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An analytical framework for digital transformation in healthcare product supply chains

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Abstract

This paper presents an analytical framework for digital transformation in healthcare product supply chains. It aims to systematically analyze the impact of digital initiatives across the Supply Chain Operations Reference (SCOR) model's categories: Enable, Plan, Source, and Deliver. The study explores how digital technology enhances access, affordability, and adoption of healthcare products while influencing decision-making architecture and improving supply chain actor agency and accountability. The methods used in this study include a systematic analysis of digital initiatives within healthcare product supply chains, framed by the Supply Chain Operations Reference (SCOR) model, supported by case studies and real-world examples. The results revealed that digital technology has a profound impact on improving healthcare product supply chains in several key areas including enhancing product availability, improving affordability, and expediting the adoption of new health products. The paper indicates that digital solutions significantly enhance access to healthcare products by improving visibility and traceability throughout the supply chain, leading to better inventory management, fewer stockouts, and more efficient distribution. Furthermore, the findings suggest that digital interventions help reduce costs, contributing to affordability by streamlining procurement processes, minimizing transaction costs, and optimizing resource allocation. Additionally, the results indicate that digital tools accelerate the adoption of health products by enabling real-time data analytics, which supports faster decision-making and more efficient approval processes. The findings also reveal that digital technology reshapes the decision-making architecture within supply chains which allows for more decentralized, data-driven decisions that enhance the agility and responsiveness of supply chain actors. However, the results emphasize that the long-term effectiveness of digital solutions hinges on their ability to empower supply chain actors and improve accountability. The paper concludes that governments when developing digital transformation roadmaps, should prioritize areas where lack of information is the primary constraint.

Keywords: An Analytical Framework; Digital Transformation; Healthcare Product Supply Chains

1. Introduction

The healthcare supply chain is a complex, interconnected network that ensures the efficient delivery of medicines and other medical supplies to patients. This system involves several key steps, including demand forecasting, procurement, distribution, and dispensation [1]. While the ideal scenario is one of seamless coordination and minimal discrepancies between supply and demand, the reality is often more challenging, with issues such as imprecise demand forecasting, lack of collaboration among supply chain actors, and disruptions in information flow [1,2,3]

Digital technology holds immense potential to transform this intricate supply chain system. Since the early 2000s, digital solutions have been instrumental in improving supply chain management across industries, including health care [4].

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Over the past decade, and particularly during the COVID-19 pandemic, the use of digital technologies in health product supply chains has increased significantly.

Digitalization can improve supply chain integration and performance in various ways. For instance, big data analytics can enhance customer customization, while sensors, cloud solutions, and additive manufacturing can shorten the distance and response time to target markets, benefiting smaller and more responsive businesses [5]. The convergence of breakthrough technologies and biomedical science is poised to reshape the healthcare ecosystem, moving beyond traditional hierarchies and empowering all stakeholders to participate and benefit. Leaders in the healthcare industry will need to reevaluate their business models, processes, and workforce structures to meet strategic objectives, such as enhancing the patient experience, optimizing outcomes, empowering healthcare workers, and increasing operational efficiency [6].

The health care sector, with its intricate and complex supply chains, has been the subject of extensive discourse surrounding the potential of digital solutions to address its myriad challenges. While some believe that digital technologies can singularly resolve all supply chain issues, others view them as largely theoretical and irrelevant, prioritizing the need to address fundamental governance and infrastructure challenges [6,7].

However, the reality lies somewhere in between these two perspectives. Digital solutions, when strategically implemented, can yield significant improvements in access, affordability, adoption, and decision-making within healthcare supply chains [7].

The responsibility for selecting and investing in digital solutions often falls on government agencies, as they typically manage the health sector supply chain in many countries. These agencies, however, often lack the in-house capacity to effectively prioritize and sequence digital solutions, as well as a comprehensive understanding of the evolving landscape of digital technologies available for supply chain optimization [7].

To address this gap, this paper presents a framework for understanding the role of digital technology in health care supply chains, highlighting the specific areas where digital solutions have demonstrated clear performance improvements.

2. Literature Review

Several authors have discussed how health product supply chain technology offers great promise in addressing the problems affecting various supply chain functions. Based on frameworks including the Supply Chain Operations Reference model, this literature examines the interactions between various supply elements concerning the role of digital tools characterized by planning, sourcing, manufacturing, delivery, and returns. Based on a synthesis of information derived from literature published in the last decade, this paper sheds light on potential strategies for using digital technology to improve SCS performance and the subsequent consequences.

2.1. Digital Interventions in Health Product Supply Chains: A Strategic Framework

Effectively managing health product supply chains requires navigating a complex landscape involving multiple steps, actors, decisions, and information sets [8]. To assist health system managers in this endeavor, this paper presents a strategic framework that leverages the established Supply Chain Operations Reference model to systematically examine the role of digital technology across various supply chain activities [2,9,10].

The Supply Chain Operations Reference model categorizes supply chain functions into six main processes: Plan, Source, Make, Deliver, Return, and Enable. This framework provides a useful lens for evaluating digital interventions and their impact on supply chain performance.

In the planning process, digital tools can enhance demand forecasting, inventory management, and overall supply chain coordination. In the sourcing process, digital technologies can improve supplier selection, contract management, and order processing [11]. In the manufacturing process, digital systems can optimize production schedules, monitor quality, and enable track-and-trace capabilities [12].

The delivery process can be enhanced through digital routing, fleet management, and customer relationship management systems. The return process can benefit from digital reverse logistics, warranty management, and customer feedback systems. Although Make and Return logistics form the fundamental loops of healthcare supply chains, this paper analyses the Plan, Source, Deliver, and Enable processes to assess the effects of digital transformation

on enhancing the performance of healthcare supply chains. As shown in Figure 1, these processes are used to illustrate how digital technologies can improve performance in availability, affordability, and access of products and services, facilitate global embrace, and redesign of supply chain.

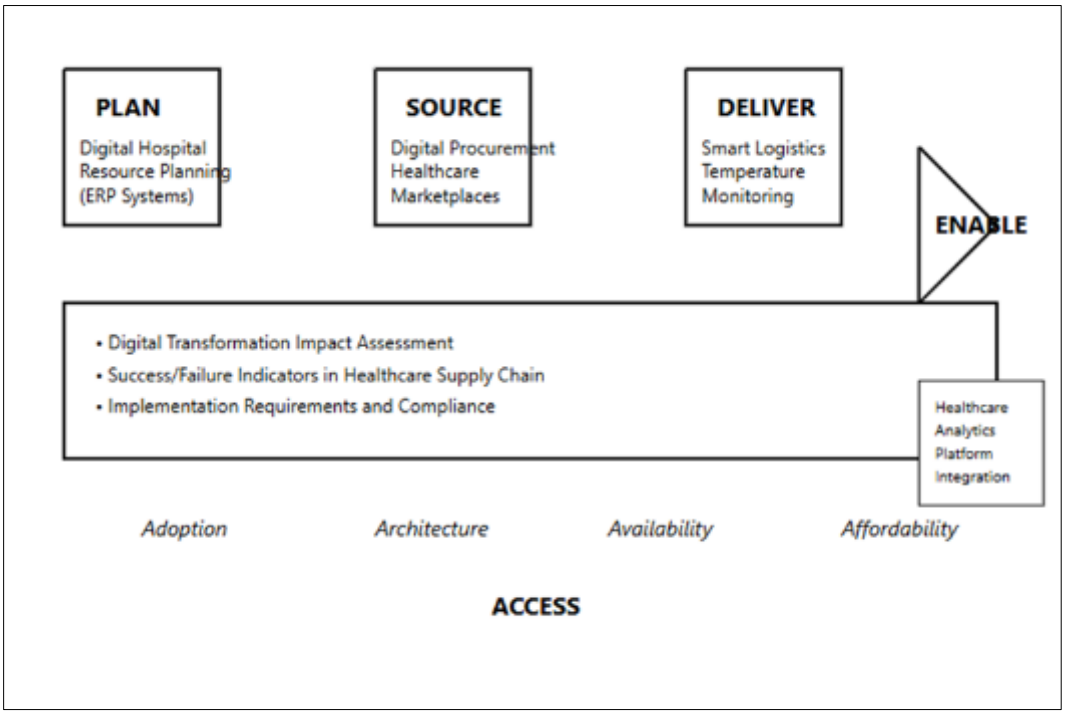

Figure 1 Framework for analysis of digital solutions in health supply chains

The Plan process entails using the process of Digital Hospital Resource Planning which is the ERP system to improve on use of resources and the flow of work. Supplier collaboration concerns are also highlighted by Source through Digital Procurement and Healthcare Marketplaces. Smart Logistics solutions actively monitor and maintain shipping conditions while keeping customers informed throughout the delivery process. These systems track critical factors like temperature in real-time, ensuring product quality and compliance with healthcare standards. The Enable process works alongside this by serving as the foundation for broader system transformation. It does this by connecting various analytics platforms, enforcing regulatory compliance, and using collected data to drive continuous improvements. Together, these processes ensure not just reliable delivery of healthcare products, but also create a framework for ongoing system optimization and quality assurance that benefits both providers and patients. Specific examples from peer-reviewed and grey literature that are incorporated into this paper demonstrate a systematic and quantifiable approach to the use of digital interventions. For example, the Enable process is described, including sections that address availability, affordability, and supply chain design. Following these dimensions incorporate the analysis in subsequent sections, into each example. Based on the findings, figure 2 summarizes the outlined digital interventions, specifying their effects on the pathways to integrating enhanced access to health care. The selected examples focus on governments, and public health care systems, in which payments can be made by GAVI, the Global Fund, or by the government of the particular country. In this case, the affordability dimension looks at service cost and the burden it imposes on the payer. Further, examples from the out-of-pocket (OOP) market have been incorporated to show how digital interventions intervene and offer immediate value propositions to the patient in terms of overcoming the last level of cost. While the components of the SCOR (Supply Chain Operations Reference) model are arranged linearly, this does not mean that they must be implemented in the same fashion. Digital transformations require interventions on all four value activities, namely Plan, Source, Deliver, and Enable. Staple and the next best solutions to address depend on aligning urgent issues that exist in healthcare systems with the most effective of digital innovations.

Supply Chain Process Category	Example(s)	Pathways to Impact on Access
ENABLE Healthcare Analytics Platforms enhance visibility throughout healthcare supply chain	Epic Analytics Cerner HealtheIntent	Availability: 1) Real-time inventory tracking 2) Predictive analytics for demand Affordability: Reduces waste, optimizes stock levels
PLAN Hospital Resource Planning Systems for forecasting	SAP Healthcare Oracle Healthcare	Availability: Accelerates response times for stock reallocation Optimizes supply distribution across departments Affordability: Automates planning tasks, reduces manual errors
SOURCE Digital Healthcare Marketplaces	GHX Medline	Availability: Better supplier selection mechanism Improved visibility of supplier inventory Affordability: Enables volume aggregation and competitive pricing
DELIVER Smart Medical Logistics Temperature Monitoring	IoT-enabled Transport Cold Chain Solutions	Availability: Reliable delivery of sensitive items Real-time tracking and monitoring Affordability: Optimized routes, reduced wastage Lower transportation costs

Figure 2 Summary of Digital Interventions across supply chain process categories and their impact on Access.

3. Digitization in the Enable Process for Improving Health Supply Chain Performance

The Enable process within the supply chain management framework encompasses all activities related to collecting, organizing, and sharing information and services among supply chain partners. This includes generating and analyzing planning and performance data to support the other supply chain process steps in achieving better operating performance [13]. Efficient information exchange across all supply chain levels is relevant for the health product supply chain to achieve its desired outcomes [14]

One key aspect of the Enable process is the use of digital tools and technologies to enhance visibility throughout the supply chain network. These digital interventions can provide granular data on stock levels, orders, shipments, and consumption, strengthening accountability and performance management in the overall supply chain and reducing stockouts [13]. Additionally, this data can create opportunities for algorithm-based decision support for forecasting, ordering/requisitioning, and inventory management, ultimately improving the availability and affordability of health commodities [15]. For instance, the eVIN system implemented in India has demonstrated how digital tools can enhance visibility and enable better supply chain decision-making. Furthermore, digital platforms that facilitate collaboration among supply chain stakeholders, such as the Global Family Planning Visibility and Analytics Network, can accelerate response times for stock reallocation or shipment transfers, optimally and expeditiously allocate surplus stock, and avoid product expiry [16].

Digital technology has the potential to enhance the end-to-end visibility of medical supplies throughout the healthcare supply chain network, including what supplies are in stock and how much has been ordered, shipped, and consumed. Digital solutions could improve the monitoring of medical supply consumption rates, stock levels at all stages, risks of stockouts or product expiration, temperature deviations in pharmaceutical cold chain equipment, and functionality of medical and diagnostic equipment. Modeling studies indicate that using digital healthcare supply chain solutions that track stock levels, receipts, and consumption information for medicines and medical supplies could potentially avert up to 5% of adverse patient outcomes in comparable healthcare settings [17].

Since 2004, many healthcare supply chain solutions have been developed using mobile devices or other digital platforms at healthcare facilities. Several such technologies are documented in healthcare literature; examples include openLMIS in hospital networks [18]. SMS-based inventory systems integrated eLMIS for healthcare facilities' digital supply chain platforms like AbastoNET [19], and automated inventory tracking systems [20]. While some have demonstrated

sustained impact, many faced challenges with slow adoption or decreased utilization after initial implementation. A major challenge was that while these digital solutions generated granular information about medical supply stockouts, hospital staff had limited authority to effect significant changes, as root causes often stemmed from procurement decisions made at regional or national levels [21]

These cases suggest that the lack of success of digital solutions in healthcare systems can be attributed to system designs that prioritize administrative reporting and central planning requirements over the needs of healthcare providers and end-users. Additionally, there is a tendency to digitize all aspects of the healthcare supply chain too rapidly, resulting in increased complexity for frontline healthcare staff [22].

4. Case Study on a Digital Solution for the Enable Block: Vaccine Tracking and Distribution System (VTDS) in the United States

A great example of digital transformation in the Enable block of the healthcare product supply chain in the United States is the Vaccine Tracking and Distribution System. Its arguments show how digital technology can improve vaccine stock management, supply chain operations, and the overall function of the healthcare sector. The VTDS in particular was proposed during the COVID-19 era because of the extraordinarily high demand for the vaccines. Fully adopting enhanced IT support, the system was intended to monitor stock of the vaccines, the field distribution as well as the consumption of vaccines. The key aim was to promote rational distribution of vaccines from central and provincial levels to afford equal vaccine coverage to different provinces, minimize the expenditure incurred by wastage, and avoid stockouts.

At the heart of the VTDS were real-time systems such as mobile applications and cloud-based platforms that enabled the recording of stock levels, patient vaccinations, and inventory usage. These were supported by digital tools augmented with thermometers at the storage centers to ensure that the vaccines stayed within the correct temperatures as required in the cold chain. The collected data was then periodically uploaded to a central database, which helped public health authorities determine where the vaccines were being administered and where there was a scarcity of these vaccines. The impact of VTDS can be assessed through the four dimensions of access within the Analytical Framework for Digital Transformation in Healthcare Product Supply Chains:

4.1. Availability

Nascent availability systems in the US health sector illustrate how digital paradigms have currently reshaped resource management networks [23]. However, through its implementation, eVIN saw a 30.4% reduction in stockouts, on the other hand, the US healthcare system presents multiple challenges owing to a multiple-payer system coupled with multiple networks of healthcare delivery [24]. Contemporary American care settings are incorporating complex IT applications that are connected with EHRs, comprehensiveness of stock, and auto-replenishment of stock. These systems incorporate demand prediction to proactively identify potential lapses in supply and manage inventory and distribution centralized across numerous facilities within hospital groups to increase the robustness and flexibility of the supply chain.

4.2. Affordability

Affordability considerations in US healthcare supply chain digitization take on particular significance given the high costs associated with American healthcare delivery. The ROI principles demonstrated by eVIN's implementation (showing a basic cost-to-return ratio of 1.41, increasing to 2.93 after amortizing fixed costs) [18]. This has become even more crucial in the US context, where healthcare systems must manage expensive specialty pharmaceuticals and complex insurance reimbursement requirements. Digital transformation initiatives in US supply chains must demonstrate clear financial benefits while supporting the transition to value-based care models and addressing the persistent pressure to control healthcare costs.

4.3. Architectural framework

The architectural framework for US healthcare supply chain digitization requires careful consideration of the nation's unique healthcare ecosystem. Unlike simpler systems, US solutions must accommodate multiple payer systems, strict HIPAA compliance requirements, and complex integration needs across different electronic health record systems. Barbarito et al., [25] underscored that “These solutions must create interoperable systems that can securely share data while maintaining patient privacy and coordinating effectively between providers, pharmacies, distributors, and manufacturers”. This complexity necessitates sophisticated technical solutions that can handle multi-stakeholder communication while maintaining regulatory compliance.

4.4. Adoption

Adoption strategies for digital supply chain solutions in US healthcare must address several relevant factors to ensure success. Per Willie, [26], Integration with existing healthcare IT infrastructure becomes paramount, as does compliance with regulatory requirements and effective training programs for healthcare staff. The scalability of these solutions across different healthcare settings, from large hospital systems to small rural clinics, requires careful consideration of varying technical capabilities and resources [26]. Successful implementation depends on gaining buy-in from healthcare administrators, support from medical staff, and clear alignment with value-based care initiatives. The sustainability of digital supply chain solutions in the US healthcare context requires attention to both technical and organizational factors [27]. Technical requirements include robust HIPAA-compliant data security measures, seamless integration with existing electronic health records, mobile accessibility for healthcare workers, and reliable offline capabilities for rural areas. The political and organizational landscape demands careful navigation, including securing support from key stakeholders, demonstrating clear return on investment, and aligning with broader healthcare quality improvement initiatives.

5. Digital transformation in US healthcare product supply chains

An important component of healthcare value planning is the digitization of the planning block in supply chains for healthcare products to effectively match supply and demand/ This efficiently procures supplies, balance supply, and meet the communication needs of the supply chain members. The core functions of the Plan block include operations such as balancing available supplies and requested orders, which are supported by digital technologies in terms of data accuracy, granularity, and availability [28]. Several of these advances allow for quicker decision-making, adaptability, and coordination across system leaders, building authorities, and district coordinators [29]. Digital tools therefore support a system where plans are dynamic and change according to real-time supply-demand conditions.

One of the rare examples of digital transformation in healthcare supply chain planning is the Global Family Planning Visibility and Analytics Network (VAN). The VAN partly automates the planning function by providing a single digital environment in which planning tasks can be performed, with data fed from other sources [30]. This platform enables CMPs to plan together effectively by synthesizing and standardizing the data that feed analytical models. For example, in July 2021, the VAN to a shortage in the supply of contraceptives that was about to happen in Togo. Using online tools, the VAN helped coordinate action, finding out there was excess stock in Niger and arranging delivery of 50 thousand pieces to Togo. They not only enabled the company to avoid stockouts but also reduced wastage due to overstocked products. What the VAN example shows is that even with the best software in place, people also still need sound institutions to rely on to make decisions, whether it is the West African Health Organization (WAHO) that had the structures through which the insights generated by the VAN could be actioned [31].

Empirically, Machine learning and Artificial intelligence are receiving an increasing role in supply chain planning and especially in demand predictions. They use data from various information systems like EMRs, logistics, and even informal reports from the front-line employees to provide very accurate prognoses [18]. For instance, advanced early adopters in the US healthcare system, such as major hospital networks and integrated delivery networks (IDNs), have demonstrated significant improvements in forecasting accuracy, with some facilities reporting up to 50% reduction in prediction errors [32].

Through more precise demand forecasts powered by AI/ML, these healthcare organizations have successfully reduced overstocking of expensive medical supplies and pharmaceuticals, minimized stockout occurrences that could impact patient care, and optimized resource allocation across multiple facilities within their networks [18]. However, all these technologies will only be as effective as the underlying process flows of requisitioning and stock allocation that accompany them. Even when perfect forecasting is possible through sophisticated AI algorithms, the lack of standardized workflows and integration with existing electronic health records (EHR) systems may hamper the mechanisms through which these predictions translate into effective inventory management. This is particularly relevant in the US healthcare context, where complex reimbursement systems, multiple stakeholders, and varying facility requirements necessitate robust processes that can effectively act on the insights generated by advanced forecasting tools.

6. Digitalization in the Context of the Source Process Block

Source is another concept in the supply chains and process block of healthcare products that comprises procurement activities such as supplier contracts, payments, and delivery performance checks. In the United States, e-procurement systems known as digital transformation in this block enhance health, transparency, efficiency, and cost in the

procurement of health products [33]. As common with other e-procurement platforms, the bidding procedures are optimized, the price haggling is facilitated, and both errors and time wastage due to inefficiencies are minimized. They also provide a structured way of acquiring data about the suppliers that can go a long way in helping inform decision-making about which supplier to select or how best to manage a given supplier [18]. These platforms prevent corruption risks and place much emphasis on public scrutiny. In turn, e-procurement has its advantages only when various complementary measures are in place, including, for example, demand aggregation incentives, since mere volume consolidation cannot be achieved through the use of the electronic procurement platform.

Initiatives by the U.S. government such as Digital Procurement through General Services Administration (GSA) eBuy have demonstrated such advantages other developing countries need to adopt digital procurement. eBuy is an online business-to-business trading portal for federal procurement that supports competitive bidding and offers easy contract management across federal departments including those in the healthcare industry [34]. It has also resulted in increased supplier opportunities, decreased procurement expenses, and overall increased transparency when granting contracts. Also, this central database improves the supplier's evaluation since the compliance record and the general performance are accessible. The ideas incorporated in these changes have concentrated procurement processes and asked the least of administrative practicalities while improving on the selection fairness of suppliers as a model of how technology is capable of revolutionizing sourcing in the healthcare chains supplied [34].

7. Digitalization in the Context of Deliver Process Block

According to Huria [35], The Deliver process block implies taking orders from customers, storage, and transportation of the consignment, which can be a serious problem in cases with vast distances, especially in rural regions. These challenges caused the inadequate distribution of health products; through inefficient transport and the unavailability of strong infrastructure which impacts the functionality of the health supply chain. In confronting these questions digitalization provides new initiatives for improving transportation and distribution. Thus, using digital technologies, the stakeholders can improve order management, merge deliveries, and optimize last mile [36]. They make supply chain supply more responsive, cheaper, and more accessible to vital health commodities, especially in hard-to-reach areas.

Some of the digital innovations in the Deliver process block in the USA are; Digital freight and logistics such as Convoy and Uber Freight. These platforms exploit the use of mobile and cloud technologies to link shippers with carriers to enhance the provision of solutions on the transport chain of products such as healthcare products in the country. For small pharmacies and health facilities in remote, or hard-to-reach areas, it allows for placing orders online and tracking the delivery in real-time. These systems take multiple quantities of small orders and consolidate them into LTL shipments, utilize pricing models that change with frequency, and put together customers with carriers who offer the best price [37]. This model shows how tremendous costs can be cut down from supply chain or distribution and how efficiently it can be made through digital logistics platforms. With aggregation of consignments and optimization of routes, these technologies help to prevent unnecessary time loss and guarantee the delivery of health products to remote regions [38]. As a consequence, there are cost reductions as regarded to be borne by both the healthcare providers and the consumers or users, thus being good for both the healthcare providers in terms of cost reduction and patients in terms of increasing the pool of available basic stock. This approach carries the message of the great capability of digital solutions in the change of the healthcare supply chains, presenting a reference for the solutions of the logistical issues and the improvement of the delivery systems across the country.

8. Summary of the Findings

Digital technologies provide prospects to revolutionize enabling, sourcing, planning, and delivery in the supply chain of the healthcare industry. These technologies are examined as factors that lead to increased product accessibility, price reduction, and enhanced efficiency within an analytical lens of digitalization. They increase the rate at which new health products are taken up and encourage innovation in the ways that organizations collaborate and in the continual measurement of performance and subsequent decision-making processes. Nevertheless, the benefits of using digital technologies in health supply chains seem rather limited at present, with few comprehensive national-scale applications achieving sustainable success. LMIC health systems have faced hurdles in implementing digital solutions for chronic disease care because of integration issues and, more often, a lack of preparedness. To successfully address these gaps, digital interventions must be integrated according to the development of the digital environment, the structures of the supply chain, and other relevant circumstances such as the agency of the frontline workers.

The framework highlights the need to establish digital solutions in operation processes, as well as the need to make sure the healthcare staff can use digital solutions to cause specific changes to the demand and supply side. Successful

initiatives have demonstrated that combining automation and integration with advanced analytics can significantly enhance efficiency and performance in private healthcare markets. However, the largest gains come from socio-political innovations that digitalization enablers as opposed to other growths in technology. Parity of power relations between buyers and suppliers through the practice of accountability and transparency, combined with accurate and timely information can create better equality. The paper also revealed that there is a need for public funding in pioneering digital services to enable them to penetrate the most challenging unrecognized territories. This cooperation between the state and commercial companies is relevant for stable development.

9. Policy Action Ideas Within an Analytical Framework for Digital Transformation in Healthcare Product Supply Chains

We find that healthcare product supply chains' digital transformation is headed or supported by private players who are well-apprised of the latest technologies. These organizations show their efficiency in the application of the most contemporary digital technologies in the sphere of the private sector. However, problems emerge when they try to engage governments or Ministries of Health which usually may not have adequate knowledge, let alone, the capacity to handle such advanced technologies efficiently. Governments, often striving to minimize costs and navigate uncertainties, face the key question: Should they use a ready-to-buy digital product, modify an existing tool, or design a solution? The decision-making is made more challenging by factors such as economies of scale in the application of supply chain solutions and this has made it challenging for governments to encourage competition in such markets. As a result, many LMICs barely act or else lose chances to capture the potential value that digital transformation can create in the field of healthcare supply chains.

10. Strategic Roadmaps in Digital Transformation Within Healthcare Product Supply Chains

To meet this challenge, national governments require roadmaps to assess where the segments of the HC product life cycle—Enable, Plan, Source, Make, Deliver, and Return—will be most favorably impacted by digital technology. These roadmaps should provide a clear assessment of the theoretical and demonstrated value of digitization while addressing the following dimensions: Technology & Infrastructure requirements evaluating the readiness or the systems' readiness level in the deployment of digital applications with reference to factors such as lower-level data infrastructure and personnel expert in technological and process elements. Organizational Readiness Assess political support, funding, roles of the implementing agency and its staff, and performance incentives which are fundamental implementation factors. Environmental Readiness Secondly, evaluate market competence, meaning competent suppliers and the government's regulation capacity for the digital technology industry. An appropriately designed strategy makes it easier to see how digital interventions will enhance existing capabilities and can be sustained in the healthcare supply chain. After years of execution of operation strategy, it became quite clear that while it might be useful for day-to-day management and to optimize and control operations, the operation strategy risks neglecting long-term innovation and strategic advancement. Therefore, the public sector healthcare supply chains face an important and challenging task of performing traditional tasks while also learning to integrate technologies. To this end, it is possible to create a supply chain 'center of excellence' within the required public agency. This center would minimize the progression of core operational activities from the development and delivery of digital mandates while facilitating well-ordered procedures for governance in addition to providing the freedom necessary for agility and density. Extending Principles all over the World & Knowledge Management International coordination can further support digital transformation by: Collaborating with key stakeholders and policymakers to design universal principles suitable to be applied to health product supply chains that will be informed by existing frameworks such as "The Donor Alignment Principles for Digital Health" Framework. That is why there should be a centralized registry of initiatives in digitization similar to the WHO Digital Health Atlas, for the participants of healthcare supply chains and with best practices concerning healthcare supply chains present in the described registry. Heuristic to Rank and Sort Technologies uses an analytical framework, such as the SCOR model (Enable, Plan, Source, Deliver), governments can systematically evaluate digital interventions based on their impact on:

Availability: Continuous deliver of identical high quality of health care products. Affordability: SKU rationalization: It is a common occurrence that many products have several SKUs satisfying the same customer needs, containing the same subassemblies or components from the same manufacturing sources but sold in different versions are identified for their cost reduction across the supply chain. Adoption: Increasing the speed at which new healthcare products are adopted as essential by people. Architecture: Restructuring decision-making power relations and organizational systems. This prioritization approach helps governments to come up with practical strategies to address problems without being overwhelmed by some processes, which this paper discusses below. Exceptionally, it also presents

opportunities for investigating the emergence of the return on investment and contextual advantages of specific digital applications through which the digital transformation of healthcare product supply chains is further enhanced.

11. Conclusion

The digital transformation of healthcare product supply chains presents an opportunity to revolutionize accessibility, affordability, and efficiency. Even though private sector players have demonstrated the effective application of digital technologies, integration challenges persist within public sector health systems, particularly in LMICs. Governments face significant decisions regarding whether to adopt, adapt, or develop digital solutions, often hindered by resource constraints, regulatory barriers, and a lack of technical expertise. To overcome these challenges, national governments must adopt strategic roadmaps that assess the impact of digital technologies across key supply chain segments, ensuring readiness in infrastructure, organizational capacity, and regulatory frameworks. A structured approach, such as the SCOR model, can help prioritize digital interventions based on their impact on availability, affordability, adoption, and architecture. Additionally, fostering international collaboration, establishing knowledge-sharing platforms, and aligning with global best practices can accelerate sustainable digital transformation. Ultimately, achieving long-term success requires technological innovation and socio-political reforms that promote transparency, accountability, and equitable power dynamics in the healthcare supply chain. Through integrating digital solutions effectively and ensuring public-private collaboration, healthcare systems can harness the full potential of digitalization to improve health outcomes and enhance supply chain resilience.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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