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Assessing the Impact of Critical Infrastructure Development on Supply Chain Optimization in Kenya

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Abstract

This study examines the impact of critical infrastructure development on supply chain optimisation in Kenya, with a focus on transport, energy, and ICT systems. Using a mixed-methods design, the research combined secondary data from the World Bank, the Kenya National Bureau of Statistics, and the Ministry of Transport with 25 semi-structured interviews conducted across agriculture, manufacturing, and retail sectors. Quantitative analysis shows that between 2016 and 2023, Kenya's Logistics Performance Index (LPI) infrastructure score improved by 13.6%, average cargo dwell time at the Port of Mombasa fell by 57.1%, and the paved road network expanded by 52.7%. Qualitative findings reveal that while flagship projects such as the Standard Gauge Railway and rural feeder road upgrades reduced logistics costs and improved delivery predictability, persistent challenges remain in last-mile connectivity, power reliability, and ICT integration—particularly in rural and informal sectors. The study concludes that infrastructure development has enhanced efficiency and resilience in Kenya's supply chains but with uneven sectoral and regional outcomes. Policy recommendations emphasise inclusive infrastructure planning, digital logistics integration, and climate-resilient investments to ensure that future infrastructure projects deliver equitable and sustainable supply chain transformations.

Keywords: Infrastructure Development, Supply Chain Optimisation, Kenya, Logistics Performance, Economic Growth

1. INTRODUCTION

Infrastructure plays a pivotal role in the socio-economic transformation of any nation, serving as the backbone for production, distribution, and consumption activities. In developing economies like Kenya, the quality and availability of critical infrastructure—such as roads, ports, railways, electricity, and digital networks—profoundly influence the performance and efficiency of supply chains. Supply chains, which encompass the movement of goods and services from source to end-user, are highly sensitive to infrastructural conditions. Poor infrastructure results in high transaction costs, inefficiencies in logistics, and barriers to market access, particularly for rural producers and small enterprises (UNCTAD, 2021; Calderón & Servén, 2014).

Over the last two decades, Kenya has made considerable investments in transport and energy infrastructure with the aim of positioning itself as a regional trade hub. Key initiatives such as the Standard Gauge Railway (SGR), the expansion of the Port of Mombasa, and the LAPSSET Corridor project exemplify the country's efforts to modernise logistics and support regional integration (AfDB, 2022). Simultaneously, the expansion of renewable energy capacity and digital infrastructure has further supported the transition towards more agile and data-driven supply chains. These improvements are intended to reduce logistics costs, improve delivery timelines, and enhance resilience against disruptions caused by external shocks such as pandemics or climate events (Gereffi, 2020; Ivanov & Dolgui, 2020).

Despite these efforts, infrastructure gaps and implementation challenges persist. Inconsistent power supply, limited rural connectivity, poor road maintenance, and underutilisation of infrastructure assets continue to hamper optimal supply chain performance (World Bank, 2023). These challenges call for a comprehensive assessment of how recent and ongoing infrastructure development initiatives affect supply chain operations in Kenya. Understanding this relationship is essential not only for academic inquiry but also for informing policy decisions and investment strategies that align with national development goals and international trade frameworks such as the African Continental Free Trade Area (AfCFTA).

This paper aims to critically assess the impact of critical infrastructure development on supply chain optimisation in Kenya. It will examine the extent to which investments in transport, energy, and communication infrastructure have enhanced supply chain efficiency, reduced operational costs, and improved logistical reliability. Using a mixed-methods approach, the study combines empirical data with qualitative insights from industry stakeholders to provide a broad perspective on the infrastructure–supply chain nexus in Kenya. The findings are expected to inform both national policy and regional infrastructure planning within the East African context.

1.1 Background

Infrastructure development is widely recognised as a foundational pillar for achieving long-term economic growth and structural transformation, especially in developing countries like Kenya. Inadequate infrastructure has historically constrained economic activities, increased production and distribution costs, and deterred foreign direct investment (FDI) (Estache & Garsous, 2012). Efficient infrastructure facilitates the flow of goods, services, and people, thereby enhancing market accessibility, labour productivity, and firms' competitiveness. In Kenya's context, infrastructural deficits in transport, power, and ICT have contributed to supply chain bottlenecks, which significantly affect both domestic businesses and regional trade flows (UNCTAD, 2021). Thus, investing in critical infrastructure is not merely a developmental aspiration but a strategic necessity for economic transformation and global integration.

Critical infrastructure encompasses transportation networks (roads, railways, and ports), energy systems, water distribution, and telecommunications infrastructure, all of which serve as the backbone of a functional economy. These elements are particularly vital for supply chain optimisation, as they enable the timely movement of goods, efficient communication between supply chain actors, and reliable access to utilities required for manufacturing and distribution (OECD, 2022). For instance, Kenya's road network—comprising over 160,000 km—plays a pivotal role in connecting rural producers to urban markets and regional export hubs. However, according to the Logistics Performance Index (LPI) by the World Bank, Kenya has consistently ranked lower than global averages in customs clearance and infrastructure quality, indicating room for improvement despite recent upgrades (World Bank, 2023). Addressing these infrastructure challenges is therefore essential for improving supply chain velocity and lowering costs in key sectors such as agriculture, retail, and manufacturing.

In response, the Kenyan government, supported by multilateral institutions and public-private partnerships, has launched ambitious infrastructure projects to close the gap. The Standard Gauge Railway (SGR), launched in 2017, is one of the largest infrastructure projects in East Africa and aims to reduce freight costs and travel time between the port of Mombasa and inland trade centres (Kenya Railways, 2020). Similarly, the Lamu Port-South Sudan-Ethiopia-Transport (LAPSSET) Corridor seeks to enhance connectivity between Kenya and landlocked neighbouring countries, opening up new trade routes and investment opportunities (African Union Development Agency [AUDA-NEPAD], 2021). These projects reflect a deliberate strategy to create regional trade corridors that align with the African Continental Free Trade Area (AfCFTA) framework, positioning Kenya as a regional logistics hub. Nevertheless, implementation delays, cost overruns, and maintenance concerns remain significant challenges that could limit the long-term benefits of such investments (Hope, 2021).

These infrastructure developments are anticipated to improve supply chain operations by reducing lead times, enhancing inventory turnover, and increasing predictability in logistics planning. Moreover, access to reliable energy and digital infrastructure facilitates real-time tracking systems, warehouse automation, and integration of e-commerce platforms—key drivers of modern supply chain performance (Gereffi, 2020). For example, the Last Mile Connectivity Project by Kenya Power has improved access to electricity for industrial clusters and small-scale manufacturers, thereby supporting local value addition (Ministry of Energy, 2021). As Kenya continues to modernise its infrastructure, a systems-based approach that aligns transport, energy, and ICT developments with supply chain strategies is essential. Doing so will not only reduce costs but also increase resilience to shocks such as pandemics, climate change, and geopolitical disruptions, all of which have exposed vulnerabilities in global and national supply chains (Ivanov & Dolgui, 2020).

1.2 Statement of Problem

Despite significant investments in transport, energy, and ICT infrastructure, Kenya continues to experience inefficiencies in supply chain operations. While projects such as the Standard Gauge Railway (SGR), the Nairobi Motorway, and the expansion of the Port of Mombasa have improved freight capacity and reduced transit times, structural bottlenecks—including poor rural road networks, limited cold chain systems, and unreliable electricity supply—remain persistent (World Bank, 2023; UNCTAD, 2021). These challenges

disproportionately affect agriculture and small-scale enterprises, where high logistics costs—estimated at over 30% of the value of goods—far exceed the global benchmark of 8–10% (African Development Bank [AfDB], 2022). As a result, Kenya's supply chains remain fragmented, with firms struggling to compete effectively in both domestic and international markets.

Moreover, while Kenya has recorded a 13.6% improvement in its Logistics Performance Index (LPI) infrastructure score between 2016 and 2023, this progress has been uneven across regions and sectors. Urban centres and export-orientated industries have benefited most, whereas rural producers and SMEs continue to face poor last-mile connectivity, seasonal disruptions, and limited integration into digital logistics platforms (Kenya National Bureau of Statistics [KNBS], 2023; Shippers Council of Eastern Africa [SCEA], 2022). These disparities suggest that infrastructure development alone is insufficient unless complemented by inclusive planning, efficient asset management, and digital transformation strategies.

The problem therefore lies not only in the existence of infrastructure but in its alignment with supply chain optimisation objectives. Existing research has often treated infrastructure investment and supply chain performance as separate issues (Calderón & Servén, 2014; Christopher, 2016), with limited empirical evidence from Kenya on how recent infrastructure projects have directly influenced efficiency, cost reduction, and resilience outcomes. This study addresses this gap by critically assessing the impact of critical infrastructure development on supply chain optimisation in Kenya, using both quantitative performance metrics and qualitative insights from key stakeholders.

1.3 Importance of Infrastructure in Economic Development

The nexus between infrastructure development and economic growth has long been a focal point in both classical and modern economic theories. Foundational models of economic development, such as the Harrod-Domar and Solow growth models, emphasise the importance of capital accumulation—including infrastructure—as a driver of productivity and output expansion (Todaro & Smith, 2020). Empirically, a large body of research supports the assertion that well-planned infrastructure investments contribute significantly to reducing transaction costs, lowering logistical inefficiencies, and enhancing overall economic performance (Calderón & Servén, 2014). For supply chains, this translates into smoother transportation, faster processing times, and improved information flow, all of which are prerequisites for achieving competitiveness in domestic and international markets. In the context of sub-Saharan Africa, infrastructure gaps are often cited as the single largest constraint on doing business and achieving sustainable industrialisation (World Economic Forum, 2022).

In Kenya specifically, supply chain operations have long suffered from infrastructural inadequacies. Poor road quality, port congestion, and unreliable electricity supply are persistent challenges that have limited the efficiency of production and distribution networks (UNCTAD, 2021). According to the World Bank's Logistics Performance Index (2023), Kenya lags in areas such as infrastructure quality and timeliness, which are crucial indicators of logistical effectiveness. The Nairobi-Mombasa corridor, for instance, is a critical trade route that handles up to 90% of Kenya's international trade; however, historical congestion, weak maintenance practices, and corruption at weighbridges have contributed to shipment delays and increased costs (Kenya Transport Sector Report, 2022). These inefficiencies result in higher inventory holding costs, reduced turnover, and limited scalability for firms, especially small and medium-sized enterprises (SMEs) that form the backbone of Kenya's economy.

Despite these limitations, Kenya has made notable strides recently to upgrade and expand its infrastructure base. Mega-projects such as the Thika Superhighway, the Standard Gauge Railway (SGR), and the expansion of the Port of Mombasa are aimed at boosting freight capacity, shortening travel times, and integrating remote regions into national and regional supply chains (AfDB, 2022). Energy infrastructure has also witnessed a significant transformation, with increased investment in renewable energy—particularly geothermal and wind power—enhancing energy access and reliability (IRENA, 2021). These developments support technology adoption and innovation within supply chains, enabling the deployment of digital logistics platforms, inventory management systems, and e-commerce solutions (Kilelu et al., 2019). Improved energy and digital infrastructure thus serve as catalysts for more agile and transparent supply chains, which are vital for participation in global value chains (GVCs).

Moreover, robust infrastructure enhances the resilience of supply chains to external shocks, such as pandemics, climate change, and geopolitical disruptions. The COVID-19 pandemic reaffirmed the need for resilient infrastructure, as countries with diversified transport and ICT systems were better able to maintain supply chain continuity (Gereffi, 2020). Kenya's over-reliance on limited entry ports and highways exposed vulnerabilities that delayed critical imports such as medical supplies and food items during lockdown periods. Going forward, investing in climate resilience infrastructure—such as flood-resistant roads and decentralised energy systems—will be essential to maintaining supply chain functionality under environmental stressors (OECD, 2022). These

considerations highlight that infrastructure is not just an economic enabler but also a strategic asset for national security and socio-economic stability.

1.4 Definition of Key Concepts

For the purpose of this study, critical infrastructure refers to physical systems and assets—such as transportation corridors, power generation facilities, and telecommunications networks—that are essential for the functioning of a society and economy (OECD, 2022). Supply chain optimisation refers to the strategic coordination of business processes and logistics to enhance efficiency, reduce costs, and improve service delivery across the value chain (Christopher, 2016). In this context, infrastructure development encompasses both the construction of new assets and the upgrading of existing systems to meet current and future demand. Understanding the interplay between these elements is essential to assess how infrastructure influences supply chain dynamics in Kenya.

1.5 Research Objectives

This study aims to critically assess the impact of crucial infrastructure development on supply chain optimisation in Kenya. Specifically, it seeks to:

i. Examine how transportation, energy, and ICT infrastructure influence supply chain efficiency and cost-effectiveness.
ii. Evaluate the extent to which infrastructure improvements enhance supply chain resilience and reliability.
iii. Identify challenges and opportunities associated with infrastructure-led supply chain transformation.
iv. Provide policy recommendations to guide infrastructure investment decisions that align with supply chain strategic needs in Kenya.

2. LITERATURE REVIEW (Revised)

The relationship between infrastructure and economic performance has long been recognised in development scholarship. Foundational studies emphasise that infrastructure not only reduces transaction costs but also facilitates productivity growth and competitiveness (Calderón & Servén, 2014). In the context of global value chains, well-functioning transport, energy, and ICT networks are central to lowering logistics costs and enabling trade efficiency (Christopher, 2016). However, critics argue that many low- and middle-income countries, including Kenya, have pursued infrastructure expansion without ensuring effective alignment with supply chain optimisation strategies (Straub, 2019). This suggests that infrastructure, while necessary, is not a sufficient condition for supply chain competitiveness unless complemented by institutional reforms and digital integration.

Empirical studies at the global level demonstrate that infrastructure investment has a direct impact on trade facilitation and logistics performance. For example, De Soyres et al. (2018) found that China's Belt and Road Initiative reduced trade costs significantly across participating countries. Similarly, OECD (2022) emphasises that multimodal transport corridors improve predictability and resilience in supply chains. Yet, the African Development Bank (2022) estimates that Africa loses up to 2% of GDP annually due to infrastructure deficits, reflecting a persistent "infrastructure paradox" where large-scale projects coexist with weak logistics outcomes. This raises the question of whether Kenya's flagship projects, such as the Standard Gauge Railway (SGR) and LAPSSET Corridor, are achieving intended supply chain efficiencies or merely expanding physical infrastructure without addressing systemic inefficiencies.

Regional studies reinforce this paradox by highlighting Africa's infrastructure-financing gap of $68–$108 billion annually, with transport and energy sectors being most underdeveloped (AfDB, 2022). Kenya's Vision 2030 agenda has prioritised large-scale infrastructure projects, yet issues of corruption, cost overruns, and weak maintenance continue to undermine their effectiveness (Hope, 2021). The World Bank (2023) further reports that while Kenya's Logistics Performance Index (LPI) score has improved, it remains below global averages in customs clearance and infrastructure reliability. Comparative evidence from neighbouring economies such as Ethiopia shows similar patterns: rapid infrastructure expansion but persistent inefficiencies in supply chain velocity (World Economic Forum, 2022). This indicates that the challenge is not only building infrastructure but also ensuring its integration into logistics systems.

The supply chain management literature increasingly underscores agility, resilience, and digitalisation as determinants of competitiveness. Ivanov and Dolgui (2020) argue that resilient supply chains are closely tied to robust transport and ICT systems, especially under conditions of uncertainty such as pandemics and climate change. Kenya's infrastructure investments have enabled partial gains—such as reduced dwell time at the Port of Mombasa—but bottlenecks in last-mile delivery, cold chain systems, and unreliable power continue to hinder supply chain resilience (UNCTAD, 2021). Kilelu, Klerkx, and Leeuwis (2019) further show that Kenyan SMEs and smallholder farmers are often excluded from modern value chains due to weak rural infrastructure and limited digital integration. These insights highlight that infrastructure-led supply chain optimisation cannot be assessed in

isolation but must be situated within broader systemic and institutional constraints.

Scholars also debate whether infrastructure development inherently leads to inclusive supply chain outcomes. Some argue that infrastructure primarily benefits urban and export-orientated sectors, while rural regions remain underserved (KNBS, 2023; SCEA, 2022). Evidence from Kenya's agricultural sector illustrates this divide: while feeder roads have reduced post-harvest losses in some counties, producers in remote areas continue to face seasonal market inaccessibility. Similar disparities exist in manufacturing and retail, where firms located along major corridors such as Nairobi–Mombasa enjoy improved turnaround times, while those in secondary towns cite persistent logistical bottlenecks (AfDB, 2022). This uneven distribution underscores the importance of evaluating not just the existence but the equity of infrastructure benefits across supply chain actors.

Taken together, the literature demonstrates a consensus that infrastructure is a critical enabler of supply chain efficiency, but it also reveals persistent limitations in how infrastructure projects translate into optimisation outcomes. Existing research in Kenya has largely focused on macroeconomic impacts of infrastructure (Calderón & Servén, 2014; World Bank, 2023) or sectoral supply chain challenges in isolation (Christopher, 2016; UNCTAD, 2021). Few studies have integrated these perspectives to examine how recent infrastructure projects directly shape supply chain outcomes such as cost reduction, lead time improvement, and resilience enhancement. This study therefore seeks to bridge this gap by providing an empirical assessment of how transport, energy, and ICT infrastructure developments influence supply chain optimisation in Kenya, drawing on both quantitative performance data and qualitative stakeholder perspectives.

2.1 Global and Regional Studies of Infrastructure

Infrastructure development is widely acknowledged as a cornerstone of sustainable economic growth, particularly in emerging and developing economies. Infrastructure, including transport networks, power systems, water services, and communication technologies, enables the efficient movement of goods and people, facilitates trade, and boosts industrial productivity. Calderón and Servén (2014) provide extensive empirical evidence that infrastructure quality has a direct impact on GDP growth, income equality, and productivity across multiple developing countries. Their analysis underscores that not just the quantity but also the quality and reliability of infrastructure significantly influence economic performance. High transaction costs, long travel times, and unpredictable logistics often stem from inadequate infrastructure, undermining national competitiveness and deterring foreign investment.

The Organisation for Economic Co-operation and Development (OECD, 2022) reinforces this view, noting that improved infrastructure—particularly in transport and energy—plays a catalytic role in reducing logistical bottlenecks and attracting private-sector investment. Infrastructure also serves as a platform for innovation and technology diffusion, especially when complemented by digital infrastructure. For instance, integrated freight corridors and multimodal logistics hubs can vastly enhance the speed and predictability of cross-border trade. DeSoyres et al. (2018), analysing the Belt and Road Initiative, demonstrate how large-scale infrastructure investment can improve trade flows and supply chain integration across multiple countries by shortening transport distances, streamlining logistics, and reducing border delays. These findings emphasise that infrastructure improvements have broad multiplier effects on both domestic and international trade.

In the African context, however, a persistent infrastructure deficit continues to stifle economic development. According to the African Development Bank (AfDB, 2022), the infrastructure investment gap in Sub-Saharan Africa ranges from $68 billion to $108 billion annually, with energy, roads, and water systems being the most underdeveloped. Inadequate infrastructure contributes to inflated logistics costs, delays in service delivery, and barriers to regional trade integration. For landlocked countries and remote rural areas, these challenges are even more pronounced, limiting access to inputs, markets, and investment. The underperformance of regional economic communities such as COMESA and EAC in achieving economic convergence has been partly attributed to poor connectivity and weak infrastructure interoperability between member states.

Kenya has responded to these challenges through ambitious national development strategies, most notably Vision 2030. Flagship infrastructure projects such as the Standard Gauge Railway (SGR), the Lamu Port-South Sudan-Ethiopia-Transport (LAPSSET) Corridor, and the Nairobi Motorway have aimed to improve logistical efficiency, reduce transport costs, and enhance regional connectivity (Kenya Vision 2030 Delivery Secretariat, 2021). However, the full impact of these initiatives has often been undermined by governance challenges, including procurement-related corruption and poor project maintenance (Hope, 2021). In addition, the effects of climate change—rising temperatures, increased flooding, and extreme weather events—place further stress on physical infrastructure, indicating the importance of resilient and adaptive systems (World Bank, 2023). This evolving landscape underscores the importance of not just building infrastructure but ensuring it is inclusive, climate-

resilient, and strategically aligned with economic goals.

2.2 Supply Chain Management

Supply chain management (SCM) is central to the efficient functioning of modern economies, encompassing the end-to-end coordination of material, information, and financial flows. At its core, SCM aims to ensure that the right products are delivered to the right places at the right times, with minimal waste and maximum value addition. Christopher (2016) highlights how effective SCM enhances operational efficiency, customer satisfaction, and cost competitiveness. In mature economies, technological innovations such as artificial intelligence, blockchain, and the Internet of Things (IoT) have been harnessed to create agile, transparent, and resilient supply chains. These technologies enable real-time tracking, demand forecasting, and inventory optimisation, which drives strategic decision-making and enhances responsiveness to market changes.

Conversely, in many developing countries, SCM systems are often characterised by fragmentation, limited coordination, and manual processes. Ivanov and Dolgui (2020) argue that the viability of modern supply chains increasingly depends on their ability to survive disruptions and adapt to uncertainty. In countries with inadequate infrastructure, even routine supply chain functions—such as warehousing, distribution, and last-mile delivery—become major operational challenges. Moreover, the lack of intermodal connectivity, poor road conditions, and erratic electricity supply can create delays, spoilage, and stockouts, especially for perishable goods. These structural inefficiencies reduce supply chain velocity and reliability, raising the cost of doing business and limiting firms' competitiveness in domestic and export markets.

In Kenya, supply chain management plays a pivotal role in supporting key sectors such as agriculture, manufacturing, retail, and pharmaceuticals. However, the country faces a complex web of logistical bottlenecks and systemic inefficiencies. According to UNCTAD (2021), Kenya's supply chains are particularly vulnerable due to weak rural-urban connectivity, insufficient cold storage, and high dependence on road transport. Logistics costs are estimated at more than 30% of the value of goods—more than double the global benchmark—primarily due to infrastructural constraints (World Bank, 2023). This situation is further compounded by fragmented supply chain actors, limited digital infrastructure outside urban centres, and insufficient government coordination across ministries responsible for trade, transportation, and industrialisation.

Despite some recent progress in customs digitalisation, e-commerce growth, and mobile money integration, these gains are unevenly distributed across regions and industries. Kilelu et al. (2019) note that smallholder farmers and SMEs often remain excluded from modern value chains due to poor infrastructure and limited innovation support. Many businesses are forced to hold excess inventory or rely on informal logistics arrangements, undermining lean and agile supply chain strategies. The result is increased waste, limited scalability, and lower profit margins. Addressing these challenges requires a holistic approach that integrates infrastructure development with institutional reform, capacity building, and investment in digital technologies to build smarter, more inclusive supply chains.

2.3 Research Gap

Although there is a substantial body of global and regional literature on both infrastructure development and supply chain management, the intersection of these two domains—particularly within the Kenyan context—remains under-explored. Existing studies tend to examine either infrastructure impacts on macroeconomic outcomes (Calderón & Servén, 2014) or supply chain challenges in isolation (Christopher, 2016; UNCTAD, 2021). There is limited empirical research assessing how recent infrastructural investments in Kenya specifically influence supply chain performance, cost reduction, resilience, or strategic agility. Additionally, the potential of infrastructure projects to enhance Kenya's participation in regional and global value chains under frameworks such as the African Continental Free Trade Area (AfCFTA) has not been sufficiently analysed.

Furthermore, most Kenyan studies focus on transport infrastructure, often neglecting the role of energy systems, ICT networks, and integrated logistics services in enabling supply chain optimisation. As Kenya invests in smart infrastructure and digital platforms, there is a pressing need for interdisciplinary research that evaluates not only the physical presence of infrastructure but also its effectiveness in transforming logistics and business performance. This study, therefore, seeks to fill this gap by providing an integrated analysis of how critical infrastructure developments impact supply chain operations in Kenya, drawing on both qualitative stakeholder insights and quantitative data.

2.4 Theoretical Framework (Revised)

A robust theoretical foundation is essential for understanding the relationship between infrastructure development and supply chain optimisation. Theories provide not only explanatory power but also analytical lenses for assessing how infrastructure investments translate into measurable outcomes in efficiency, cost reduction, and resilience. In the context of Kenya, where major infrastructural projects coexist with persistent logistical bottlenecks, theoretical perspectives help to interrogate whether infrastructure expansion inherently

leads to improved supply chain performance or whether other institutional and technological factors mediate this relationship. This study draws on three interrelated frameworks—Infrastructure-Led Growth Theory, Supply Chain Resilience Theory, and Technological Determinism—to provide a multidimensional analysis. Together, these perspectives capture the economic, adaptive, and technological dynamics of supply chains, thereby offering a comprehensive framework for evaluating the Kenyan experience.

2.4.1 Infrastructure-Led Growth Theory

Infrastructure-led growth theory posits that investment in infrastructure is a catalyst for long-term economic growth by enhancing productivity, reducing transaction costs, and stimulating private sector activity (Aschauer, 1989; Straub, 2019). From this perspective, infrastructure is not merely a support service but a driver of economic transformation. Calderón and Servén (2014) demonstrated that countries with higher infrastructure quality experience more sustained growth and reduced inequality. In supply chain terms, well-developed transport and energy systems lower logistics costs, improve market access, and facilitate faster circulation of goods and services.

Applied to Kenya, this theory suggests that flagship projects such as the Standard Gauge Railway (SGR), LAPSSET Corridor, and expansion of the Port of Mombasa should yield positive impacts on supply chain efficiency by reducing freight costs, cutting travel times, and enhancing regional integration. Indeed, Kenya's Logistics Performance Index (LPI) score improved by 13.6% between 2016 and 2023 (World Bank, 2023), lending partial support to the infrastructure-led growth hypothesis. However, critics argue that such investments have not uniformly benefited all sectors, as rural areas still face weak road connectivity and limited digital penetration (UNCTAD, 2021). This uneven distribution challenges the assumption that infrastructure investment automatically translates into inclusive supply chain optimisation.

The theory also helps to frame the tension between quantity and quality of infrastructure. While Kenya has expanded its paved road network by over 52% in the last decade (KNBS, 2023), issues of corruption, poor maintenance, and underutilisation reduce the expected benefits (Hope, 2021). Thus, infrastructure-led growth theory provides a useful lens for understanding both the promise and limitations of Kenya's development trajectory: infrastructure investments are necessary but insufficient unless coupled with institutional reforms and sustained maintenance.

2.4.2 Supply Chain Resilience Theory

Supply chain resilience theory emphasises the ability of logistics systems to anticipate, absorb, and recover from disruptions, whether caused by natural disasters, pandemics, or geopolitical shocks (Ponomarov & Holcomb, 2009; Ivanov & Dolgui, 2020). It posits that robust infrastructure—particularly transport, energy, and ICT—forms the backbone of resilient supply chains. Redundancy, flexibility, and diversification of logistics routes are critical elements of resilience, ensuring continuity of supply even when primary channels are disrupted.

Kenya's experience during the COVID-19 pandemic illustrates the relevance of this framework. While the SGR and port expansions allowed for continued cargo movement, over-reliance on specific entry points and highways created vulnerabilities when lockdowns and border restrictions were imposed (Gereffi, 2020). Similarly, unreliable electricity supply continues to expose manufacturers to costly downtimes, undermining resilience in production networks. These challenges confirm Ivanov and Dolgui's (2020) argument that resilience is not just about infrastructure capacity but also about its adaptability and reliability under stress.

Applying this theory underscores the importance of last-mile infrastructure and ICT integration in Kenya. For example, feeder roads and cold chain systems in agriculture are critical for reducing post-harvest losses, while digital logistics platforms enable firms to reroute deliveries in real time. Yet, many SMEs remain excluded from such systems due to poor rural connectivity and limited investment in digital infrastructure (Kilelu et al., 2019). Thus, supply chain resilience theory highlights that Kenya's infrastructure development must go beyond physical construction to ensure flexibility, inclusivity, and robustness in logistics operations.

2.4.3 Technological Determinism and Digital Logistics

Technological determinism theory argues that technological innovations fundamentally shape social and economic systems, including business processes and supply chains (Smith & Marx, 1994; Castells, 2010). In the context of supply chain management, digital infrastructure—such as broadband, mobile money platforms, blockchain, and artificial intelligence—plays a transformative role in enhancing efficiency, transparency, and optimisation (Christopher, 2016). This framework suggests that infrastructure development in Kenya cannot be analysed solely in terms of roads and ports but must also incorporate digital technologies that drive modern supply chains.

Kenya has been a pioneer in mobile-based innovations such as M-Pesa, which revolutionised financial transactions and e-commerce logistics. The expansion of broadband and mobile networks has further enabled growth in digital marketplaces, route optimisation, and inventory management platforms (KEPSA, 2023). However, digital divides remain significant: rural producers often lack access to reliable

internet, and SMEs struggle to integrate into formal logistics platforms. These gaps demonstrate the asymmetric effects of technological change, whereby urban firms benefit disproportionately while rural and informal actors are left behind.

From this perspective, Kenya's infrastructure investments must be seen not only as physical capital but also as digital enablers of supply chain optimisation. Technological determinism predicts that as ICT systems become more integrated with logistics—through tracking systems, blockchain-enabled transparency, and AI-driven demand forecasting—supply chains will achieve higher levels of efficiency and resilience. Yet, unless digital infrastructure is equitably distributed, Kenya risks deepening supply chain inequalities. Therefore, this theory directs attention to the strategic role of ICT in bridging existing infrastructure gaps and achieving inclusive supply chain transformation.

2.5 Empirical Review (Revised)

Empirical research has consistently demonstrated the positive impact of infrastructure on logistics performance and economic outcomes. For example, De Soyres et al. (2018) found that large-scale transport investments under China's Belt and Road Initiative reduced trade costs and enhanced regional integration across Asia and Europe. Similarly, Calderón and Servén (2014) showed that infrastructure investment in developing countries correlates with higher productivity and reduced inequality. However, most of these global studies are macroeconomic in focus; they treat infrastructure as an aggregate input for growth rather than analysing its direct influence on supply chain optimisation. As a result, there is limited empirical evidence connecting infrastructure development to supply chain outcomes such as lead-time reduction, inventory turnover, and last-mile delivery.

African-based studies confirm the persistence of infrastructure bottlenecks in limiting supply chain efficiency. The African Development Bank (2022) estimates that logistics costs in Sub-Saharan Africa are up to 75% higher than global averages, with poor transport networks and weak energy supply as major contributors. The World Economic Forum (2022) similarly identifies Africa's annual infrastructure financing gap of $68–$108 billion as a key constraint on competitiveness. Kenya-specific initiatives such as the Standard Gauge Railway (SGR) and LAPSSET Corridor have been evaluated in terms of cost savings and time reductions (KNBS, 2023), but studies often overlook how these projects affect different supply chain actors, particularly small and medium-sized enterprises (SMEs) and rural producers. This limits the ability to understand whether infrastructure gains are equitably distributed across the economy.

Other empirical works focus on sectoral dimensions of supply chain challenges. Kilelu, Klerkx, and Leeuwis (2019) demonstrated that Kenyan smallholder farmers face systemic constraints due to weak rural road networks and limited cold chain facilities, resulting in high post-harvest losses. UNCTAD (2021) highlighted how poor logistics infrastructure hinders Kenya's integration into regional agricultural value chains despite rising export demand. In the manufacturing sector, Hope (2021) noted that unreliable electricity supply and inefficiencies in transport corridors increase production costs and reduce competitiveness. While these research studies offer helpful information about sector-specific supply chain challenges, they fall short of linking such constraints to national infrastructure developments and policy frameworks.

Taken together, empirical evidence points to a fragmented understanding of how infrastructure influences supply chains in Kenya. Global and regional studies emphasise macroeconomic effects, while local sectoral research highlights operational bottlenecks. Few studies combine these perspectives through a mixed-methods approach that integrates performance metrics with stakeholder insights. Therefore, this study addresses the gap by empirically assessing how transport, energy, and ICT infrastructure developments shape supply chain optimisation in Kenya. By drawing on both quantitative data and qualitative evidence from agriculture, manufacturing, and retail sectors, the study contributes a multidimensional perspective that is currently lacking in the literature.

3.0 METHODOLOGY (REVISED)

This chapter outlines the research methodology employed to investigate the impacts of critical infrastructure development on supply chain optimisation in Kenya. The section details the research design, sampling strategy, data collection methods, analysis techniques, and ethical considerations. A mixed-methods approach was adopted to capture both the breadth of quantitative performance indicators and the depth of qualitative stakeholder experiences, thereby enabling a more holistic assessment of the infrastructure–supply chain nexus.

3.1 Research Design

The study utilised a mixed-methods research design that integrated quantitative and qualitative approaches. According to Creswell and Plano Clark (2018), mixed methods enable triangulation, thereby enhancing the reliability of findings by combining statistical evidence with contextual insights. The quantitative strand focused on analysing secondary data on logistics performance and infrastructure indicators, whereas the qualitative strand involved semi-structured interviews with key stakeholders across priority sectors. This design was considered appropriate because infrastructure

development affects supply chains through both measurable outcomes (e.g., transit time, logistics costs) and experiential dimensions (e.g., stakeholder perceptions, operational challenges).

3.2 Population and Sampling Strategy

The study population comprised stakeholders within Kenya's infrastructure and supply chain ecosystem, including government agencies, private sector firms, and industry associations. A purposive sampling strategy was employed to ensure that respondents had relevant expertise and direct experience with infrastructure projects and supply chain operations. The qualitative component involved 25 semi-structured interviews with logistics managers, manufacturing executives, agricultural exporters, government officials, and representatives from the Kenya Private Sector Alliance (KEPSA) and the Shippers Council of Eastern Africa (SCEA). This sample size was deemed sufficient to achieve thematic saturation (Guest, Bunce, & Johnson, 2006).

For the quantitative component, secondary data were obtained from reputable sources, including the World Bank's Logistics Performance Index (LPI), the Kenya National Bureau of Statistics (KNBS), the Ministry of Transport, and the African Development Bank (AfDB). These sources provided indicators such as infrastructure expenditure, port throughput, dwell time, and road coverage, which were used to assess trends in infrastructure investment and logistics performance between 2016 and 2023.

3.3 Data Collection Methods

Quantitative data were collected through desk review of reports, databases, and statistical abstracts from international and national agencies. These data were coded and tabulated to capture trends in key infrastructure and supply chain metrics.

Qualitative data were gathered using semi-structured interviews, which allowed for flexibility in probing issues while maintaining consistency across respondents. An interview guide was developed around key themes such as infrastructure bottlenecks, operational efficiencies, resilience to disruptions, and policy gaps. Interviews were conducted both physically and virtually, depending on participants' availability, and lasted an average of 45 minutes each. Notes and recordings (with consent) were transcribed and prepared for thematic analysis.

3.4 Data Analysis

Quantitative data was analysed using descriptive statistics to identify changes in infrastructure indicators and logistics performance over time. Trends such as percentage changes in dwell time, road coverage, and LPI scores were calculated to illustrate improvements or persisting inefficiencies.

Qualitative data was analysed using thematic content analysis (Braun & Clarke, 2019). Transcripts were coded to identify recurring patterns, and themes were developed around infrastructure successes, remaining challenges, and sector-specific impacts. Data triangulation was employed by cross-referencing quantitative results with qualitative insights, thereby strengthening the validity of interpretations.

3.5 Validity and Reliability

Several measures were taken to enhance the validity and reliability of the study. In the quantitative component, reliance on official and internationally recognised data sources (e.g., the World Bank and KNBS) ensured data credibility. In the qualitative component, triangulation across different stakeholder groups reduced bias and improved robustness. Member checking was conducted by sharing summaries of interview transcripts with participants to confirm accuracy. Reliability was further enhanced by employing a systematic coding procedure for thematic analysis.

3.6 Ethical Considerations

Ethical approval was sought from relevant institutional review boards. Informed consent was obtained from all interview participants, who were assured of confidentiality and anonymity. Sensitive information was securely stored, and participants were free to withdraw at any stage of the research without consequence. Ethical guidelines recommended by the American Psychological Association (APA, 2020) were strictly adhered to throughout the study.

4. RESULTS AND ANALYSIS (Revised)

This chapter presents the findings of the study by integrating quantitative performance data with qualitative insights from key stakeholders. The analysis is structured in three sections: (i) (i) infrastructure investment trends and logistics metrics, (ii) stakeholder insights from agriculture, manufacturing, and retail sectors, and (iii) theoretical interpretation of results. By combining descriptive statistics with thematic analysis, the findings provide a holistic picture of how infrastructure development has shaped supply chain optimisation in Kenya.

4.1 Infrastructure Investment Trends and Supply Chain Metrics

Quantitative data from the World Bank, KNBS, and the Ministry of Transport indicate a sharp rise in Kenya's

infrastructure investments between 2016 and 2023. Government expenditure on transport, energy, and ICT infrastructure increased from KES 327 billion in 2015 to KES 668 billion in 2022 (KNBS, 2023). Key outcomes include:

i. The Logistics Performance Index (LPI) infrastructure score improved from 2.43 (2016) to 2.76 (2023), a 13.6% increase (World Bank, 2023).
ii. Dwell time at the Port of Mombasa reduced by 57.1%, from 11.2 days (2016) to 4.8 days (2023).
iii. The paved road network expanded by 52.7%, reaching 16,800 km by 2023 (KNBS, 2023).

These figures lend support to Infrastructure-Led Growth Theory (Calderón & Servén, 2014), which posits that infrastructure expansion lowers transaction costs and stimulates efficiency. However, the uneven distribution of benefits—concentrated in Nairobi–Mombasa and major urban corridors—raises questions about whether infrastructure growth translates into inclusive supply chain transformation.. This details are showed in table 1 and figure 1.

Table 1: Selected Infrastructure and Supply Chain Metrics in Kenya (2016–2023)

Indicator	**2016**	**2019**	**2023**	**% Change (2016–2023)**
LPI Infrastructure Score	2.43	2.59	2.76	+13.6%
Port of Mombasa – Avg. Dwell Time (Days)	11.2	6.5	4.8	–57.1%
Government Infrastructure Spending (KES billion)	327	488	668	+104.3%
National Paved Road Network (Kilometres)	11,000	14,300	16,800	+52.7%

Sources: *KNBS (2023); World Bank (2023); Ministry of Transport (2022)*

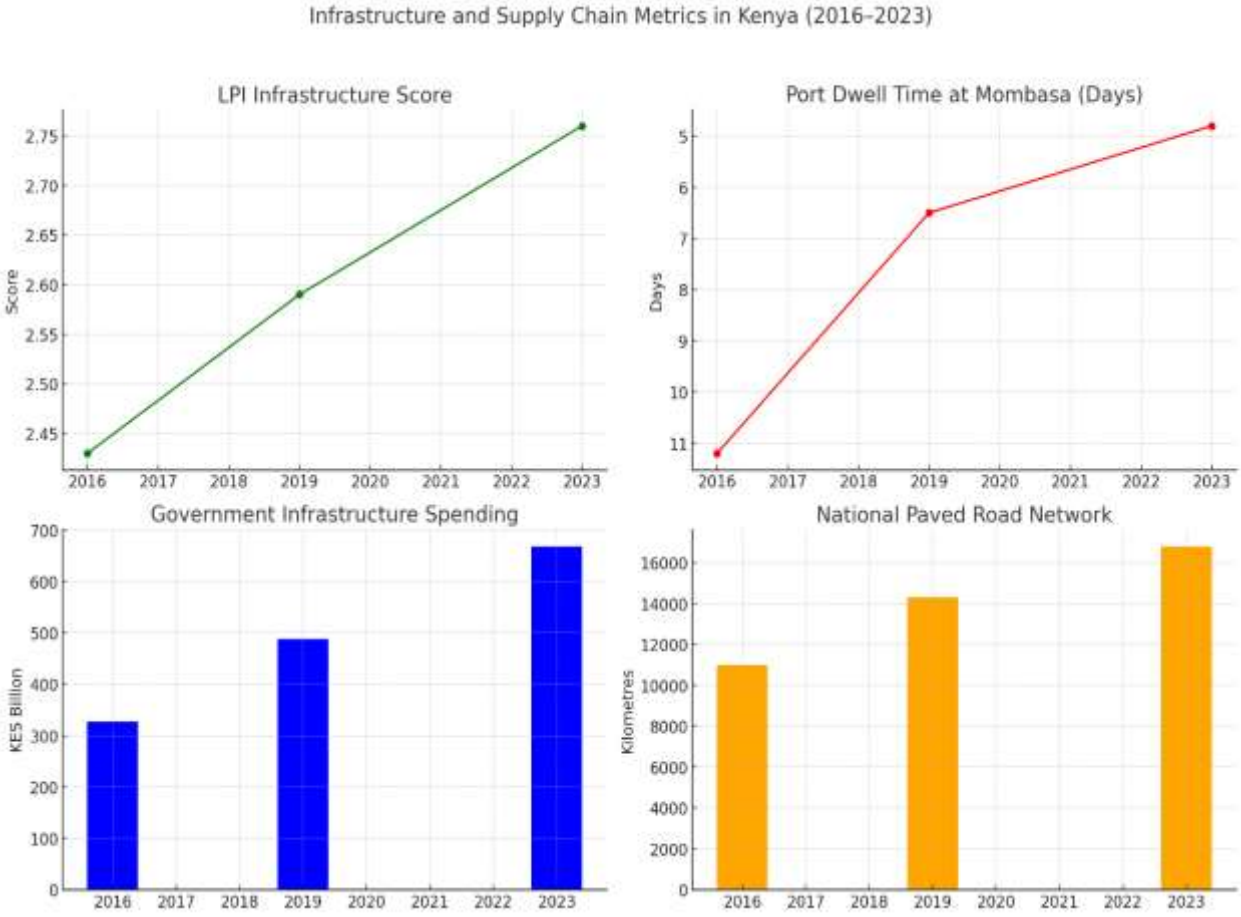

Figure 1: Infrastructure Investment Trends and **Supply Chain Metrics 2016-2023**

Despite this progress, the data also reveal structural inefficiencies, especially in rural logistics. Agricultural exporters in counties like Bungoma and Kitui still face high costs due to poor rural road access and lack of cold

chain infrastructure. This limits the benefits of national transport upgrades for rural supply chains, especially for perishable goods.

4.2 Stakeholder Insights and Case Study Findings

4.2 Stakeholder Insights and Sectoral Case Studies

Semi-structured interviews with 25 stakeholders provided insights into the sectoral impacts of infrastructure.

i. Manufacturing sector respondents reported reduced delivery times (up to 40%) due to the SGR and Nairobi Motorway. However, they highlighted persistent issues **of power instability and last-mile delivery costs**, which disrupt production schedules and reduce competitiveness.

ii. Agricultural exporters noted that feeder road upgrades under KeRRA improved access to markets, reducing post-harvest losses by 17% between 2018 and 2022 (Ministry of Agriculture, 2022). Yet, exporters in western Kenya emphasised that rainy seasons render roads impassable, undermining supply chain reliability.

iii. Retail and logistics firms praised the Nairobi Motorway and digital tracking platforms for improving urban deliveries. However, SMEs in peri-urban areas cited ICT gaps and unreliable rural depots as major barriers to integrating with e-commerce value chains.

These findings illustrate that while infrastructure has improved efficiency and speed, supply chain resilience remains uneven. The results align with Supply Chain Resilience Theory (Ivanov & Dolgui, 2020), which stresses that robustness requires not only new infrastructure but also adaptability to external shocks and inclusivity across actors.. The details are showed in table 2.

Table 2: Stakeholder Perspectives by Sector

Sector	Infrastructure Success	Remaining Challenges
Manufacturing	Faster transport via SGR; improved order fulfilment	Power instability; poor regional logistics access
Agriculture	Reduced losses in counties with feeder road upgrades	Limited cold chains; impassable rural roads
Retail	Urban deliveries faster with expressway	Poor ICT and roads in informal settlements
Logistics	Faster port clearance and digital tracking	Lack of rural depots and truck parking facilities

Source: *Author interviews, 2024*

Overall, the case studies confirm that infrastructure development has enhanced efficiency, but the effects are uneven and often constrained by sectoral and regional limitations. Infrastructure investment alone is insufficient without supportive institutional frameworks, regular maintenance, and stakeholder-driven planning.

4.3 Theoretical Interpretation of Results

The findings reveal three important patterns when interpreted through the theoretical framework:

1. **Infrastructure-Led Growth in Practice**

Kenya's flagship projects (SGR, Nairobi Expressway, Port expansion) have produced measurable efficiency gains—shorter dwell times, reduced freight costs, and improved LPI scores. This confirms the infrastructure-led growth proposition (Calderón & Servén, 2014). However, the theory's assumption of broad-based benefits is only partially realised: rural producers and SMEs remain excluded due to weak last-mile connectivity and power reliability gaps (Hope, 2021).

2. **Resilience as a Conditional Outcome**

Infrastructure has increased resilience in certain corridors by reducing dependency on congested roads and ports. Yet resilience is conditional: agriculture still suffers seasonal disruptions, and manufacturing remains vulnerable to unstable electricity supply. These outcomes support Ivanov and Dolgui's (2020) argument that resilience is not achieved through infrastructure capacity alone but through redundancy, diversification, and digital integration.

3. **Technological Determinism and Digital Divide**

ICT-enabled logistics platforms have transformed urban supply chains, allowing for real-time tracking, route optimisation, and e-commerce integration. However, rural and peri-urban actors remain disadvantaged due to poor internet penetration and lack of digital logistics hubs (KEPSA, 2023). This demonstrates both the promise and limitations of **Technological Determinism**: while technology drives logistics

innovation, unequal access reinforces structural supply chain inequalities.

4.4 Synthesis of Findings

The synthesis of quantitative and qualitative data suggests that infrastructure development in Kenya has produced **tangible efficiency gains**, particularly in major trade corridors and urban supply chains. However, these benefits are uneven and constrained by persistent systemic weaknesses—especially in energy reliability, last-mile rural access, and digital inclusion. The evidence therefore supports a nuanced conclusion: infrastructure development is a **necessary but insufficient condition** for supply chain optimisation. Effective integration with ICT systems, inclusive planning for rural regions, and sustained asset maintenance are required for Kenya to fully realise the potential of its infrastructure investments.

5.0 DISCUSSION, CONCLUSIONS, AND POLICY RECOMMENDATIONS (REVISED)

5.1 Discussion

The results of this study reaffirm the central role of infrastructure in enabling supply chain efficiency, but they also highlight the conditional and uneven nature of these outcomes. The significant improvements in Kenya's LPI infrastructure score, reduced port dwell times, and expanded road network demonstrate that investments in transport and logistics align with the principles of **Infrastructure-Led Growth Theory** (Calderón & Servén, 2014). However, as Straub (2019) cautions, the growth potential of infrastructure is often constrained by governance weaknesses, maintenance gaps, and uneven regional distribution. This was evident in Kenya, where urban corridors such as Nairobi–Mombasa benefited disproportionately, while rural and marginalised regions continued to face severe last-mile bottlenecks.

The findings also support **Supply Chain Resilience Theory**, which posits that infrastructure enhances resilience but only when designed with flexibility and redundancy (Ivanov & Dolgui, 2020). Although flagship projects such as the SGR and the Nairobi Expressway improved predictability in freight movement, systemic vulnerabilities persist. In agriculture, for example, poor feeder roads in western counties made supply chains highly susceptible to seasonal disruptions. Similarly, in manufacturing, unreliable electricity supply limited production continuity. These outcomes echo Gereffi's (2020) observation that resilience requires a systems-based approach integrating transport, energy, and ICT, rather than isolated project-based interventions.

From a technological perspective, the results lend strong support to **Technological Determinism** (Smith & Marx, 1994; Castells, 2010). ICT-enabled logistics—such as real-time tracking, digital route planning, and e-commerce integration—have transformed supply chains in urban areas, reducing delivery times and increasing transparency. However, the persistence of a digital divide in rural and peri-urban areas underscores that technological transformation is not automatically inclusive. KEPSA (2023) has similarly highlighted that SMEs and smallholder farmers are often excluded from digital logistics platforms due to inadequate internet access and high integration costs. Thus, while technology drives supply chain optimisation, it also risks reinforcing structural inequalities unless digital access is equitably distributed.

5.2 Conclusions

This study concludes that infrastructure development in Kenya has had a measurable positive impact on supply chain optimisation. Investments in transport, energy, and ICT infrastructure have improved efficiency, reduced logistics costs, and enhanced predictability—especially in major trade corridors. However, these benefits are uneven, with rural and marginalised regions continuing to face significant challenges in last-mile connectivity, energy reliability, and digital inclusion.

The research objectives were met in the following ways:

1. **Examining how infrastructure influences efficiency**: The study found reduced transit times, lower post-harvest losses, and improved order fulfilment in agriculture, manufacturing, and retail.
2. **Evaluating infrastructure's role in resilience**: While national corridors gained robustness, sectoral and regional vulnerabilities persisted.
3. **Identifying challenges and opportunities**: Key challenges include poor rural roads, unstable electricity, and ICT gaps; opportunities include leveraging digital platforms and climate-resilient infrastructure.
4. **Providing policy recommendations**: The study proposes measures to ensure that infrastructure investments translate into inclusive and sustainable supply chain transformation.

Overall, the evidence supports the conclusion that infrastructure is a **necessary but insufficient condition** for optimising supply chains. Integration with digital technologies, institutional reforms, and inclusive planning are essential for achieving equitable benefits.

5.3 Policy Recommendations

Based on the findings, the following recommendations are proposed for policymakers, industry actors, and development partners:

1. **Prioritise Inclusive Infrastructure Development**

National planning should deliberately target rural and peri-urban areas where supply chain inefficiencies remain greatest. Investment in feeder roads, rural depots, and cold chain facilities is critical to bridging the rural–urban divide.

2. **Strengthen Maintenance and Governance Mechanisms**

Infrastructure benefits are often undermined by poor maintenance and corruption (Hope, 2021). Dedicated maintenance funds, independent oversight agencies, and digital asset-tracking systems should be established to safeguard infrastructure quality.

3. **Integrate ICT into Supply Chains**

Expanding mobile broadband coverage and supporting SMEs with subsidised access to logistics technologies will reduce digital exclusion. A centralised logistics data platform could enhance transparency and coordination across stakeholders.

4. **Enhance Interagency and Regional Coordination**

Infrastructure planning should align with supply chain strategies through inter-ministerial committees and cross-county coordination mechanisms. This will reduce fragmentation and improve synergies between transport, energy, and ICT sectors.

5. **Promote Private Sector Participation**

Expanding public–private partnerships (PPPs) in logistics hubs, industrial parks, and renewable energy systems can mobilise additional resources and expertise. Incentives such as tax breaks and risk-sharing instruments can attract private investment.

6. **Invest in Climate-Resilient Infrastructure**

With climate change posing increasing risks, infrastructure should be designed to withstand floods, droughts, and other shocks. This includes flood-resistant roads, renewable-powered transport systems, and energy-efficient warehouses.

5.4 Future Research Directions

Future research could build on this study in three ways. First, **comparative studies** across East African countries could benchmark Kenya's infrastructure impacts against regional peers. Second, **sector-specific case studies** in healthcare, energy, and digital services could provide deeper insights into infrastructure–supply chain linkages. Finally, applying **advanced modelling tools** such as cost–benefit analysis, agent-based simulation, or AI-driven forecasting would strengthen the empirical evidence base for infrastructure–supply chain optimisation in Sub-Saharan Africa.

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