

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/377471436>

Digital Transformation in Pharmaceutical Supply Chain: An African Case

Article in Matrix Science Pharma · January 2024

DOI:10.4103/mtsp.mtsp_16_23

CITATIONS

4

READS

598

5 authors, including:



Bankole Ashiwaju

College of Medicine University of Lagos

13 PUBLICATIONS 55 CITATIONS

SEE PROFILE



Ochuko Felix Orikpete

Bristow Helicopters ExxonMobil Operations Qua Iboe Terminal Eket Akwa Ibom Stat...

50 PUBLICATIONS 169 CITATIONS

SEE PROFILE



Chibuikwe Daraojimba

University of Pretoria

61 PUBLICATIONS 507 CITATIONS

SEE PROFILE

Digital Transformation in Pharmaceutical Supply Chain: An African Case

Bankole Ibrahim Ashiwaju, Mercy Odochi Agho, Casandra Okogwu¹, Ochuko Felix Orikpete², Chibuike Daraojimba³

Independent Researcher, ¹Independent Researcher, Lagos, ²Bristow Helicopters Nigeria Limited, ExxonMobil Qua Iboe Terminal, Eket, Akwa Ibom, Nigeria, ³Graduate School of Technology Management, University of Pretoria, Pretoria, South Africa

Abstract

Background: The pharmaceutical supply chain, pivotal in ensuring timely and efficient delivery of medical goods, has experienced significant challenges in the African context. Infrastructure deficiencies, fragmented distribution networks, and limited transparency have historically been obstacles in ensuring the consistent flow of essential drugs and treatments. **Materials and Methods:** The transformative power of digital technologies in reconfiguring the pharmaceutical supply chain across Africa. Drawing on multiple case studies, this paper presents evidence of how technologies such as blockchain, artificial intelligence, and the Internet of Things (IoT) are being employed to enhance traceability, improve inventory management, and optimize distribution routes. These digital innovations are not only ensuring the integrity of medicines by reducing counterfeit products but are also enhancing the agility of the supply chain to respond to sudden market and health demands. **Results:** Executed in a thorough data analysis strategy to interpret the results and extract significant insights by investigating the challenges faced in this digital transformation, which include the need for skills development, infrastructure investment, and the creation of supportive regulatory environments. The study underscores the role of partnerships between governments, international organizations, and private enterprises in driving these innovations. **Conclusion:** While the journey of digital transformation in Africa's pharmaceutical supply chain is ongoing, there are promising strides being made. By embracing digital solutions, Africa is positioning itself to better tackle health challenges and ensuring that its populace has access to genuine and essential medicines. This research contributes to a deeper understanding of digital transition strategies and offers actionable insights for stakeholders involved in global health and supply chain management.

Keywords: Africa, counterfeit products, digital technologies, pharmaceutical supply chain, traceability

INTRODUCTION

The pharmaceutical supply chain serves as a crucial lifeline in the health-care ecosystem, responsible for delivering life-saving medicines from production facilities to the hands of patients. Its seamless operation ensures that health challenges, from chronic illnesses to sudden outbreaks, can be addressed timely and effectively.^[1] In the vast and diverse continent of Africa, the importance of this chain is accentuated, given the range of health issues faced by its populace, including endemic diseases such as malaria, emerging health threats, and a rising tide of noncommunicable diseases.^[2]

However, the pharmaceutical supply chain in Africa is fraught with complexities and hurdles. Historically, factors such as infrastructural shortcomings, disparate distribution networks, lack of real-time transparency, and issues of counterfeit drugs have tested its resilience.^[3] These impediments, while

challenging, offer a canvas of opportunity. With the global tech arena witnessing unprecedented strides in digital innovations, there is enormous potential to recalibrate and enhance Africa's pharmaceutical supply chain, making it more robust, transparent, and efficient.^[4-7]

The aim of this study is to explore the transformative role that digital technologies can play in reshaping the pharmaceutical supply chain in Africa. More specifically, we seek to understand how innovations such as block chain,

Address for correspondence: Dr. Chibuike Daraojimba,
University of Pretoria, Pretoria, South Africa.
E-mail: chibuike.daraojimba@tuks.co.za

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: WKHLRPMedknow_reprints@wolterskluwer.com

How to cite this article: Ashiwaju BI, Agho MO, Okogwu C, Orikpete OF, Daraojimba C. Digital transformation in pharmaceutical supply chain: An African case. *Matrix Sci Pharma* 2023;7:95-102.

Received: 30-08-2023,

Revised: 02-09-2023,

Accepted: 04-09-2023,

Published: 16-01-2024

Access this article online

Quick Response Code:



Website:
<https://journals.lww.com/mtsp>

DOI:
10.4103/mtsp.mtsp_16_23

artificial intelligence (AI), and the Internet of Things (IoTs) can address existing challenges, enhance traceability, improve inventory management, and optimize distribution pathways. Furthermore, by drawing insights from specific African contexts, we aim to offer a holistic view of the ground realities, the successes achieved, the hurdles faced, and the lessons learned in the journey of digital transformation. Ultimately, this study aspires to provide a roadmap for stakeholders, suggesting strategies to leverage digital innovations for a resilient and efficient pharmaceutical supply chain, thereby elevating health-care outcomes across the African continent.

MATERIALS AND METHODS

DIGITAL TRANSFORMATION IN AFRICA'S PHARMACEUTICAL SUPPLY CHAIN LANDSCAPE

The pharmaceutical supply chain serves as a vital conduit, seamlessly connecting a diverse range of stakeholders, from drug manufacturers to end-users. This intricate network ensures the uninterrupted flow of medicinal products, which are foundational to maintaining global health and well-being.^[8,9] However, when we zoom into the African context, this seemingly fluid chain encounters a barrage of challenges. These challenges have roots stretching back to historical legacies while also being shaped by current geopolitical and socioeconomic dynamics. This section delves deep into these multifaceted issues, contrasting them with the transformative power that digital technologies offer. As we navigate this terrain, we not only uncover the depth and breadth of the challenges at the hand but also spotlight the bright horizons that digital solutions can unveil for the future of Africa's pharmaceutical supply chain.

Pharmaceutical supply chain challenges in Africa

The historical legacies of colonial rule, combined with the aftermath of postindependence political turbulence and ever-shifting economic terrains, have deeply influenced the evolution of Africa's pharmaceutical supply chain. These historical footprints, left behind by ages of external domination and internal strife, cast long shadows on the present day infrastructure and operations. The cumulative effect of these historical contexts presents itself in a myriad of challenges. These challenges, deeply rooted in past events, have consistently impeded the seamless distribution and accessibility of vital medicines throughout the African continent. Consequently, while the rest of the world advances, many parts of Africa still grapple with the repercussions of its tumultuous past, reflecting in the periodic shortages and inefficiencies in the medical supply chain.^[10]

First and foremost, the challenges stem from significant infrastructural and logistical barriers. Africa's vast geographical expanse, intertwined with diverse landscapes ranging from dense forests to arid deserts, makes transportation a particularly intricate task. Certain areas, especially those that are isolated or embroiled in conflicts, often grapple with

inconsistent access to essential medicines. The situation is further complicated by an inadequate road infrastructure, a limited presence of railway systems in several countries, and a shortage of well-structured storage and warehousing facilities. These logistical intricacies, when combined, frequently result in extended delivery times. In more extreme circumstances, these factors can lead to a total halt in the supply of pharmaceutical products, leaving communities without access to vital medical supplies.^[11]

The challenges facing the pharmaceutical supply chain in Africa go beyond mere infrastructure. Distribution networks across the continent are notably segmented. This fragmentation can be attributed to a myriad of reasons: Diverse political landscapes, administrative discrepancies, and at times, linguistic variations. As a result, pharmaceutical products often embark on complex, winding journeys before arriving at their final destinations. Such segmented pathways necessitate the involvement of multiple intermediaries, each introducing its own set of challenges. These intermediaries not only add layers of intricacy but also can result in delivery delays. Furthermore, each additional step often translates to increased costs, placing additional financial burdens on the supply chain.^[12]

A particularly alarming aspect of the pharmaceutical landscape is the rampant spread of counterfeit drugs within the supply chain. The presence of these fake medications can be attributed to inconsistent regulatory vigilance and the intricate challenges surrounding the authentication of drug origins. As counterfeit medicines infiltrate the market, they bring along a host of concerns. First, they pose a severe health threat, as these drugs may either be ineffective or, worse, harmful. Consuming counterfeit drugs can lead to adverse reactions, potential complications, or a failure to treat the illness. Second, their prevalence erodes trust in the medical system and undermines the integrity of the supply chain. As a result, not only is public health jeopardized, but the faith of consumers in the authenticity and safety of their medicines is continually tested, weakening the overall public health framework.^[13]

Shortcomings are also prominently evident in the realm of inventory management. This sphere faces challenges stemming from unpredictable demand fluctuations, which become particularly pronounced during health crises. The situation is further complicated by the absence of real-time, data-driven decision-making processes. Historically, these factors, when combined, have produced starkly contrasting scenarios within the supply chain. While some regions grapple with acute stock shortages, causing potential disruptions in medical care, others are burdened with overstocked warehouses. Such disparities not only underscore inefficiencies in resource allocation but also highlight the pressing need for a more synchronized, responsive, and technologically equipped inventory management system. This dichotomy of scarcity in one area and abundance in another poses significant challenges, both in terms of cost and effective health-care delivery.^[14]

Financial limitations act as a magnifying glass to these already pressing challenges. Several countries, each wrestling with a myriad of developmental goals and constrained by tight budgets, often struggle to dedicate adequate resources to refining the pharmaceutical supply chain. This financial squeeze does not just apply pressure to a single aspect but reverberates through the entire supply chain continuum. From the initial stages of procurement to the final processes of distribution, each step feels the pinch of underfunding. Consequently, the system grapples with inefficiencies, delays, and sometimes even lapses in delivering essential medicines. As health-care remains paramount to societal well-being, such financial barriers not only hinder the immediate functioning of the pharmaceutical supply chain but also have broader implications for public health and trust in the health-care system.^[15,16]

Finally, the landscape of the pharmaceutical supply chain is further complicated by regulatory hurdles. Across the African continent, drug approval protocols are not standardized, leading to discrepancies in how medications are reviewed and greenlit for use. In addition, disparate tariff structures, customs clearance procedures, and distinct national policies add layers of bureaucratic challenges to the process. Each country, with its unique set of regulations, creates a mosaic of rules that pharmaceutical distributors must navigate. This variance often acts as a bottleneck, slowing down inter-country distribution and sometimes even leading to extended waiting periods for essential medications. Such inconsistencies not only strain the efficiency of the supply chain but also underscore the need for more harmonized regulatory frameworks to facilitate smoother, swifter distribution across borders.^[17]

Role of digital technologies in modern supply chains

In the annals of technological advancement, there is a discernible shift in how global supply chains are perceived, structured, and executed. At the heart of this metamorphosis are digital technologies. The influence of these tools and methodologies is not just limited to enhancing operational efficiency or streamlining processes. They are reimagining the very fabric of traditional supply chains, integrating layers of transparency, accountability, and innovation.

The vanguard of transformation: Internet of things

The IoTs stands prominently as a vanguard in the age of digital transformation. Its essence lies in interlinking physical objects embedded with sensors, software, and other technologies with robust internet connectivity. This melding creates a nexus that offers a previously unimaginable level of real-time monitoring and data collection.

In the pharmaceutical realm, this translates to a seismic shift in how products move through the supply chain. Consider a scenario where every drug, from its inception as a raw ingredient to its final encapsulation as a life-saving pill, can be monitored in real-time. Such monitoring extends beyond mere location tracking. It delves deep into the granular conditions the drug is subjected to during its journey – ambient temperature,

humidity, exposure to light, and potential tampering. Such granular tracking becomes the lifeline for industries like pharmaceuticals where the viability of a product can be jeopardized with the slightest deviation from its required storage conditions.^[18]

However, the prowess of IoT is not just in ensuring product safety and integrity. It is also about data. Volumes of data harvested from these interconnected devices offer insights that are a goldmine for process improvement, cost-cutting, and innovation. Pharmaceutical companies can tweak storage methods, optimize transportation routes, or even reconsider supplier choices based on insights derived from IoT data. And as this industry continues to evolve in response to consumer demands for greater transparency and traceability, IoT is there, ensuring all stakeholders remain in the loop, informed, and assured.^[19]

Block chain: Beyond cryptocurrencies to pharmaceutical titans

The world first took notice of block chain technology when cryptocurrencies such as Bitcoin started making headlines. However, its utility extends far beyond creating and managing digital currencies. Block chain's decentralized ledger system, where each transaction is recorded in an unalterable, time-stamped block, finds profound applications in the pharmaceutical supply chain. Imagine a world where every touch point of a drug's lifecycle, from sourcing of raw materials to dispensation at a local pharmacy, is immutably documented. The benefits are multifold. First, it negates the infiltration of counterfeit drugs, a menace that the pharmaceutical industry has been grappling with for years. The presence of a transparent yet secure record ensures every drug can be traced back to its origin, confirming its authenticity.^[20]

Moreover, with recalls being a costly and reputation-damaging affair for pharmaceutical companies, having a block chain system means pinpointing the exact batch or even the specific units that might be compromised. This ensures swift, efficient recalls that minimize patient risk. Furthermore, in the context of regulatory compliance, which can often be a complex process for pharmaceutical giants, block chain simplifies matters. With real-time data readily available and shared across all relevant stakeholders, reporting becomes streamlined. Regulatory bodies can access information instantaneously, expediting approval processes and ensuring patient safety.^[21]

Artificial intelligence and machine learning: The predictive pioneers

The last few years have seen AI and machine learning (ML) come to the forefront of technological innovation, and their integration into supply chain management underscores their criticality. These technologies thrive on data, and in an industry as data-intensive as pharmaceuticals, their potential is monumental. One of the standout capabilities introduced by AI and ML is predictive analytics. In simple terms, these technologies can gaze into the vast datasets of the past and

present to forecast the future. They scrutinize historical sales data, juxtapose it against factors such as market trends, socioeconomic shifts, regional health concerns, and even global events to predict demand.^[22]

The implications of this predictive power in the pharmaceutical world are vast. Medications, some of which can mean the difference between life and death, need to be available at the right place and at the right time. AI and ML ensure just that. By predicting demand surges, these technologies enable pharmaceutical companies to stock medications proactively, thus averting potential crises. However, their utility is not confined to inventory management alone. By analyzing the data, AI and ML can spotlight inefficiencies across the board – be it in manufacturing, distribution, or even marketing strategies. This continual learning and adaptation mean that as the market evolves, the pharmaceutical supply chain does too, always staying one step ahead.^[23]

Digital twin technology and cloud computing: The modern-day stalwarts

Another set of technologies that are molding the future of pharmaceutical supply chains are Digital Twin Technology and cloud computing. Both offer unique capabilities that, when combined, form a formidable force in supply chain optimization. Digital Twin Technology is, in essence, the creation of a virtual counterpart of a physical entity.^[24,25] In the pharmaceutical sector, this can be a representation of anything from a manufacturing unit to the entire supply network. With this virtual replica, companies can run countless simulations, anticipate potential pitfalls, and fine-tune processes without risking real-world repercussions.^[26] Simultaneously, cloud computing is reshaping data handling. Traditional data storage methods are making way for cloud platforms, offering scalability, accessibility, and collaboration like never before. This is particularly crucial in a globally intertwined industry like pharmaceuticals. With research in one corner of the world, manufacturing in another, and the end consumer in yet another region, the cloud ensures data uniformity, real-time updates, and collaboration.^[27,28]

When a new drug is in its trial phase, insights can be shared in real time with researchers across the globe, hastening the development process. Similarly, inventory levels across multiple locations can be monitored simultaneously, ensuring demand is met without overstocking. In essence, while AI and ML bring to the table the power of prediction and optimization, Digital Twin Technology and cloud computing offer the tools and infrastructure to implement these insights. Together, these technologies create an ecosystem where data-driven insights meet execution excellence, ensuring the pharmaceutical supply chain remains robust, efficient, and patient-centric.

The confluence of these diverse yet interconnected digital technologies promises a future where pharmaceutical supply chains are not just efficient but are also resilient, transparent, and agile. As the world continues to grapple with health challenges, having a supply chain fortified by these

technologies ensures that the right medication reaches the right person at the right time, every time.

Potential benefits of digital transformation in Africa's pharmaceutical supply chain

Africa, a continent with diverse cultures, economies, and infrastructures, has always faced unique challenges when it comes to health care. The pharmaceutical supply chain, a critical component of the health-care system, is no exception. However, in the era of technological advancement, digital transformation emerges as the potent solution to Africa's longstanding obstacles. By embedding cutting-edge digital technologies into the pharmaceutical supply chain, there lies the potential to revolutionize a system that has, for too long, been beleaguered by inefficiencies.

Enhanced traceability and transparency

At the forefront of these transformative benefits is enhanced traceability. Implementing block chain technology in the supply chain means that every drug, from its production to its final dispensation, has a transparent and unchangeable record. Each transaction, every shipment, and all storage conditions can be documented on the block chain. This unparalleled level of documentation is a strong deterrent against counterfeit drugs, a significant concern in many African nations. By ensuring that every medicine can be traced back to its origin, block chain technology not only safeguards the health of the populace but also bolsters confidence in the pharmaceutical supply chain.

Revolutionized inventory management

Inventory mismanagement, characterized by stock-outs or overstocking, has been a persistent challenge. Enter AI and ML, which, with their predictive analytics capabilities, can transform this scenario. These technologies analyze past consumption patterns, regional disease outbreaks, population demographics, and other pertinent factors to predict future drug demand with high accuracy. Such foresight ensures that medicines are available where they're needed most, reducing wastage and maximizing resource utilization.^[29]

Real-time quality assurance with internet of things

For a continent with varied climatic conditions, maintaining the efficacy of medicines, especially those requiring specific storage conditions, becomes crucial. IoT devices, equipped with sensors, can monitor storage conditions continuously. Any deviation from required conditions triggers alerts, allowing for timely interventions. This continuous surveillance ensures that medicines maintain their potency until they reach the patient.

Streamlining fragmented distribution networks

Digital platforms are game-changers in addressing Africa's fragmented distribution networks and variegated regulatory landscapes. These platforms provide a unified space for stakeholders from different countries to collaborate, share best practices, navigate regulatory nuances, and streamline inter-country pharmaceutical distributions.^[30]

Cost-efficiency and optimal resource utilization

By addressing inefficiencies, digital technologies pave the way for significant cost savings. Ensuring timely deliveries, optimal storage, and reduced wastage means that every dollar invested in the pharmaceutical supply chain yields a higher return, crucial for a continent where resources are often limited.

Empowerment of the end consumer

Digital transformation's ripple effect touches the end consumer, too. With clear, transparent systems, patients can track their medicines, understand their origins, and be assured of their quality. This transparency fosters trust and encourages adherence to medication regimens, which directly influences health outcomes.^[31]

A proactive supply chain model

Transitioning from a reactive model to a proactive one is perhaps the most profound change digital transformation can bring. Instead of reacting to challenges as they arise, the supply chain becomes equipped to anticipate and address potential issues in advance, ensuring uninterrupted medicine supply.^[32]

In understanding the potential of digital transformation in Africa's pharmaceutical supply chain, it is evident that it is not just about overcoming challenges. It is about elevating the entire system, making it more resilient, efficient, and patient-centric. By embracing and integrating these digital technologies, there is an opportunity to weave a new narrative for Africa's health-care story – one where access to medicines is democratized and patient well-being is at the heart of every decision. The journey might be laden with challenges, but the horizon promises a healthier, more empowered Africa.

RESULT

CHALLENGES AND BARRIERS TO DIGITAL TRANSFORMATION

The wave of digital transformation, while bringing immense potential to revolutionize the pharmaceutical supply chain in Africa, is not without its share of impediments. Acknowledging these barriers, understanding their origin, and crafting solutions are paramount to ensuring the successful and seamless integration of digital technologies. Delving deeper into these challenges, we focus on three core areas – infrastructure limitations, skill and knowledge gaps, and regulatory and policy concerns – that demand attention and resolution.

Infrastructure limitations

Africa's infrastructural landscape, both digital and physical, remains a mixed bag. On one hand, we observe rapid urbanization and growth in certain regions, while on the other, there are areas still grappling with rudimentary challenges, creating an uneven foundation for the introduction of advanced digital solutions. The physical infrastructure, particularly in remote regions, often lags behind the required standards for advanced technological deployments. This manifests in various

forms. Unreliable power supplies, for instance, can hamper the continuous operation of digitally driven supply chain solutions, leading to system downtimes and consequently, interruptions in essential services. For technologies like the IoT, which rely on real-time data transfer and monitoring, such interruptions can be detrimental.^[33,34]

Digital infrastructure, while seeing a steady rise in its reach and quality, still has its challenges. Limited access to high-speed internet in certain areas can hinder the operation of cloud-based platforms and real-time data sharing systems that are paramount to modern supply chain solutions. Furthermore, the absence of robust data centers within the continent often means reliance on offshore centers, leading to potential data latency issues and concerns over data sovereignty. Addressing these infrastructure limitations requires a multipronged approach. Investments in physical infrastructure, like power grids and transportation networks, are essential. Similarly, fostering partnerships with global tech giants and local startups can pave the way for the development of robust, localized digital infrastructure solutions tailored for African needs.^[35]

Skill and knowledge gaps

Technological tools, regardless of their advanced capabilities, are only as effective as the people operating them. There exists a conspicuous skill and knowledge gap within the continent when it comes to digital technologies. Many parts of Africa still experience a scarcity of experts proficient in block chain, AI, or IoT. The reasons for this are multifaceted. Historical underinvestment in Science, Technology, Engineering, and Mathematics (STEM) education, coupled with a lack of specialized training programs tailored to the nuances of the pharmaceutical supply chain, are among the culprits. In addition, the rapid pace of technological advancement often outstrips the rate of educational curriculum updates, leading to a lag in current knowledge impartation.^[36]

Addressing this challenge requires both short-term and long-term strategies. In the short term, initiatives like workshops, certification programs, and partnerships with global tech institutions can help upskill the existing workforce. For a long-term solution, revamping educational curricula, fostering research, and creating centers of excellence within the continent dedicated to digital technologies in supply chains can ensure a steady pipeline of skilled professionals ready to harness the power of digital transformation.^[37]

Regulatory and policy concerns

The final, yet equally daunting challenge lies in the regulatory and policy domain. Digital transformation, especially in a sector as sensitive as pharmaceuticals, brings with it a myriad of concerns – data privacy, cybersecurity, intellectual property rights, to name a few. Regulations, while crafted with the intent of safeguarding stakeholder interests, can sometimes become unintentional roadblocks. For instance, stringent data localization laws can hinder cloud-based solutions that rely on offshore data centers. Conversely, a lack of clear regulations

around data privacy can dissuade companies from adopting digital solutions, fearing potential legal ramifications.^[38]

Furthermore, as these technologies are relatively new, many countries might not have a comprehensive framework to regulate their use, leading to a state of ambiguity. This regulatory vacuum can be a deterrent for companies looking to invest heavily in digital transformation, fearing potential future restrictions. To navigate these waters, a collaborative approach is vital. Governments, industry leaders, tech experts, and global regulatory bodies must come together to craft policies that balance innovation with safety, ensuring that regulations act as facilitators, not deterrents.^[39]

To encapsulate the key points discussed, while the path to a fully digitized pharmaceutical supply chain in Africa shows immense promise, it's laden with challenges. However, with concerted efforts, strategic investments, and collaborative endeavors, these barriers can be surmounted. The future, while challenging, holds the promise of a digitized, efficient, and robust pharmaceutical supply chain that not only caters to Africa's unique needs but also stands as a global exemplar.

DISCUSSION AND RECOMMENDATIONS

RECOMMENDATIONS: CHARTING A WAY FORWARD FOR AFRICA'S PHARMACEUTICAL SUPPLY CHAIN

In the heart of Africa, against the backdrop of a rich cultural tapestry and immense potential, lies a challenge. A challenge that, while daunting, isn't insurmountable. The pharmaceutical supply chain in the continent, though integral, has historically grappled with inefficiencies. But with the dawn of the digital age, there emerges a beacon of hope. As we navigate the labyrinth of digital transformation and its implications for Africa's pharmaceutical landscape, several strategic pathways beckon, promising not just resolution but rejuvenation.

The issue at the heart of it all is infrastructure. Africa's patchwork quilt of urban growth juxtaposed against stretches of underdevelopment paints a complex picture. Cities like Nairobi or Johannesburg are bustling hubs of technological innovation, but venture a little further out, and the story changes. Unreliable power supplies, rudimentary transportation systems, and inconsistent digital networks form a trifecta of obstacles. So, how do we bridge this gap? Investment is the key. Both Governments and private entities need to recognize the immense potential lying dormant and act on it. By prioritizing funds in infrastructure development, we can pave the way for not just a more reliable power grid but also more efficient transportation networks. Imagine a future where medicines, even in the remotest parts of the continent, are delivered seamlessly, thanks to an intricate web of digitally powered networks.

But hardware alone isn't the solution; it's the people behind it that matter. The continent has long battled a knowledge chasm.

Not many are adept at harnessing block chain's power, making sense of AI's algorithms, or integrating IoT's capabilities. This isn't a reflection of capability but exposure. Historically, there's been an underinvestment in STEM fields. The ultimate remedy to address this challenge? A comprehensive and robust education system tailored to meet the evolving demands of the digital age. It's time institutions across Africa revamped their curriculum. By integrating modern digital tools and techniques, we can ensure that graduates step out, not just with degrees, but with expertise. Moreover, collaborations with global tech giants can facilitate specialized training programs, providing hands-on experience. This synergy between academia and industry can produce a workforce ready to spearhead Africa's digital revolution.

Yet, even as we arm ourselves with tools and talent, a shadow looms large: Regulation. Digital transformation, particularly in a sector as sensitive as pharmaceuticals, is fraught with concerns. Data privacy, cybersecurity, intellectual property rights – the list is exhaustive. Regulations are, no doubt, imperative, crafted meticulously to safeguard the interests of stakeholders. However, they often lag, unable to keep pace with the rapid technological advancements. The need of the hour is clear, concise, and forward-thinking regulatory frameworks. Governments across the continent need to be proactive. Engaging in regular dialogues with industry leaders, tech maestros, and consumers can usher in balanced regulations that foster growth while ensuring safety. Standardized protocols can act as a catalyst, instilling trust and transparency and promoting widespread digital adoption.

Awareness is another piece of this intricate puzzle. The African populace needs to understand the monumental shifts digital transformation can bring. Public campaigns, success stories, anecdotes of how a digitized supply chain transformed lives – these can act as powerful tools of persuasion. An informed and educated populace can drive demand, pushing companies and governments to expedite their digital journey.

Lastly, innovation needs to be at the core of this transformation. While global solutions provide a starting point, Africa's unique challenges require tailored solutions. Governments, by offering incentives, grants, and fostering a culture of research, can stimulate localized innovation. Establishing hubs that focus on devising digital solutions for the pharmaceutical supply chain can ensure that the solutions developed are not just effective but also sustainable.

In essence, the road to digital transformation for Africa's pharmaceutical supply chain, while dotted with challenges, is one of promise. By amalgamating investment, education, regulatory clarity, awareness, and innovation, the continent can herald a new era. An era where medicines reach every nook and cranny, not because of mere chance, but because of a well-oiled, digitally powered supply chain. The dream of a healthier, better-connected Africa is within reach; it's time to make it a reality.

CONCLUSION

Africa, a land of unparalleled diversity and unbridled potential, stands at the cusp of a digital revolution. At the heart of this transformative journey lies the pharmaceutical supply chain – A critical conduit for the health and well-being of its residents. Historically, the continent's supply chain has been marred by inefficiencies, largely stemming from infrastructural deficits, knowledge gaps, and regulatory challenges. However, as this paper has underscored, the advent of digital technologies offers a promising remedy.

Block chain can infuse traceability and security, ensuring that counterfeit medications – a persistent ailment in the continent's pharmaceutical landscape – become relics of the past. AI promises a future where supply matches demand, where inventory management is more science than guesswork. The IoTs, with its interconnected mesh of devices, can revolutionize monitoring and real-time updates, ensuring timely delivery and optimal stock levels.

Yet, while the potential is immense, the journey is not devoid of roadblocks. Infrastructure, both physical and digital, requires a massive overhaul. The workforce needs to be equipped with the skills of tomorrow, demanding both a revamp in educational curricula and continuous training. Regulations, often playing catch-up with technology, need to be agile, fostering growth while ensuring safety.

As the continent grapples with these challenges, there emerges a narrative of hope. Collaborative efforts between Governments, industry leaders, and the public can bridge existing gaps. Investments in infrastructure, a focus on education, regulatory clarity, and a push towards localized innovation can drive the much-needed transformation.

In closing, the digital overhaul of Africa's pharmaceutical supply chain is not just a matter of economic prudence – it's a moral imperative. Every missed delivery, every stock-out, has human consequences. By embracing digital tools and strategies, Africa has the opportunity to ensure that its pharmaceutical supply chain, much like the mighty Nile, flows uninterrupted, nurturing life in its wake. The future beckons, and with concerted efforts, a healthier, digitally empowered Africa awaits.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Kaylor A. Fundamentals of the Pharmaceutical Supply Chain; 2023. Available from: <https://www.pharmanewsintel.com/news/fundamentals-of-the-pharmaceutical-supply-chain>. [Last accessed on 2023 Jul 10].
- Hailu R, Gizaw T, Berhanu N, Mulugeta T, Boche B, Gudeta T. Exploring the role of ICT in pharmaceutical supply chain practices and operational performance in Ethiopia: A structural equation modeling approach. *BMC Health Serv Res* 2023;23:634.
- Woodburn PA. Analysis of Challenges of Medical Supply Chains in Sub-Saharan Africa Regarding Inventory Management and Transport and Distribution. London Westminster Business School; 2013. Available from: <https://www.iaphl.org/wp-content/uploads/2016/05/Medical-Supply-Chain-Challenges.Masterthesis.ASchoepperle.pdf>. [Last accessed on 2023 Jul 10].
- Adebisi YA, Nwogu IB, Alaran AJ, Badmos AO, Bamgboye AO, Rufai BO, *et al.* Revisiting the issue of access to medicines in Africa: Challenges and recommendations. *Public Health Chall* 2022;1:e9.
- Ekeigwe AA. Drug manufacturing and access to medicines: The West African story. A literature review of challenges and proposed remediation. *AAPS Open* 2019;5:3.
- Kuteyi D, Winkler H. Logistics challenges in sub-Saharan Africa and opportunities for digitalization. *Sustainability* 2022;14:2399.
- Olutuase VO, Iwu-Jaja CJ, Akuoko CP, Adewuyi EO, Khanal V. Medicines and vaccines supply chains challenges in Nigeria: A scoping review. *BMC Public Health* 2022;22:11.
- Moosivand A, Rajabzadeh Ghatari A, Rasekh HR. Supply chain challenges in pharmaceutical manufacturing companies: Using qualitative system dynamics methodology. *Iran J Pharm Res* 2019;18:1103-16.
- Yousefi N, Alibabaei A. Information flow in the pharmaceutical supply chain. *Iran J Pharm Res* 2015;14:1299-303.
- Goshorn B, Usswald C. Pharmaceutical supply chains in Africa – Overcoming unique transport security challenges. *J Transp Secur* 2014;7:333-7.
- Moradeyo AA. Rudimentary causes and impacts of supply chain risks in sub-Saharan Africa. *J Oper Supply Chain Manage* 2018;11:16-31.
- Aigbavboa S, Mbohwa C. The headache of medicines' supply in Nigeria: An exploratory study on the most critical challenges of pharmaceutical outbound value chains. *Procedia Manuf* 2020;43:336-43.
- Nebot Giralt A, Schiavetti B, Meessen B, Pouget C, Caudron JM, Marchal B, *et al.* Quality assurance of medicines supplied to low-income and middle-income countries: Poor products in shiny boxes? *BMJ Glob Health* 2017;2:e000172.
- Leung NH, Chen A, Yadav P, Gallien J. The impact of inventory management on stock-outs of essential drugs in sub-Saharan Africa: Secondary analysis of a field experiment in Zambia. *PLoS One* 2016;11:e0156026.
- Danzon PM, Mulcahy AW, Towse AK. Pharmaceutical pricing in emerging markets: Effects of income, competition, and procurement. *Health Econ* 2015;24:238-52.
- Yenet A, Nibret G, Tegegne BA. Challenges to the availability and affordability of essential medicines in African countries: A scoping review. *Clinicoecon Outcomes Res* 2023;15:443-58.
- Horner R. Global value chains, import orientation, and the state: South Africa's pharmaceutical industry. *J Int Bus Policy* 2021. p. 1-20. [doi: 10.1057/s42214-021-00103-y].
- Clauson KA, Breeden EA, Davidson C, Mackey TK. Leveraging Blockchain Technology to Enhance Supply Chain Management in Healthcare: Blockchain in Healthcare Today. *Leveraging Blockchain Technology to Enhance Supply Chain Management in Healthcare: Blockchain in Healthcare Today* 2018;1:1-12. [doi: 10.30953/bhty.v1.20].
- Wang X, Kumar V, Kumari A, Kuzmin E. Impact of digital technology on supply chain efficiency in manufacturing industry. In: *Digital Transformation in Industry: Digital Twins and New Business Models*. Cham: Springer International Publishing; 2022. p. 347-71.
- Gruchmann T, Elgazzar S, Ali AH. Blockchain technology in pharmaceutical supply chains: A transaction cost perspective. *Mod Supply Chain Res Appl* 2023;5:115-33. [doi: 10.1108/mscra-10-2022-0023].
- Mohsen BM. Developments of digital technologies related to supply chain management. *Procedia Comput Sci* 2023;220:788-95.
- Tirkolaei EB, Sadeghi S, Mooseloo FM, Vandchali HR, Aeni S. Application of machine learning in supply chain management: A comprehensive overview of the main areas. *Math Probl Eng* 2021;2021:1-14.
- Vora LK, Gholap AD, Jetha K, Thakur RR, Solanki HK, Chavda VP. Artificial intelligence in pharmaceutical technology and drug delivery

- design. *Pharmaceutics* 2023;15:1916.
24. Busse A, Gerlach B, Lengeling JC, Poschmann P, Werner J, Zarnitz S. Towards digital twins of multimodal supply chains. *Logistics* 2021;5:25.
 25. Lu Y, Liu C, Kevin I, Wang K, Huang H, Xu X. Digital twin-driven smart manufacturing: Connotation, reference model, applications and research issues. *Robot Comput Integr Manuf* 2020;61:101837.
 26. Kmiecik M. Digital twin as a tool for supporting logistics coordination in distribution networks. *Int J Supply Chain Manage* 2023;12:1-6.
 27. Kochan CG, Nowicki DR, Sauser B, Randall WS. Impact of cloud-based information sharing on hospital supply chain performance: A system dynamics framework. *Int J Prod Econ* 2018;195:168-85.
 28. Shashi M. Sustainable digitalization in pharmaceutical supply chains using theory of constraints: A qualitative study. *Sustainability* 2023;15:8752.
 29. Raj A, Mukherjee AA, de Sousa Jabbour AB, Srivastava SK. Supply chain management during and post-COVID-19 pandemic: Mitigation strategies and practical lessons learned. *J Bus Res* 2022;142:1125-39.
 30. Ndomondo-Sigonda M, Miot J, Naidoo S, Masota NE, Ng'andu B, Ngum N, *et al.* Harmonization of medical products regulation: A key factor for improving regulatory capacity in the East African community. *BMC Public Health* 2021;21:187.
 31. Backes C, Moyano C, Rimaud C, Bienvenu C, Schneider MP. Digital medication adherence support: Could healthcare providers recommend mobile health apps? *Front Med Technol* 2020;2:616242.
 32. Vial G. Understanding digital transformation: A review and a research agenda. *Managing Digital Transformation* 2021;28:13-66. [doi: 10.4324/9781003008637].
 33. Eyita-Okon E. Urbanization and human security in post-colonial Africa. *Front Sustain Cities* 2022;4:917764.
 34. Güneralp B, Lwasa S, Masundire H, Parnell S, Seto KC. Urbanization in Africa: Challenges and opportunities for conservation. *Environmental research letters* 2017;13:015002.
 35. Mondejar ME, Avtar R, Diaz HL, Dubey RK, Esteban J, Gómez-Morales A, *et al.* Digitalization to achieve sustainable development goals: Steps towards a smart green planet. *Sci Total Environ* 2021;794:148539.
 36. Ojukwu E. Digital Skills Gap in Africa. Tekedia; 2022. Available from: <https://www.tekedia.com/digital-skills-gap-in-africa/>. [Last accessed on 2023 Jul 10].
 37. Li L. Reskilling and upskilling the future-ready workforce for industry 4.0 and beyond. *Inf Syst Front* 2022. p. 1-16.
 38. Hamma-Adama M, Labaran MJ. The Nigerian pharmaceutical supply chain: Blockchain adoption, counterfeit drugs and successful deployment of COVID-19 vaccine in Nigeria. *J Sci Res Rep* 2021;27:20-36.
 39. Bansal S, Kumar V, Kumari A, Kuzmin E. Understanding the role of digital technologies in supply chain management of SMEs. In: *International Scientific Conference on Digital Transformation in Industry: Trends, Management, Strategies*. Cham: Springer Nature Switzerland; 2022. p. 195-205.