Less unstable processes within a SC allow for more supplies to be available to all the partners. This is because SC members can more accurately collaborate and coordinate stock from one end to another. However, HSC must first have confidence in its own internal numbers before making decisions that will affect the whole HSC.

4.2 Coordination

Heinrich and Betts [16] suggest that after visibility, community coordination needs to take place to achieve adaptability. According to Heinrich and Betts [16], a core concept of community coordination is the ability to achieve "real time inventory count that is, having inventory counts that reflect what a company actually has on hand moment to moment, as close to instantaneously as possible". This can come from visibility of inventory levels and its located through coordination. Heinrich and Betts [16] recommend bar code scanner or radio frequency identification (RFID) technology, to record and track the movement of goods throughout the manufacturing process. These forms of technology contribute to a linked procedure or activity and increase coordination. In an HSC, the bar code system is perhaps the easiest and most cost-effective choice for inventory tracking, specifically when dealing with vaccines and other medication types. While barcode tracking is prevalent in the modern-day SC Near Field Communication and Bluetooth contact tracing is another type of e-health technology gaining popularity throughout the world.

4.3 Collaboration

Briggs et al. [6] argues that a SC design must have seven layers of collaboration (SLMC) to obtain collaboration. The HSC must have a Goal Layer in which all the partners within the HSC commit to collaborate even through challenging periods like a pandemic. Barnhill [3] argued that if the partners within the vaccine distribution were more committed to getting supplies to different countries, there would have been fewer capacity issues in the early stages of the vaccine distribution (see Fig. 2). The Products Layer within the SLMC also encourages the products made available to meet the standards and specifications set out in the first Goal Layer. This was a key issue in the vaccine distribution. For example, the Pfizer vaccine has to be kept in temperatures colder than Antarctica (−70 °C), causing infrastructure problems within the HSC [10]. Briggs et al. [6] argue that The Activities Layer points out that no activities have a purpose if there are no actual products. Mid 2020, there was no vaccine distribution plan. Fast forward to January 2021, there needs to be a robust SC vaccine distribution plan to administer the vaccine and get it to the places where people need it most. The final four layers include: The Patterns of Collaboration Layer, The Techniques Layer, The Techniques Layer, The Tools Layer, and The Scripts Layer [6]. The Patterns of Collaboration Layer refers to what patterns need to be identified to create a product. For example, there needs to be several different combinations or partnerships that need to take place to get the vaccine from one partner to another. When scientists created the first Pfizer/BioNTech Covid-19 vaccine, countries worldwide tried to build relationships with Europe to gain access to their HSC [15]. The Techniques Layer refers to what "techniques are used to invoke patterns of collaboration" [6] such as the brainstorming technique to invoke synergy and improve the number and quality of ideas produced by groups [29].

4.4 Education

Jansson [20] argues that with the introduction of technology, workers now need to have a baseline understanding of what different forms of technology (e.g. SAP) do to get by within a supply chain. Jansson [20] argues that workers education can be done in two different ways, either through a 'British way' or a 'Swedish way.' The British method involves splitting the SC into several various organizations and utilizing teacher-led hieratical classes. During different parts of the day, different workers spend time with a teacher to learn how to use different applications. These lessons will allow workers to understand how the entirety of the SC works. The classes will enable workers to be upskilled and better understand how the SC functions. An increase in education within the SC will allow workers to do their jobs better with the entire SC in mind. The Swedish way recommends that workers education is done through a more self-learning/democratic way. The method acknowledges that workers have different strengths and weaknesses. Jansson [20] recommends that workers teach each other how to do each other's roles at a low level. The method increases knowledge within the SC and increases flexibility. The form of education is traditionally organized through labour movement organizations.

4.5 Automation

Another element that will increase the number of skilled workers, increase education, and decrease work is automation. People throughout the SC should learn automation at a base level to understand how the different systems work within the supply chain. Automation involves routine tasks, structured data, and deterministic outcomes.

According to Aguirre and Rodriguez [1], recent studies report the benefits of the application of automation for productivity, costs, speed, and error reduction.

4.6 Flexibility

Once a certain level of education and automation have been completed, flexibility becomes the next target. SC flexibility can be achieved by adopting a three-stage approach, First, identify the flexibility required, second implement it and third monitor it through feedback and control [21]. The SC should formulate its competitive strategy in line with external environment, uncertainties, and relationships with suppliers and customers. If the SC can successfully target and eliminate unreliable suppliers and partners, fewer problems will occur due to members reliable nature [21]. Environmental uncertainties mean organizations have to create contingency plans which are included in an organization's business strategy. Hence, environmental uncertainties compel organization to develop different types of flexibilities [8]. Once developed, managers need to focus on implementing these flexibilities throughout the SC system along with the necessary people, processes and in particular, technology to achieve the flexibility requirements (e.g., information technology, relationship with key suppliers and customers, skilled workers, etc.). This implies that all of the HSC partners must consider sharing the responsibility for implementing and managing the required SC flexibility [20].We recommend that the IS requirements are pitched at a relatively low level as that is where the SC is least flexible [2].

The third and final stage highlights the importance of a control mechanism to monitoring and control the implemented flexibility [21]. Kumar [21] and Rosemann [36] recommend a feedback loop to assess the flexibility of the supply chain. If there was a feedback loop within the HSC that could provide meaningful feedback about its flexibility the HSC will come out of its vaccine distribution more resilient. Adaptability and flexibility ensure that a feedback loop exists. If not the control mechanism would signal that some adjustments are needed to realize the required flexibility necessary to improve the SC and subsequent business performance [21].

4.7 Adaptability

The top of the triangle and the final step of an HHSC is adaptability [16]. Haeckel [17] argues that there are four phases in adaptability. Sensing, interpreting, responding, and acting. According to Haeckel [17], environmental change is first sensed by adaptive individuals and adaptive organizations. These adaptive individual and organizations then interpret the changes based on their experience, aims, and capabilities, identifying threats and opportunities while discarding irrelevant information. They then decide on a response and implement it. This process of sense, interpret and respond becomes an iterative loop. The results are monitored by the adaptive system which enables the detection of environmental changes that have occurred since the previous cycle [17].

Adaptability is not a goal; it is a way for the SC to respond to environmental changes to survive [16]. When individual partners start the adaptability process, they establish a set of baseline key performance indicators for both the SC and themselves. This allows them to measure performance and set time frames for achieving critical objectives. The primary purpose of adaptability in an HHSC is to have information about patient demand communicated instantaneously to all partners. To achieve this, to some extent, automated decisions based on a set of pre-determined business rules should operate within the SC network. Adaptability requires standardization of services and processes across the network. This will allow for automate decision making and shared information throughout the network in near-real-time [16].

5 Healthy Healthcare Supply Chains

The adaptability and flexibility elements illustrated in Fig. 3 were applied to the UHSC model (Fig. 2) to provide potential solutions for the identified problems. The model developed in Fig. 4 is used to illustrate a systems view of an HHSC.

The elements increase *Automation* outlined by the academics Aguirre and Rodriguez [1], Dash et al. [9], and Parker [31]. We recommended that the HSC use robotic processing automation to achieve automation within the supply chain. The elements also increase *SC Coordination* which in turn increases *Employee's Health*. We recommend that collaboration systems are used to encourage coordination.

An increase in *Employees' Health* also contributes to enhanced adaptability and flexibility and improves *Patients' Health* when they are able to take care of more patients by giving them better healthcare. This reduces the number of *Employees Working Overtime* which improves their health as staff are able to better cover for each other when the aforementioned elements are implemented (see Education Sect. 4.4).

The adaptability and flexibility elements also increase *Knowledge in the SC* [26]. When there is increased knowledge in the supply chain, members in the HSC can proactively cover for each other as they understand the supply chain, increasing the supplies available [16]. We recommend that this is done through transaction processing systems along with decision support and knowledge management systems.

Automation increases *Capacity* and the number of *Skilled Workers within the SC* [1, 9]. Employees also experience increased *Job Enrichment* [31], which in turn increases the sufficient *Capacity* [3, 31]. Dash et al. [9] also link an increase in *Skilled Workers* and capacity to increased *Service Levels*.

An increase in *Automation* increases *Education* within the supply chain, according to Maier [26], Heinrich and Betts [16], Schlechty [37], and Watson and Watson [39]. In line with these academics, we recommended that SCs should use learning management systems and knowledge management systems together to maintain a high level of *Education* across the supply chain. Finally, through all these seven IS and *Waste Management* techniques decrease the strain on the HSC and reduces *Overall Waste*.

Briggs [5] argues that implementing models into networks can often be done more easily with IS. To better integrate adaptability and flexibility into the current UHSC we recommend that IS are used at every level of the model. We propose that Workflow Management Systems (WMS), Collaboration Systems (CS), Learning Management Systems (LMS), Robotic Processing Automation (RPA), Transaction Processing Systems (TPS), Knowledge Management Systems (KMS), and Decision Support Systems (DSS) can all be used help integrate the adaptability and flexibility into an HSC.

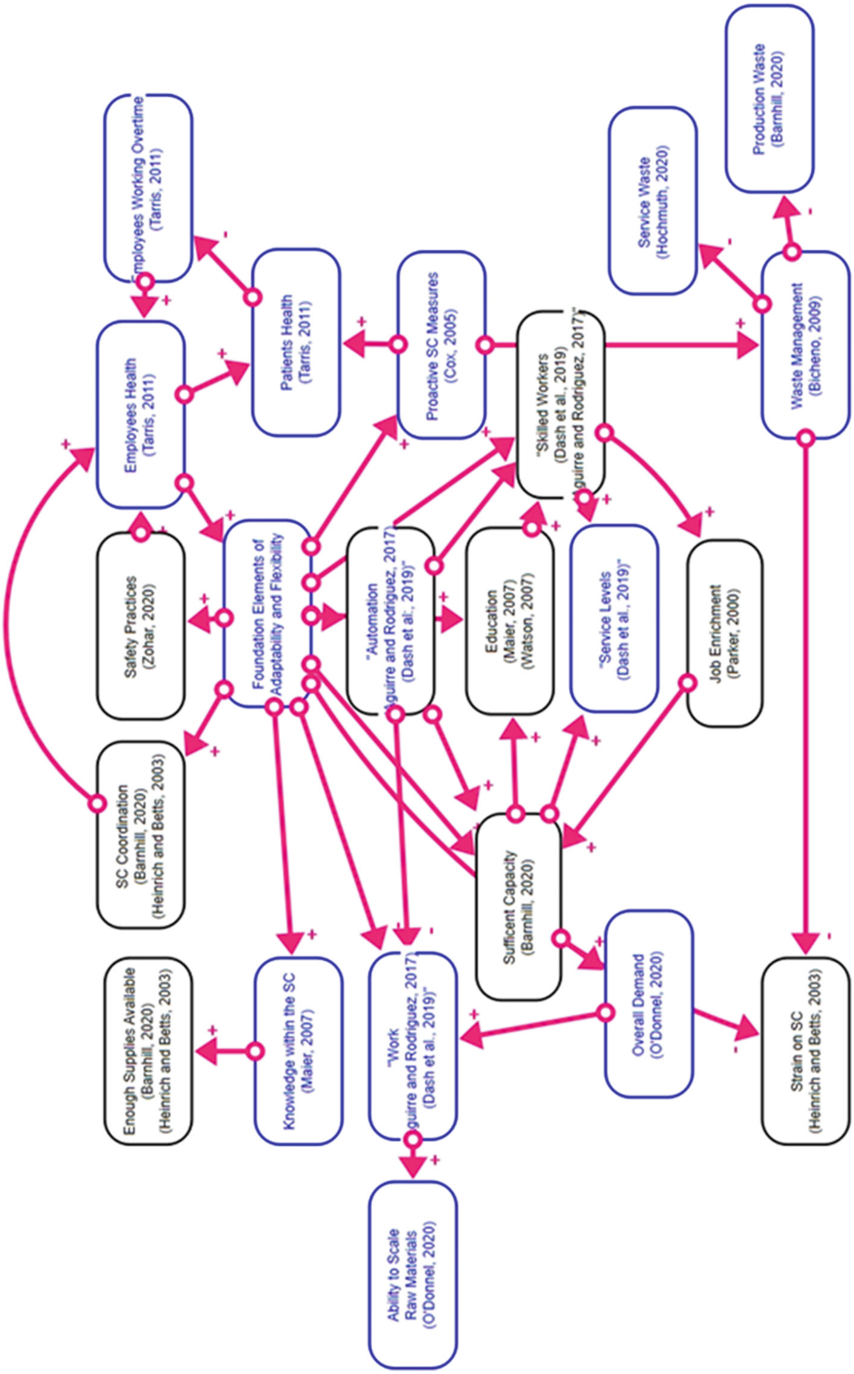

Fig. 4. Causal loop diagram of a healthy healthcare supply chain

6 Healthy Healthcare Supply Chains Systems

The problems identified by in the literature have made it extremely hard for the HSC to function effectively during the pandemic, for instance with the vaccine distribution. There is a significant amount of literature that reinforces the role of information systems to achieve adaptability and flexibility in HSC [35]. For example, Rakovska and Stratieva [35] identified from the literature HSC management practices, types of flows and IS that impact healthcare performance. The adaptability and flexibility elements illustrated in Fig. 3 are founded upon literature to optimize the current SC landscape through different types of IS.

Incorporating these elements through the implementation of appropriate information system can make the process easier [34]. These core IS are illustrated in Fig. 5 and discussed in detail in the following paragraphs.

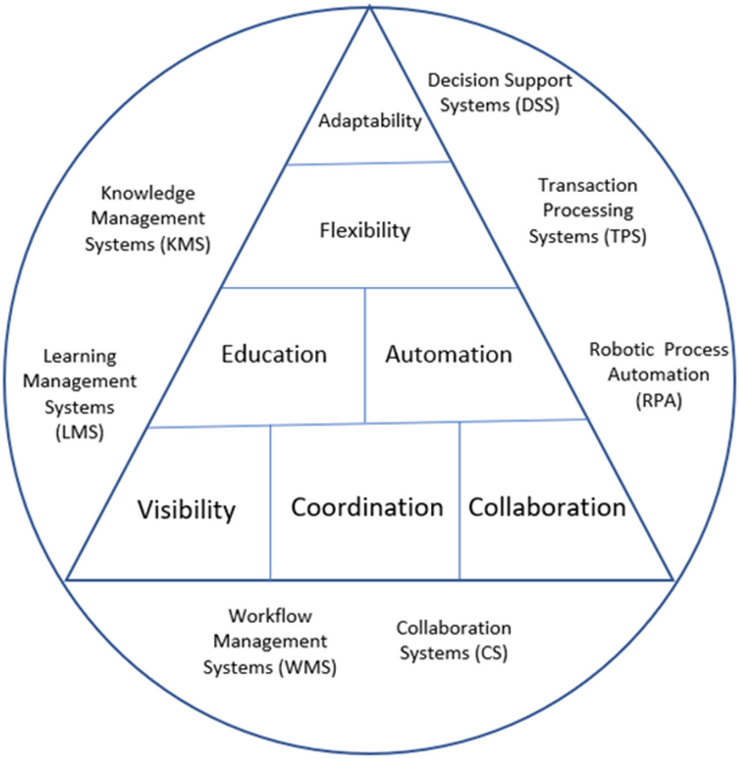

Fig. 5. Core systems to deliver adaptability and flexibility

6.1 Collaboration Systems

According to Heinrich and Betts [16] step four to build an adaptive SC network is collaboration. They recommend using enterprise systems, vendor managed inventory, and other forms of CS. "A collaborative Advanced Planning System is required for successful collaboration" [16]. Collaboration within a healthy SC refers to an increase in production speed between different partners within the supply chain. In Fig. 2 of an UHSC, the collaboration between various partners within the health care SC caused an increase in waste and an increase in the supply chain's overall strain (i.e., fewer resources within the SC causing significantly more pressure on all partners). CS should be used frequently to brainstorm solutions to problems within the SC in the context of an HSC. These meetings should be both internally and externally to ensure that the SC encourages visibility. Finally, the Tools Layer refers to "the capabilities required to instantiate a collaboration technique" [6]. These tools are the CS themselves and how the different partners communicate with each other within the supply chain. Examples of CS include various forms of technology that could increase visibility within the SC [5]. Scripts are "guidance about the things people in various roles should do and say with their tools to instantiate the techniques selected for the group" [6]. In the context of an HSC, partners might consider creating scripts of each other's roles so that in the event of large-scale SC disruption, the SC is not hugely affected. Scripts may require education and other types of IS to be successful.

Having stabilized processes and data, allows companies to better respond to unforeseen circumstances. Without stabilized processes and qualify information responding to these unplanned events will lead to further chaos [16]. Briggs [5] urges those within a complex SC to communicate using CS, mainly through group support systems, which will identify any inaccurate numbers that a supplier may be relying on, further reducing waste within the supply chain. Briggs [5] maintains that when CS is used to increase visibility in a supply chain, there is greater group cohesion and satisfaction and the SC will be able to flow with minimal waste. Further, it is generally agreed in the literature that in certain situations, people who engage with CS are significantly more productive than people who do not [13]. According to Heinrich and Betts [16], the benefits of CS are that there are significant cost savings within the SC and that it "reduces the need for costly emergency and less-than-full truckload shipments." Heinrich and Betts [16] claim that when companies increase visibility in the SC through CS it will reduce the frustration level between a supply chains' employee and its customers, making the company easier to do business with. Heinrich and Betts [16] also cite "better production schedule" as a benefit to increased visibility in the supply chain. Total personnel's cost will also decrease as enough staff will be hired and prepared to complete their roles.

6.2 Workflow Management Systems

Eder [11] suggests that WMS allows for coordination to occur more frequently between community members. WMS allows for traditional tasks like coordination to be done through an "automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules" [11]. Heinrich and Betts [16] builds on Eder [11] work when they suggest that a SC community needs to be able to coordinate and communicate with all the stakeholders to share up-to-date schedules, plans, and forecasts, and mechanize day-to-day orders and other transactions. They recommend inventory tracking systems which contribute to a more adaptable business network allowing for more automated streamlined data processing. Community coordination through WMS encourages activities like day to day ordering to be streamlined through coordination resulting in a more adaptable network [16]. WMS also allows for further cost saving measures, increased safety measures, increased coordination, and overall reduction in service and production waste as well as reduced strain on the supply chain.

For a SC to move towards automation and educating different community members, there are three key requirements: stable technology; accurate data and; procedures are standardized [16]. Referring to the key problems identified during the Covid-19 Pandemic (Fig. 2) the HSC has failed at almost all these steps. If the HSC were able to incorporate some of the WMS discussed above, there would be more stable technology within the SC allowing for medical supplies like the vaccine to be distributed to different countries without so many infrastructure problems [28]. Increased data accuracy would mean that the appropriate about of people would be able to distribute the vaccine, and there would be fewer problems with personnel [3].

6.3 Knowledge Management Systems and Learning Management Systems

One of the critical problems within the SC was 'personal,' according to Barnhill [3]. There was a large shortage of trained healthcare workers within the SC causing further issues with capacity and SC waste [3]. In line with [20] we propose a solution in which all HSC members are educated to do each other's work at a base level. The education process will be done through KMS and LMS. When the education process is done, skilled workers will increase, and further job enrichment will take place. Education will further contribute to flexibility as the SC will suffer less when workers get sick or have to quarantine for an extended period because other members within the SC will be able to fill in for each other.

Maier [26] argues that most KMS have an intranet and a groupware platform in place that offer basic knowledge management functionality and a solid foundation for KMS. Maier [26] goes on to say that these platforms come together with add-ons and extensions, further increasing the functionality of these KMS. Each organization can tailor its own KMS to fit its own organizations' needs. KMS is extremely important for internal visibility, especially with its inbuilt "advanced processes along with advanced information and communication needs" [26]. However, Maier [26] also notes that many KMS' functions are implemented, but not used intensively [26]. This is important as using a KMS as a forum for educational learning would come at a minimal cost to most organizations with an a robust KMS setup. "Therefore, there still seem to be considerable potentials when applying ICT to KM initiatives" [26]. We recommend that different key stakeholders within the SC create and upload videos, scripts, and other forms of notes to their organizations' KMS. The solution will ensure that when there is a reduced amount of personal or a shortage of workers [3] as different employees can step in and help each other out, encouraging flexibility with roles and responsibility and increasing adaptability [16]. It is important to note that currently organizations do not assign people for knowledge management tasks. "About a third of the organizations just assigned responsibility for basic tasks related to the publication and distribution of knowledge, but do not pay equally high attention to what happens to the knowledge once it is documented and inserted into the organizations' knowledge bases" [26]. This means that ideally for the model to flourish organization will need to assign some of these educational tasks to individual departments or specific people to ensure that employees are interacting with the KMS and are working with each other to complete their knowledge management tasks.

In line with the adaptability and flexibility elements, we also recommend that partners integrate an LMS with their KMS to enhance capability to achieve the education element. Schlechty [37] argues that technology will be needed to track each person's progress towards mastering a role. A LMS will assess each employee's learning and how quickly they are able to grasp different roles and responsibilities. An LMS is not common in traditional organizations, however, it is common in the healthcare industry [39]. An LMS could test an employee's understanding of another person's role, assess learners' knowledge and skill level. It will also allow management to work with workers to identify appropriate learning goals, identify and sequence instruction appropriate for the individual learner, store evidence of certification, support collaboration and generate reports [39] to provide information to maximize the effectiveness of learning within the entire HSC. The LMS could recognize if the employee has enough knowledge to assist another person with completing or doing their job.

6.4 Robotic Process Automation

"RPA is an automation technology based on software tools that could imitate human behavior for repetitive and non-value added tasks such as tipping, copying, pasting, extracting, merging and moving data from one system to another" [1]. Dash et al. [9] argue that Artificial Intelligence (AI) can be used as a type of automation to improve SC management at a decision-making level. "AI consists of a set of computational technologies developed to sense, learn, reason, and act appropriately" [9]. Supply-chain leaders use AI-powered technologies to make efficient designs, eliminate waste, increase service level, and increase the number of skilled workers within the SC when they learn how to automate tasks. Automation is essential in the critical role of work redesign and job enrichment [31]. They argue that when automation occurs within a supply chain, workers can be upskilled and learn how to automate. Automation will increase the number of skilled workers in the SC and encouraging job enrichment.

As RPA usually sits on top of an already existing system [1], we recommend that this RPA sits on top of the KMS discussed previously. This will allow employees within the SC to increasing their skills through job enrichment. Job enrichment aims to create more challenging activities for the involved employees. It combines activities on different levels of qualification. A main assumption of job enrichment is that people become motivated by more challenging tasks [1]. One example of job enrichment is the task of getting different employees to learn how to automate easier tasks to make their jobs much easier. The main benefit of RPA is cost reduction, based on productivity improvements, as the case study reveals [1]. In the context of an HSC, RPA could take over repetitive tasks like low-level reporting, purchasing stock, sending out emails, and making and creating meetings. According to Aguirre and Rodriguez [1], other benefits such as process agility are relative to the RPA configuration, hardware capacity, and response time of the applications that the robot needs to access. Error reduction is also a measure that was not measured in the case study [1], however, it could too be improved by using an RPA.

6.5 Transaction Processing Systems

The problems that have arisen from the pandemic have presented an opportunity for the HSC to redesign its systems to create more flexibility within the end-to-end supply chain. For a more flexible process, organization may consider process engineering is one of its main objectives [36]. We recommend that the process re-engineering takes place at the TP IS level. The lowest level TP supports the processing of a firm's business transactions. The HSC can reduce some of its problems by keeping an organization running smoothly by automating the processing of the voluminous amounts of paperwork that must be handled daily [25]. If TP is done by all business partners there may be a reduced strain on the supply chain, and increased information (through visibility) within the SC [21].

6.6 Decision Support Systems

We recommend that the HSC uses Decision Support Systems (DSS) to contribute towards adaptability. Often DSS are considered to be designed for collecting, manipulating and distributing information. Rather, DSS are primarily used by managers to support their decision making process [2]. In the context of adaptive business networks, such as adaptive HSC, Heinrich and Betts [16] posit that organizations have access to an abundance of accurate, real time information which enables operational agility and rapid response to market changes. For example, organizations will be able to gather information about actual patient healthcare and changes in patients' demands in real time. In addition, costly delays that may eventuate when engaging with patients and suppliers are reduced or eliminated when DSS are used to automate a wider range of decisions. Another important aspect of an adaptable SC is having each partner within the SC network exchange a wealth of information related to their business's success. This allows access to more timely and accurate information, which is shared among all appropriate parties in order to react immediately and solve problem when they occur [16]. A useful DSS in an HSC will combine all the relevant information from the entire network and predict what the decision-maker will do by allowing them to select the best response to a potential disruption in the SC or in the environment. A DSS can only have capability when a certain level of standardization takes place however it will only have functional capability when adaptability takes place [16].

7 Conclusion

The research conducted in the area of HSC has experienced growth over the years, particularly with the increased focus on technology and IS. To build upon and contribute to this research, we looked at HSC literature from a post Covid-19 pandemic perspective. This research aims to first look at the problems that arose from the pandemic and provide solutions using principles of e-health, SC and IS. Adaptability, flexibility, education, automation, visibility, coordination, and collaboration were all looked at in the context of a post-pandemic world. These elements were interwoven with seven types of relevant IS to enhance the model, and better allow a UHHSC to transform into an HHSC. The literature was viewed from two main views, an UHSC view and an HHSC view. Two system dynamic models were illustrated to showcase relationships between the different aspects and to elaborate on the views. Each aspect and its relevant relationship were taken from literature. This research is by no means definitive, and the solutions provided will not be applicable to every supply chain; however, at the least, the elements of adaptability and flexibility and the system dynamic views of UHSC and HHSC provide the basis for further research.

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