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Digital transformation in the health product supply chain: A framework for analysis

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Abstract

Well-functioning supply chains for medicines and other health products are vital for a health system's goals of ensuring access, quality, and efficiency. However, in several countries the performance of government-run supply chains for health products remains subpar. The widespread adoption of digital technology presents new opportunities for enhancing the performance of the health product supply chain. This paper aims to provide a practical and systematic analysis of digital initiatives within health product supply chains. It provides examples of successful digital interventions in each of the Enable, Plan, Source, and Deliver categories of the Supply Chain Operations Reference model. The examples provide clear evidence that the use of digital technology in the health supply chain can improve access and affordability; in some instances, use of digital technology can lead to faster health product adoption and alter the overall architecture of decision making. While many of the digital interventions in the public sector supply chain target the collection of data and its analysis and use for reporting, the long-term effectiveness of digital solutions hinges on their ability to enhance the agency of supply chain actors. A thorough and systematic inquiry about the logic model of how a particular digital solution enhances agency and improves accountability is essential at the outset. In developing roadmaps to prioritize and sequence digital solutions in health supply chains, governments should start by asking where the lack of information is the primary constraint impeding supply chain performance.

Introduction

The healthcare supply chain is a vast interconnected network of sub-systems that collectively ensure the production, distribution, and delivery of medicines and other healthcare supplies to patients (Yadav 2015). Within most health systems, the journey of health products from manufacturers to end-patients involves several key steps. First, both public and private entities within the health system analyze historical demand and future events to forecast demand. Using this information, procurement agencies then plan and initiate purchase orders, which are fulfilled by manufacturers or their authorized agents from either existing inventory or newly-produced batches. Once the products arrive at a central distribution center, they are then transported to various health clinics, pharmacies, and hospitals.

Ideally, the system operates smoothly with minimal discrepancies between demand and supply at each point. However, achieving this ideal state is rare. Forecasting demand remains an imprecise science, and data on demand can be inconsistent and incomplete. Lack of collaboration and coordination within the system often leads to a lack of understanding between different links in the supply chain, resulting in disruptions to the flow of information. This disruption occurs in both directions, from the end-patient to the manufacturer and from the manufacturer to the clinic or healthcare service delivery point (such as clinics, pharmacies, health posts, communities, or even patients' homes).

Digital technology holds the promise to transform multiple aspects of this intricate supply chain system. Since the early 2000s, digital technology has been instrumental in improving supply chain management across various industries (Simchi Levi et al. 2008, Angelopoulos et al. 2023), including healthcare. Over the past decade, and particularly during the COVID-19 pandemic, digital solutions have found increased use in supply chains for health products, in high-income countries as well as in low- and middle-income countries (LMICs). This has yielded a spectrum of outcomes; some instances of employing digital technology in healthcare product supply chains have demonstrated success, while others have faltered.

The role of digital technology in heath product supply chains, especially in LMICs, is often misunderstood. Many erroneously believe that digital solutions can singularly resolve all supply chain issues in the healthcare sector, while others perceive digital technology as largely theoretical and irrelevant in contexts where fixing governance and infrastructure challenges must take precedence. Neither of these perspectives is entirely accurate. This dual understanding is, in part, attributable to the intricate nature of supply chains themselves and, to some extent, to the absence of a comprehensive framework for analyzing the applications, potential benefits, and challenges of digital technology in healthcare product supply chains.

The development and implementation of supply chain digital solutions is typically carried out by global or local private technology companies. In many countries where the government manages the health sector supply chain, the responsibility for choosing and investing in digital

solutions typically falls on the government agency. However, these agencies have limited in-house capacity to prioritize and sequence digital solutions and lack full information about the landscape of new digital technologies for the supply chain.

The main objectives of this paper are to help governments determine: where to implement digital technologies in the health product supply chain; how to sequence and prioritize different use cases; and, how to avoid the pitfalls of digital solutions without clear logic models that will not yield long-term performance improvements. The paper starts with a framework for understanding the role of digital technology in health product supply chain. For each of the categories in the framework, it provides examples in which digital technologies have led to clearly-demonstrated improvements in access, affordability, adoption, or decision architecture. The paper then proceeds to explore insights that are common across the different categories and examples. It concludes by offering recommendations on how policymakers can more efficiently harness digital technologies to achieve sustainable long-term performance improvement in the health system.

A framework for understanding the role of digital in health product supply chains

Considering the multiple steps, actors, decisions, and information sets involved, it is important for health system managers to have a strategic framework which they can use to analyze the role of digital technology in health product supply chains. In this paper, I utilize a simple framework for categorizing digital interventions within health product supply chains. The framework attempts to distill the various activities in the supply chain into a handful of readily comprehensible categories, link them to desired performance dimensions, and provide 1-2 notable examples for each.

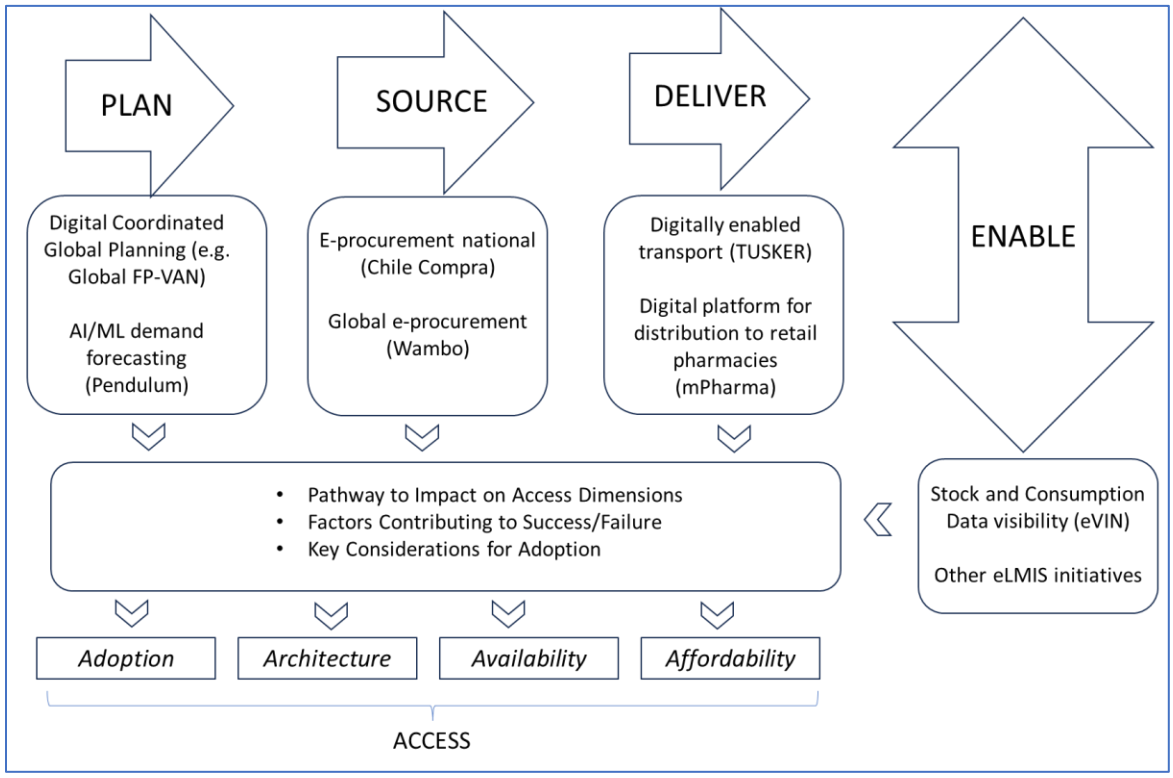
For categorizing different activities in the supply chain, I use the Supply Chain Operations Reference (SCOR) model (APICS 2017, Lambert 2005). The SCOR model was created in 1996 by the Supply Chain Council, a voluntary consortium of over 60 leading manufacturing and supply chain companies, in order to have a common set of supply chain definitions across disparate industries (Huan et al. 2004, Bolstorff and Rosenbaum 2003). As supply chain practices have evolved, the SCOR model has been updated regularly by the Association for Supply Chain Management (ASCM) (which merged with the Supply Chain Council in 2014). In the SCOR model, supply chain activities/functions are categorized into six main processes: Plan, Source, Make, Deliver, Return, and Enable (Bolstorff and Rosenbaum 2003). Source, Make and Deliver concern the procurement, manufacturing and delivery of goods. The Return process regards the reverse flow of goods, while the Plan process is about the planning of all the above processes. Finally, the Enable process refers to overall management activities of supply chains, such as coordination and information flows.

The SCOR model also includes best practices and performance indicators, but those aspects of SCOR are more applicable for commercial firms involved in supply chain management and do

not exactly fit public health and health system performance dimensions. Therefore, I integrate the SCOR model for supply chain functions with the performance dimensions outlined in the Access framework of Frost and Reich (2006).

While Make and Return logistics are significant areas where digital technologies can enhance performance, in order to maintain brevity and manage the scope of this paper, I focus on four of the processes: Plan, Source, Deliver, and Enable. This paper delves into each of these processes individually, discussing how digital technology can improve availability and affordability. It also notes select cases when digital technology can also influence global adoption and provide new ways of reconfiguring the architecture around access (Figure 1).

Figure 1: Digital Solutions in Health Supply Chain: A Framework for Analysis



Each block is supported by 1-2 specific examples where evidence of systematic use or impact has been documented in peer-reviewed or gray literature. The initial example in the Enable block provides details on its impact on availability, affordability, and architecture as distinct subsections. Subsequently, these aspects are integrated into the narrative of the example itself. Table 1 presents a summary of the digital interventions discussed, along with a brief description of the pathways through which they impact different dimensions of access.

While these SCOR blocks are presented sequentially, this does not imply that a health system should implement digital intervention in this order. Over time, it is important to implement

digital interventions across all of these elements to realize the synergistic benefits of digital technology throughout the supply chain. Prioritizing and sequencing require matching the most significant health system challenge with the saliency of the digital solution available to address it (WHO 2019).

Digitization in the Enable process block

The Enable process includes all activities related to the collection, organization, and sharing of information and services among supply chain partners. This includes the generation and analysis of planning and performance data. The Enable process supports all the other process steps with the data, information and tools they need to achieve better operating performance.

Efficient information exchange across all levels is vital for the health product supply chain to achieve its objectives of improving access. However, in most health supply chains today information flow from patients and health clinics to district and national levels is incomplete and delayed. When information about stock levels of medicines at health clinics and warehouses and detailed consumption figures reaches different levels in the chain in an incomplete and untimely manner, it hinders effective forecasting, procurement, and distribution decisions. Sub-optimal decisions on forecasting, procurement, and distribution allocation lead to stock outs of health products at clinics and service delivery points.

Digital technology has the potential to enhance end-to-end visibility of what medicines are in stock and how much has been ordered, shipped, and consumed throughout the levels in the supply chain network. Digital solutions for monitoring the rate of consumption of health products, stock levels at all stages, risks of stock outs or expired products, temperature deviations in cold chain equipment, functionality of cold chain or diagnostic equipment are some of the important digital solutions in the health product supply chain. Modeling studies indicate that the use of digital supply chain solutions, which track stock levels, receipts, and consumption information for medicines and vaccines, could potentially avert up to 5% of neonatal and under-five child deaths in Mozambique, Tanzania, and Ethiopia (Fritz et al. 2021).

Since 2004, many such solutions have been developed using mobile phones or other digital devices at health clinics. Several such solutions are mentioned in the literature; a few notable ones are openLMIS in Malawi (USAID 2019), a SMS-based system in Kaduna State in Nigeria (Alayande et al. 2016), eLMIS in Tanzania (Mwencha et al. 2017, Gilbert et al. 2020), AbastoNET in Mexico (Tapia-Conye et al. 2016), and SMS for Life in Kenya (Githinji et al. 2013). While some of these have been sustained over time and demonstrated impact, many suffered from the challenges of slow adoption or decrease in adoption/systematic use after the first few months of implementation. While all of these digital solutions generated granular information about drug stockouts, staff at health clinics had limited authority/agency to effect significant changes, as the root causes of these stockouts were supply decisions made at the

state or federal levels (Mackey and Cuomo 2020, Gilbert et al. 2017, Githinji et al. 2013, Tapia-Conye et al. 2016). The lack of success of digital solutions in LMIC health systems and humanitarian settings can be attributed to system designs that prioritize administrative reporting and the requirements of central planners over the needs of end-users. Additionally, there is a tendency to digitize all aspects of the supply chain information too rapidly, resulting in increased cognitive complexity for last mile supply chain staff (De Boeck et al. 2023).

A notable example in digitizing stock and consumption data that has succeeded at large scale is the eVIN solution in India. Around 2009, Logistimo in India developed a simple mobile phone-based solution to digitally capture stock, order, and receipt information of vaccines and select medicines in real-time from clinics. This solution was piloted for medicines and vaccines in the state of Karnataka and for vaccines in two districts of Uttar Pradesh. It achieved high adoption, stability in its use, and resulted in decreases in health product stockouts (Gilbert et al. 2017). Starting in 2014, this digital supply chain solution was implemented in 12 states in India by the Ministry of Health and Family Welfare (MoHFW), Government of India, in partnership with UNDP and GAVI as the "eVIN" project. eVIN involved using smartphones to capture stock, consumption, and receipts data for vaccines, combining with temperature loggers at vaccine cold chain points; all of the data was fed into a cloud-based server from where it could be visualized and analyzed using a web-based application (Gurnani et al. 2020).

Availability

A pre-post study conducted in the 12 states where the eVIN digital supply chain solution was first implemented, showed a statistically significant reduction of 30.4% in the number of facilities having stock out of any vaccine (Gurnani et al. 2022). eVIN and other such solutions make supply chain performance data available to all actors involved in the supply chain (in some cases even the end-patient). The impact on availability occurs predominantly through two pathways: 1) granular data measurement strengthens accountability and performance management in the overall supply chain (Vledder et al. 2019); and, 2) it enables new algorithmic-aided models of decision support for forecasting, ordering/requisitioning, and inventory management (Leung et al. 2016, Gallien et al. 2021).

Affordability

The digital supply chain solution also reduced vaccine wastage that used to occur due to poor matching of demand and supply. This resulted into savings of approximately 90 million doses of different vaccines (Gurnani et al. 2022). A return of investment analysis of eVIN shows a cost-to-return ratio of 1.41, and 2.93 after fixed costs of implementation have been amortized (Gurnani et al. 2022).

eVIN and similar digital solutions enhance efficiency and affordability by minimizing redundant tasks, reducing overall inventory, mitigating the need for last-minute expedited orders and uncoordinated purchases, and minimizing product wastage and expiration.

Architecture

Full visibility in the supply chain allows clinics, pharmacies, distribution agencies, and manufacturers to establish a shared logistics data infrastructure, enabling them to collaborate more effectively on specific supply chain tasks. Such collaboration leads to subtle, slow changes in the overall architecture of the supply chain decision making. Equipped with the real-time information on stock and consumption, higher-level planning staff of the health system develop more confidence in the forecasting, ordering, and requisitioning processes of the districts and clinics and allow more such decisions to be decentralized.

Adoption

Digitization efforts and achieving comprehensive visibility across the supply chain can expedite the transition to new treatment regimens, such as the adoption of new HIV regimens or new vaccines, on a national scale. The visibility provided by digitization facilitates informed decision-making regarding the optimal timing for switching regimens, ensuring a balance between swift implementation and minimizing waste of existing stock. Visibility through eVIN was one of the contributors to the fast introduction of rotavirus vaccine in India in 2016.

In addition to the previously mentioned advantages, digital solutions within the Enable process category not only enhance visibility regarding stock levels, consumption patterns, and supply chain flow—they also prove invaluable for asset reconfiguration and government contracting processes. While these were not realized for eVIN, they are important elements to be recognized. Governments have the option to outsource supply chain functions to private companies, utilizing them as service providers on a usage-based model, instead of maintaining these assets and capabilities in-house. While the benefits of specialized private supply chain service providers in achieving economies of scale and scope have been recognized (Agrawal et al. 2016), the lack of supply chain visibility poses challenges in terms of measuring proof of delivery, establishing service-level agreements, monitoring performance, and ensuring accountability. Systematic collection of stock and flow data creates opportunities for efficiently outsourcing supply chain functions, when it is economically rational and viable.

Factors Contributing to Success

While it may appear simple, the stable and enduring use of digital solutions for stock and consumption tracking is no easy task. It requires both technical sophistication in the tool and the need to navigate a complex political economy of supply chain actors who gain from supply chain obfuscation.

Several factors contributed to the success and stability of eVIN. Firstly, it was integrated into the national/federal system right from the beginning; as it began to demonstrate early signs of success, this allowed it to garner strong political support. Other factors included the development of a bottom-up design that aligned with the top-down supply chain planning hierarchy and ensured that the incentives of the top-down supply chain planners were compatible with those of the frontline health workers in the clinics. The system started out simple and gradually increased the complexity of the information it captured. This flexibility allowed users to adapt and choose the level of system complexity based on their familiarity and comfort with the system. Technical features of the solution, such as flexible data transmission and offline/caching capabilities, enabled the use of widely available devices, which were already in use by frontline health staff, for data collection. Additionally, partnerships were established with academia to conduct analytics and impact studies on the solution.

Digitization in the Plan process block

The Plan block involves core planning functions associated with matching demand and supply, i.e., balancing available supplies with requested orders and communicating it along the entire supply chain. Forecasting, procurement timing, quantities, order/delivery frequency, and distribution allocation are some of the key Plan functions within health product supply chains.

Digital technologies can improve the accuracy, granularity, and speed in the availability of supply chain data, and as a result facilitate faster execution of a wide range of ordering and allocation decisions. Adjustments to plans can be quickly communicated across different functions, such as from demand planning to procurement to distribution, and from health system leadership to facility and district managers. As a result, plans do not have to be static, but can be dynamic and better aligned to match supply with demand.

For health products that are procured by international agencies and donors, the coordination aspect of planning assumes even greater significance. Take contraceptives, for example, which are procured by USAID, UNFPA, and individual country governments. For more than a decade, a mechanism known as the Coordinated Supply Planning group (CSP) has performed several crucial planning coordination functions. These include developing unified forecasts for procurement and stock allocation, as well as exchanging country-specific data on stock levels. Previously, these functions were carried out based on multiple data streams, such as RH Interchange and PPMR, through a series of coordination meetings and extensive manual analytics and iterative adjustments. Approximately 20 people had to meet twice a month to triangulate, cross-reference, and analyze data from numerous sources.

The Global Family Planning Visibility and Analytics Network (VAN) digitized some of these steps under a single umbrella. The VAN captures data from multiple sources and serves as a platform to assess and prioritize supply needs, communicate with one another, and act when supply imbalances loom. The digital platform on which VAN operates had to create standard

data labels, rules, and aggregation formulae, and automate pulling together order and shipment data from many different tools and data sources into one single platform. The Family Planning VAN is currently being implemented in the West Africa region, and while it is still early to conduct large-scale impact studies, several instances of improved planning have come to light. For instance, in July 2021, utilizing the VAN platform, an analyst in Togo detected an imminent shortage of specific contraceptives. This prompted a search for a country in West Africa with an excess supply of the product that could be shipped to Togo. A planning team led by West African Health Organization (WAHO) collaborated with the technical implementers of VAN to figure out that Niger had a surplus of the specific contraceptives. Consequently, 50,000 units of contraceptives were transferred from Niger to Togo (Mierzwa et al. 2022). This collaborative effort among multiple stakeholders ensured that Togo had an adequate supply of contraceptives, while also preventing the overstocked products in Niger from expiring. VAN's digital solution provided the essential backbone, while the coordination structures established under WAHO created the necessary space for decision-making based on the information supplied by VAN. In addition to its use in contraceptive supply chains for regional coordination, the concept of VAN is also being implemented at the country level for vaccines (Altaf 2021, Charo 2016, Ottih 2018).

The FP VAN case demonstrates how digital technology in global supply chain planning can yield several benefits. By automating basic tasks essential for collaborative planning and effectively leveraging analytics, it enhances collaboration among supply chain stakeholders. Enhanced collaboration around forecasting and stock allocation decisions boosts efficiency by eliminating redundant and repetitive data retrieval tasks from various sources; through clever analytics, it accelerates response times for stock reallocation or shipment transfers. Quicker stock reallocation contributes to waste reduction and minimizes product expiry. Digital solutions to support planning for health product supply chains thereby improve ***affordability*** for both payers and end-patients, enhancing efficiency in overall system. It also leads to improved ***availability***, as it reduces potential stockouts.

Digital systems for planning also contribute to making the ***architecture*** for health systems planning more robust. In Ethiopia, a project using digital and data science technology from Zenysis Technologies integrates data from various fragmented systems (EDHAP 2019). This allows planning to be based not just on regional-level data but health facility-level data. Decisionmakers at local, regional, and federal level can utilize highly granular data from different sources, reconciled meaningfully, enabling them to make more informed plans and decisions. Access to new information sets of collated data is thus changing the architecture for decision making.

It is important to note that realizing these potential benefits hinges on two crucial prerequisites. First, there should be a well-established planning process and organizational structure in place that digital technologies can complement and streamline (reducing friction

in the process). In the case of the Global Family Planning VAN, the existence of both CSP as a collaborative process and WAHO as an institutional structure allowed achievement of the benefits of the digital planning platform.

In addition to global planning, another promising area for the use of digital technology in planning at the national/sub-national level is the use of Artificial Intelligence (AI) and Machine Learning (ML) tools to improve demand forecasts. Traditionally forecasting at different levels in the health system is carried out by either epidemiological-based forecasting or past consumption data-based demand forecasting (Levine et al. 2008). New AI/ML systems can collate extensive volumes of historical and current data from a variety of systems, such as District Health Information Systems (DHIS), Electronic Medical Records (EMR), Logistics Management Information Systems (LMIS), publicly accessible satellite imagery, population data, granular weather information, local news reports, and unstructured data in the form of notes and insights from frontline staff. Such tools are becoming increasingly accessible to LMIC governments. While limited in the scale of their use, early use of such systems in Tanzania and Côte D'Ivoire are reported to have decreased forecasting errors by 30 to 50% (Hariharan et al. 2020).

Detailed information about patients and their preferences in accessing health products allows the development of more precise demand forecasting methods. AI/ML tools are capable of efficiently managing the vast array of data related to patient journeys, integrating it with historical consumption data, epidemiological insights, and other pertinent information. This approach minimizes the chances of holding excess or surplus inventory and avoids stockouts caused by inadequate anticipation of customer requirements. While these initiatives can undoubtedly enhance forecast precision, their effectiveness ultimately depends on whether the improved forecasts lead to changes in decision-making. The latter, in turn, hinges on the existence of a well-established process for decisions on requisitioning and stock allocation. Legacy operational practices and workflows are hard to adjust, and people tend to resist change. To truly harness the impact of digital technology on affordability and access through enhanced demand forecasts, digital technologies and predictive analytics need to be built on top of established processes.

In addition to forecasting and inventory management, AI/ML tools can also play a vital role as anti-corruption tools in the supply chain. They can help in detecting corruption (both large-scale and petty corruption) by identifying potential issues and provide early warnings by cross-referencing quantity and price data with public databases. This will also be relevant for the SOURCE process.

Digitization in the Source process block

The Source block covers activities related to the procurement of health products and the associated infrastructure required for efficient sourcing. This includes activities such as

supplier agreements, procedures for managing supplier payments, and the verification of delivery performance.

One significant application of digital technology in sourcing is electronic procurement, which has garnered interest and traction among public and private entities operating within the healthcare product supply chain. “E-procurement” allows for better price negotiation by enabling improved mechanism design and reducing the potential for supplier collusion during tendering processes. Additionally, e-procurement reduces lead times, leading to more efficient operations and fewer delays. It also enables transparency and public scrutiny, while minimizing the likelihood of errors, thereby enhancing the accuracy of procurement activities and reducing the risks of corruption. Moreover, it facilitates the systematic collection of supplier quality information, which in turn enables well-informed supplier selection decisions. However, it is important to note that while digital platforms can aid in aggregating purchases, the incentives for purchasers to consolidate their demand are distinct from the mere presence of a digital procurement platform, making a digital platform neither necessary nor sufficient for volume aggregation to occur.

Many countries at all income levels have started utilizing electronic procurement methods for their healthcare products (CMS Law 2019). The results have been mixed. Chile has been an early frontrunner in public sector e-procurement. It started digitalization of its public procurement procedures in the early 2000s, with the introduction of a government e-procurement system named ChileCompra. In 2004, new legislation mandated that all public entities, including the central procurer of medicines, Central Nacional de Abastecimiento (CENABAST), public hospitals, and municipalities, must utilize ChileCompra e-platform for their entire procurement workflow, from posting requirements to disseminating outcomes.

Studies have shown that electronic procurement through ChileCompra demonstrated an overall 8% reduction in medicine prices (Raventos and Zolezzi 2015). This cost reduction was attributed to the advantages of e-tendering, such as volume aggregation (resulting in 2.8% lower prices) and an increased number of suppliers participating in each public tender. In addition to volume aggregation and increased competition, the benefits of ChileCompra also come from:

- Electronic bidding and bid announcements enhance the fairness and transparency of the selection process, granting all participating suppliers equitable access to information. Moreover, this practice encourages increased participation from small- and medium-sized enterprises.

- The establishment of a centralized supplier database that captures all relevant details about registered suppliers, including regulatory approvals, historical performance, and compliance records.

- Digital procurement streamlines contract management procedures and diminishes the likelihood of contract manipulation or concealed terms, as all involved parties can reference a standardized electronic contract that outlines terms and conditions clearly.

While the impact of ChileCompra in enhancing availability and affordability are evident, it becomes difficult to distinguish between the benefits derived from demand aggregation and pooling (which could potentially have been accomplished without a digital platform) and those benefits directly attributable to the automation and efficiency benefits of the digital platform itself. The challenge of disentangling these two aspects is not unique to ChileCompra, but is a common characteristic of various e-procurement initiatives.

Another illustration of digital technology's role in sourcing is Wambo.org, a digital procurement platform introduced by the Global Fund in 2016. It serves as the technological backbone for the Global Fund's pooled procurement mechanism, which grants recipient countries access to competitive pricing, increased transparency, and a dependable supply of quality health products.

The total value of purchase orders processed through Wambo reached $1.37 billion in 2020 (Global Fund 2022). The platform is designed to expedite procedures, enhance interdepartmental communication, and reduce the time required for countries and the Global Fund secretariat to initiate purchase order placement, identify and approve suppliers, and ensure timely payments after verifying product delivery. Employing Robotic Process Automation (RPA) to automate certain straightforward sourcing tasks, such as creating purchase orders, generating invoices, and reconciling quantities ordered, delivered, invoiced, and paid, has proven to be beneficial in various supply chains (Flechsig et al. 2022). However, the efficiency gains are only realized when the processes for these tasks are standardized. In situations where many of these activities require substantial manual interactions and exchanges between supply chain stakeholders (e.g., different entities within a national purchaser, payer, procurement agent, and supplier), the anticipated benefits of digital sourcing remain unrealized. Standardization of data and well-established processes for requisitioning at the national purchaser end of the system are pre-requisites. This observation is consistent with the findings of the Global Fund's audit of Wambo (Global Fund 2022), which indicated a continued heavy reliance on manual processes and controls for requisition generation, approval, and placing electronic purchase orders.

The benefits of enhancing procurement efficiency and transparency through digital technology are theoretically sound, but in practice they often remain unrealized due to the complex political economies surrounding sourcing and procurement systems in many countries. Digitization in the sourcing function is neither a necessary nor a sufficient condition to improve transparency, efficiency, and affordability. A digital platform may serve more as a means to navigate and manage the intricacies of the political landscape, ensuring smoother

change management to institutionalize pooled procurement or bring about procurement transparency. One area which remains underutilized in public sector health procurement is the use of digital solutions to help analyze market trends and optimize sourcing strategies by identifying cost savings opportunities in specific therapeutic areas.

Digitization in the Deliver process block

The Deliver component involves activities related to receiving customer orders, warehousing, and transporting orders. In many countries, the logistics market faces numerous inefficiencies when it comes to delivering to rural and remote areas. This leads to costly and unreliable transportation of goods, ultimately hampering availability and the overall performance of the healthcare supply chain. Private transport operators often do not serve these regions, while government-owned and operated transport systems suffer from numerous issues, such as inadequate maintenance of vehicles, lack of cash for driver per diems and fuel, and other factors that render them non-functional or ineffective. Digital technologies thus have the potential to bring about significant transformation in the transport and distribution segments of the healthcare supply chain.

Tusker is one example of a digital solution for rural freight transport for health products. It facilitates same-day delivery of health products to pharmacies, even in remote and rural areas, within the Indian state of Karnataka. Tusker Transport was introduced in 2016; by 2019, it had garnered substantial market acceptance in the northern region of Karnataka (Shell Foundation 2021). The Tusker model operates in the following manner: owners of small pharmacies situated in rural areas, who previously had to travel to the nearest town to procure their supplies (Yadav et al. 2012), can now place orders through a mobile phone to Tusker. Tusker consolidates orders and shipments from multiple small pharmacies onto a single truck. Small truckers then bid to handle the shipment, and the one offering the most competitive price is selected to transport the load. This consolidation of shipments results in cost efficiencies, which are subsequently reflected in lower transportation costs for pharmacy owners. These cost savings are then passed on to the end-patients. While the practice of combining small loads to create an aggregated shipment (called Less than Truckload/LTL shipping) is fairly common on well-established routes, it is less frequently seen in rural areas in LMICs.

The Tusker example underscores a critical point regarding digital solutions in the Delivery block, particularly when it involves transport and warehousing. These solutions must cater to a diverse range of sectors and cannot be limited exclusively to the health sector. By doing so, they can effectively spread their substantial fixed costs across a broader volume base, achieving greater efficiency in consolidation. However, this approach also necessitates addressing the unique characteristics of each sector, including considerations such as seasonality, pricing preferences, volume requirements, and other distinctive features. While doing so, it raises the question of whether health product priorities and preferences remain at the forefront of these solutions. An insightful finding from the Tusker analysis (Shell Foundation 2021) reveals that

pharmaceutical wholesalers tend to be situated in relatively congested market clusters, which are not convenient for freight vehicles to access directly. This requires an additional process whereby suppliers/wholesalers can conveniently drop off their boxes at designated Tusker collection points.

There are multiple examples of digital tools tailored specifically for transport and warehousing of health products. One recent example is the Electronic Proof of Delivery app (ePOD) for truck drivers developed by USAID implementer Chemonics (Chemonics 2019). The app empowers truck drivers to upload pictures of proof of delivery, including recipient details and shipment documentation, all tagged with time and location information. This can enable better performance management of the transport function by providing the government with verifiable information about deliveries. However, one of the challenges associated with sector-specific solutions lies in achieving widespread adoption. Truck drivers employed by private companies that offer transportation services to Ministries of Health often serve multiple sectors, not the health sector exclusively. Consequently, while such digital solutions may prove effective for government-owned fleets of trucks, they may encounter difficulties in scaling up for broader adoption within the transportation market. Unless the company providing the solution has a business model that accommodates multiple sectors, widespread implementation can be challenging.

In many LMICs, patients typically initiate their care-seeking journeys by visiting community pharmacies (Wirtz 2022). This behavior is driven by several factors, including the lack of available medicines in government clinics, as well as the pharmacies' closer proximity to people's homes, extended operating hours, and shorter wait times. Private retail pharmacies and drug shops often face severe working capital constraints. As a result, they tend to maintain lower stock levels of slow-moving or expensive medicines (Yadav et al. 2012a). Furthermore, wholesalers and distributors located in large cities and towns do not consistently supply medicines to rural pharmacies (Yadav et al. 2012b). As mentioned, pharmacy owners must personally travel to procure stock or rely on additional intermediaries, like sub-wholesalers. Collectively, these factors increase the retail prices of medicines and lead to gaps in the availability of essential medications.

mPharma offers a digital solution-based model to address some of these problems. mPharma is headquartered in Ghana and operates in nine countries in Africa. It provides medicines "on consignment" to retail pharmacies; that is, mPharma owns the stock until it is sold to the end-patient, thus freeing the pharmacy owner of the need for working capital. In each pharmacy, mPharma installs technology for point-of-sale tracking, inventory management, and ordering. The system gives mPharma real-time information about stock and consumption at the retail pharmacies, which it then utilizes to run an efficient Vendor Management Inventory (VMI) system.

Availability improves as a result of both better stocking decisions resulting from the software-managed VMI system and alleviating the constraints of working capital. The model also affects affordability: fewer intermediaries between the manufacturer and patients result in reported decreases of 30%-60% in retail prices of medicines in the private out-of-pocket market. In addition to increasing availability and affordability for patients, the solution also increases revenue for retail pharmacies. Pharmacies that join the mPharma network have reported up to 120% growth in peak revenue and some doubled their revenue within the first 12 months (mPharma Annual Impact Report 2021).

A common criticism of models like mPharma is that they tend to cater primarily to urban areas and higher socioeconomic segments. Understandably, technology-driven businesses with private funding focus on customer segments where they can achieve sufficient customer density to break even and eventually turn a profit. However, mPharma was able to extend its model to Patent and Proprietary Medicine Vendors (PPMVs), which are lower-tier pharmacies that serve lower socioeconomic segments compared to formal retail pharmacies. With a modest amount of support from the Gates Foundation, mPharma initiated a project in 20 PPMVs. This pilot demonstrated that, when logistical and working capital constraints were addressed through mPharma's technology, most PPMVs could increase their sales significantly. Indeed, some PPMVs increased their average basket value by 80%, providing them with the financial capacity to expand their product offerings and invest in improving their physical infrastructure. This demonstrated that PPMVs represent a servable market, and mPharma expanded its network to serve more PPMVs without relying on donor support.

Maisha Meds, SwipeRx, and Kasha are three other examples of business models that serve retail pharmacies using digital solutions for ordering, inventory, sourcing, and peer information sharing (Yadav and Glassman 2019). MaishaMeds, primarily operating in East Africa, leverages its technology platform to assist retail pharmacies to maintain the right depth and breadth of inventory. They also enable targeted subsidies for health products that offer substantial public health benefits. SwipeRx has a strong presence in Southeast Asia; it serves as an information intermediary connecting retail pharmacies, pharmaceutical companies, and government stakeholders. Kasha, operating in Rwanda and Kenya, addresses many Delivery challenges by bypassing traditional retail channels. Instead, Kasha offers direct-to-home or designated pick-up point delivery of women's health products. In addition to addressing supply chain and retail competition issues, Kasha's digital ordering and home delivery model provides women with confidentiality and privacy.

These innovative digital-led delivery models feature ingenuity and rapid design improvements. However, they currently rely entirely on patients making out-of-pocket payments to obtain medicines and health products. For these systems to achieve sustainable and widespread impact in improving access to health products, they need to be integrated into national insurance reimbursement networks, especially as national insurance networks expand to

include private pharmacies and clinics (Yadav and Glassman 2019, Wirtz 2022). To achieve this integration, these systems need to enhance their digital platforms to perform functions such as verifying dispensing, generating invoices, and processing payments within the framework of national insurance systems.

Principal Findings

Digital technologies present health systems with an opportunity to overhaul health product supply chain operations, including enabling, sourcing, planning, and delivery. As summarized in Table 1, digital technology in the health supply chain can lead to improvements in product availability and affordability with clear theoretical causal pathways. They can also lead to faster adoption of new health technologies. The digitization of health supply chains opens the door to novel models of collaboration and performance monitoring approaches, which, in turn, can influence the decision-making dynamics across various supply chain functions, and potentially alter the architecture of where supply chain decisions are made.

Table 1: Summary of digital interventions across supply chain process categories and their impact on access

Supply Chain Process Category	Example(s)	Pathways to Impact on Access
ENABLE		
Digital tools enhance visibility of what medicines are in stock, how much has been ordered, shipped, and consumed, throughout the levels in the supply chain network	eVIN	*Availability:* 1) Granular data strengthens accountability and performance management in the overall supply chain and reduces stockouts 2) Granular data and sharing creates opportunities for algorithm-based decision support for forecasting, ordering/requisitioning, and inventory management *Affordability:* Minimize redundant tasks, reduce overall inventory, mitigate the need for last-minute expedited orders and uncoordinated purchases, and minimize product wastage and expiration *Architecture:* Real-time information on stock and consumption creates greater confidence in decentralized decision making *Adoption:* Expedited transition to new treatment regimens or new vaccines on a national scale
PLAN		
Digital platform	Global Family Planning	*Availability*: Accelerates response times for stock reallocation or shipment transfers.

Supply Chain Process Category	Example(s)	Pathways to Impact on Access
enhances collaboration among supply chain stakeholders to carry out joint forecasts and allocate supplies in a timely and coordinated manner	Visibility and Analytics Network (VAN)	*Affordability:* Automates basic tasks for collaborative planning, boosts efficiency by eliminating redundant and repetitive data retrieval tasks from various sources. Optimally and expeditiously allocates surplus stock to avoid product expiry.
Use of Artificial Intelligence (AI) and Machine Learning (ML) tools to improve demand forecasts	Pendulum Systems in Tanzania	*Availability*: Reduces forecast errors and thereby reduces stockouts. *Affordability*: Reduces forecast errors and thereby reduces product expiry; addresses corruption by identifying expedited or maverick ordering.
Granular data from various sources reconciled for multi-level decision making	Zenysis Technologies, Ethiopia EHDAP	*Architecture:* Access to granular data sets, reconciled with different levels of aggregation, to enable an architecture where decision making can be done at local, regional, and national level.
SOURCE		
Electronic procurement to enhance transparency, better supplier performance management, and increase bid competition	ChileCompra WAMBO	*Availability:* More bids and better mechanism design enable shorter lead-times; better prior information on supplier performance. *Affordability:* Enables volume aggregation (not a pre-requisite); enables some new types of bidding mechanisms; increases competition in bids; transparency mitigates corruption risks.

Supply Chain Process Category	Example(s)	Pathways to Impact on Access
DELIVER		
Digital transport solutions	Tusker Transport	*Availability*: Same day delivery for small shipments/loads to rural pharmacies. *Affordability*: Load consolidation and bid-based trucker selection reduces transport cost which may be passed on as lower prices to patient.
Digital platforms for distribution in private out of pocket markets	mPharma Maisha Meds Swipe Rx Kasha	*Availability*: Better stocking decisions resulting from the digital system and reduced working capital constraints. *Affordability*: Fewer intermediaries between the manufacturer and patients result in reduced retail prices.

However, despite the substantial potential for impact and examples presented in the preceding sections, the actual realized effects of digital technology on health product supply chains have generally been modest. Only a handful of noteworthy national-scale implementations have delivered their promised impact. Many countries have been slow to embrace digital solutions within the health product supply chain as they feel ill-prepared to navigate the complexities and intricacies involved. As a result, there are currently only a few LMIC health supply chain examples with systematic evidence of digital technology adoption leading to long-term improvements in product availability, efficiency, affordability, or the expedited adoption of new health technologies.

To ensure the effective and sustainable implementation of digital solutions in health product supply chains, it is essential to integrate technology with the underlying processes and incentives of the internal actors involved. Confidence in a digital solution quickly wanes among healthcare system staff if it does not result in rapid and visible improvements in the delivery of supplies to them. Supply chain digitization efforts in public sector health systems do not endure when frontline staff receive more detailed and granular information from digital supply chain tools but lack the agency to make operational decisions. Digital solutions typically provide information but fail to provide opportunities to make changes to the demand- or supply-side operating processes based on that information. Incorporating digital interventions into health product supply chains should thus be carefully sequenced based on the level of digital ecosystem maturity within the healthcare system, the maturity of the supply chain in a given country, and contextual realities regarding the agency of frontline and district staff.

Many current implementations of digital technology in the health product supply chain focus on enhancing the efficiency of public sector health product provision by introducing

automation, integration, and advanced analytics. However, the most significant advantages of digital technology in healthcare supply chains do not result from technological advancements. Instead, improvements stem from social and politico-economic innovations resulting from digital technology.

Digital technology needs to be used as tool to bolster the accountability of the health product supply chain by furnishing detailed, timely, and granular information to personnel at all levels of the healthcare system, as well as to citizens and patients. Digital solutions in the supply chain can shift power between levels of the health system internally, and between the health product provisioning system and its beneficiaries/patients. Admittedly, such an application of digital technology in the health supply chain carries a substantial political dimension. While digital supply chain innovators may be reluctant to engage with political risks, the pathways to achieving impact through the use of digital technology in healthcare supply chains require a meticulous understanding of the political landscape within health systems, particularly in areas like manufacturing, procurement, and delivery.

Some highly successful digitalization initiatives in health supply chains have been implemented in the private out-of-pocket market (encompassing pharmacies, hospitals, private wholesalers, and distributors), but there is a need for public investments to expand their reach into rural areas and ensure greater equity. Additionally, efforts should be made to encourage private sector digital supply chain players to serve the public sector healthcare market and become better integrated with national health insurance networks.

Discussion: Ideas for Policy Action

Similar to other digital health solutions, the development and deployment of digital supply chain solutions are typically undertaken by private companies, both local and global. These companies have more up-to-date knowledge regarding technology and its associated uncertainties than the government. They speedily and eagerly implement “state-of-the-art” digital solutions in the private portion of the health product supply chain, but face challenges when working to partner with the government. When governments or Ministries of Health are contracting to purchase digital solutions for its supply chain, they have imperfect information and are trying to minimize transaction costs. They often ask the question, “Is it best to purchase a complete digital product, configure an existing tool, or build a custom tool (internally or by contracting to build)?” In addition, digital supply chain solutions, especially those that involve building supply chain data infrastructure, are associated with large economies of scale, which makes it more challenging for governments to maintain a competitive supply market for such solutions.

All together, these factors make the process of procuring, regulating, and formulating policy for digital supply chain solutions highly complicated for LMIC governments. Consequently, they often remain in a state of indecision, opting to delay making choices until some of the

uncertainties have resolved. Unfortunately, this approach also deprives them of the chance to harness the value-creating potential that digital technology could offer their health product supply chain.

Given the proliferation of potential applications for digital technology in health product supply chains, national governments need to formulate strategic roadmaps to evaluate which parts of the health product supply chain can benefit most from digital technology. These roadmaps should take into account the internal capabilities, talent, and process considerations required within ministries to ensure their capacity to smoothly manage the transition to digital technology. Moreover, these roadmaps should provide clarity on the value that digitization can bring to specific areas of the supply chain along the Enable, Plan, Source, Make, Deliver, and Return spectrum. Finally, the roadmaps must delineate ownership, accountability, and governance responsibilities. An effective way to guide roadmap development is to assess the system's readiness across three dimensions for each function/process in the supply chain:

- **Technological and Infrastructure Readiness**: What is the health system's capability to deploy new digital applications in a given supply chain area? This dimension hinges on two sub-elements: first, having the foundational infrastructure of data systems and underlying processes; and, second, having (or being able to attract) skilled professionals well-versed in both technological and process aspects of supply chain digital technologies for the specific area in question.

- **Organizational Readiness**: This dimension assesses the contextual prerequisites needed to implement new digital technologies, including factors like political support, financial resources, organizational structure (i.e., which government agency will manage the platform) and staff incentives.

- **Environmental Readiness**: This dimension considers both whether there are suppliers or vendors that are capable and ready to serve the government's needs, and whether the government possesses the capacity to regulate digital vendors for any given segment of the supply chain.

Managers overseeing health product supply chains in the public sector face a dual challenge: they must effectively oversee and enhance conventional supply operations, while simultaneously fostering an atmosphere conducive to digital innovation. The former necessitates a higher degree of structure and formal governance, while the latter demands organizational latitude and adaptability to facilitate swift cycles of experimentation, testing, and implementation of digital supply chain solutions. One approach to reconcile these somewhat conflicting objectives is to establish a supply chain center of excellence within the broader organizational structure of the public agency that manages medicine procurement and distribution. The core premise of a center of excellence is that, while staff with day-to-day

execution roles can continue to focus on running the core supply chain operation, some experts who report directly to the agency leadership can step out of line management responsibilities to lead and help build digital supply chain initiatives.

In addition to the necessary actions by national governments outlined in the preceding paragraphs, it is essential to establish a set of global high-level principles tailored specifically to digital solutions within health product supply chains. These principles would allow coordination among Ministries of Health, donors, and technical agencies, helping them identify the most crucial applications of digital technology within healthcare supply chains. These principles can draw inspiration from the “Principles of Donor Alignment for Digital Health” outlined in “The Principles of Donor Alignment for Digital Health 2018.” However, they should provide greater specificity and granularity to address the unique challenges and intricacies of health product supply chains. Utilizing a common framework such as the SCOR model, as illustrated in this paper, can serve as a foundation for establishing and implementing these principles.

Another avenue for global investment is to create a registry to serve as a centralized repository for healthcare supply chain digitization initiatives across countries. This registry would facilitate knowledge sharing and collaboration among stakeholders. It could function in a manner similar to the WHO's Digital Health Atlas, but would be specifically dedicated to digital initiatives within health product supply chains. Together, common principles and a registry would enhance coordination, promote institutionalization, and scale up the adoption of digital solutions within the supply chain. They would increase the likelihood that digital solutions within the health product supply chain indeed deliver value and achieve an impact.
Health product supply chains face unique and complex challenges when it comes to adopting, implementing, and effectively utilizing digital solutions. In this article, we introduced a categorization framework designed to assist national governments and international agencies in prioritizing digital tools for these supply chains. By assessing potential digital initiatives through the lens of the “Enable, Plan, Source, Deliver” framework outlined in this article, and by analyzing their impact on Availability, Affordability, Adoption, and Architecture, governments can formulate clear plans for implementation, rather than getting stuck in the process. This would also create opportunities for further context-specific research and in-depth analyses on other problems, such as estimating return on investment or the value derived from each specific digital intervention in the supply chain.

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