

**Building a Resilient Sustainable Economy through Green and Closed-Loop
Supply Chain Management in the Context of Circular Economy: A Sub-
Saharan African Manufacturing Setting**

By

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Declaration and Approval

Declaration

I declare that this work is the output of my hard work. Besides, I acknowledge the support of my supervisors and various pacesetters. This work also relies on prior scholars' thoughts, ideas, and opinions. With that, submitting this research thesis is the first of a kind toward a doctoral philosophy award. Finally, this research thesis aligns with Strathmore University's PhD conduct and guidance.

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Abstract

Over the past two to three decades, there has been a growing focus among scholars, practitioners, and policymakers on incorporating green, closed-loop, circular economy, sustainability, and resilience principles into managing supply chains. The increasing recognition of these principles as crucial elements in establishing stable and dependable supply chains has been spurred by various challenges in the global ecosystem, notably climate change. This study aimed to explore the development of a resilient and sustainable economy by employing green and closed-loop supply chain management within the framework of the circular economic model, specifically in the context of manufacturing businesses in a Sub-Saharan African economy. To achieve this objective, the study delved into integrating concepts that have received limited joint exploration in existing literature. In light of this context, a robust triadic conceptual framework was developed and subjected to empirical examination. The framework encompassed 83 factors organized into three aspects: (1) Practices associated with green and closed-loop supply chain management, (2) dimensions concerning resilient sustainability, and (3) internal environmental management practices. The suggested conceptual framework was tested through a novel structured survey distributed to 159 manufacturing businesses in a Sub-Saharan African economy. Survey participants included supply chain line managers, managing directors, and chief executive officers selected for their expertise and experience, resulting in 100 valuable responses. The empirical data collected was tested using the Partial Least Squares Structural Equation Modelling ran through Smart PLS version 4. The findings of the empirical investigations showed that practices such as cleaner production/green manufacturing, a combination of green procurement and design for the environment, and the application of reverse logistics had the most significant impact on the resilient sustainability of supply chains. The triadic-dimensional conceptual framework put forth in this study and its fundamental motivation represent novel contributions to existing literature. Moreover, this research explored a unique link in the investigation of green and closed-loop supply chain practices on the resilience of supply chains, offering a new avenue for industry practitioners and scholars to consider the uptake of green and closed-loop supply chain practices not only for their sustainability but also for their resilience and on their combined resilience and sustainability. This study is one of a few conducted in a Sub-Saharan manufacturing context and country, contributing valuable perspectives to the broader sustainable supply chain management body of knowledge.

Keywords: Circular Economy, Closed-Loop, Green, Resilience, Supply Chain and Sustainability.

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List of Abbreviations and Acronyms

GCLSCM:	Green Closed-Loop Supply Chain Management
GDP:	Gross Domestic Product
GHGs:	Green House Gases Emissions
LCA:	Life Cycle Assessment
MtCO ₂ :	Million Tons of Carbon Dioxide Equivalent
SC:	Supply Chain
SCM:	Supply Chain Management
SCs:	Supply Chains

Definition of Terms

Term	Definition
Supply Chain Management	The administration of the flow of materials and their conversion from sourcing to the distribution of final products to customers (Cooper et al., 1997).
Circular Economy	An economic model that moves away from the traditional linear take-make-dispose model to a circular model based on designing out wastes, keeping materials in the loop, and being regenerative of the earths' systems (MC Arthur Foundation, 2020).
Green Supply Chains	The integration of environmental thinking into supply chains (Sarkis, 2006).
Reverse Logistics	The management of product returns through remanufacturing, recycling, and repair or reuse (Govindan et al.,2014; Alkahtani et al., 2021).
Sustainable Development	“Development that seeks to meet the needs of the present without compromising the ability of future generations to meet their own needs” (United Nations, 1987, p.3).

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As I close this file, I would like to appreciate the works of Saint Jose Maria Escriva, particularly His famous quote that guided me all through, “*it is in the simplicity of your ordinary work, in the monotonous details of each day, that you have to find the secret, which is hidden from so many, of something great and new: Love.*”

May God bless you all, and may this work be a game-changer for our beautiful home, planet Earth.

Dedication

Growing up as a child in a green highland full of trees and other green vegetation, our fences were done using the Kayaba (Kei-Apple), which brought out an excellent green fence design in homesteads, especially in our home. We planted trees and fruit trees (avocados, loquats, guavas, to name a few) and climbed those planted earlier. I remember my siblings and I spending most of our time at our grandmother's place; she loved us deeply. My grandmother's compound was full of trees. In the front yard, the Eucalyptus trees had a design where treetops hugged each other, and in the middle, there was a path we enjoyed walking, sitting, and playing under. The backyard was full of other species of gum trees and other tree types used as medicine in our culture. I remember us digging through a kind of small forest in the backyard that stretched many miles to enjoy purple raspberries and gooseberries.

My grandmother served us kefir from a gourd and porridge in a calabash. My grandmother taught us many things that are now redefined in the circular economy and sustainability realm. I witnessed my grandmother creating an industrial symbiosis ecosystem in her home. She taught us to combat the cold by boiling and sniffing eucalyptus leaves. Waste from one part of the home was an input in another part of the home. I saw her grow nduma (arrow roots) by digging trenches and letting the taps quench them to grow nduma in a soil not typical for its cultivation. She belonged to the circular economy tribe!

Her compound was well done with grass and decorated with various flowers. The avocados, loquats, and guava trees were the most pronounced in the homestead. The guava tree was particularly of keen interest to us children. I remember us climbing up and enjoying the juicy red and white guavas. This experience of growing up with my grandmother indirectly nurtured me to have a deep sense of nurture to nature, igniting my interest in circular economy and sustainability at a time like this. Looking back, today, I dedicate this write-up to my late grandmother who loved nature deeply and valued education exceptionally, not forgetting my grandfather, who gave up the spirit before I was born.

With the influence of my grandmother's enthusiasm for nurturing the environment on my thoughts and my own reflections, I marvel....

Will the outcomes of this thesis ever influence the people of the need to take care of the planet, its people, and its inhabitants through their industrialization and consumption choices, both at the consumption and production levels?

Well, I am guided by the story of an eagle and that of a hummingbird. *"The Eagle has the longest life span of its species. It can live up to 70 years. However, the eagle must make a tough decision to reach this age!"*

“In its 40th year, the eagle’s long and flexible Talons can no longer grab prey, which serves as food. Its long and sharp beak becomes bent. Due to their thick feathers, their old and heavy wings stick to their chests, making flying difficult. Then, the eagle is left with only two options: DIE or go through a painful change process! This process lasts for 150 days (5 months). The eagle must fly to a mountaintop and sit on its nest. The eagle knocks its beak against a rock until it plucks it out. Then, the eagle will wait for the new beak to grow back, after which it will pluck out its talons. When its talons grow back, the eagle starts plucking its old-aged feathers. After this, the eagle takes its famous flight of rebirth and LIVES for 30 more years(<https://timesofindia.indiatimes.com/readersblog/vishwabramana/story-of-an-eagle-23667/>).”

If an eagle can bounce back through a rebirth, I believe, humanity can also make a lifesaving about turn and make sustainable decisions through change of their mindset and behavior to build both resilient and sustainable communities. For this alone, I am grateful to the author of this poem as it gives hope for a rebirth in hopeless situations like the climate change situation.

Looking back yet again, the thought of doing a Ph.D. for me spans back to my curiosity to know the highest form of education that a person can pursue when I was a little girl. I persistently inquired from my parents, who kept on quoting a Ph.D. Starting my Ph. D journey meant spreading my wings to new territories; the decision was a difficult one; it was a dilemma. This is when I encountered the poem by Robert Frost on the Road Not Taken. To Robert Frost, I am grateful you wrote this poem that influenced my thoughts in my Ph. D journey.

“Two roads diverged in a yellow wood, and sorry I could not travel both and be one traveler, I stood and looked down one as far as I could to where it bent in the undergrowth. Then took the other, as just as fair, and having perhaps the better claim because it was grassy and wanted wear. Though as for that, the passing there had worn them really about the same, and both that morning equally lay in leaves, no step had trodden black. Oh, I kept the first for another day! However, knowing how way leads on to way, I doubted if I should ever come back. I shall be telling this with a sigh, somewhere ages, and ages hence: two roads diverged in a wood, and I took the one less traveled by, which has made all the difference.” I marvel yet again.....

As I walk in my grandmother’s footsteps, like an eagle, I know my contribution means something in giving hope to the oppressed planet.

Yet still, the hope from Robert Frost's poem, that of the hummingbird parable, together with my own reflections, I believe of a small change, however small it might be, this thesis will be worth the long wait!

This again brings me to the hummingbird parable as told by the late Prof. Wangari Maathai, which again kept me going.

“The story of the hummingbird is about this huge forest being consumed by a fire. All the animals in the forest come out and they are transfixed as they watch the forest burning and they feel very overwhelmed, very powerless, except this little hummingbird. It says, ‘I am going to do something about the fire! ‘So it flies to the nearest stream and takes a drop of water. It puts it on the fire and goes up and down, up and down, as fast as it can. In the meantime, all the other, much bigger animals—like the elephant with a big trunk that could bring much more water—are standing there helpless. Moreover, they are saying to the hummingbird, ‘What do you think you can do? You are too little. This fire is too big. Your wings are too small, and your beak is so small that you can only bring a small drop of water at a time. ‘But as they continue to discourage it, it turns to them without wasting any time, and it tells them ‘I am doing the best I can’”. With the lessons in this parable, I marvel.....

Will the outcomes of this thesis ever convince scholars, practitioners, policymakers, and the general public of the urgency of building both resilience and sustainability in our communities? I almost conclude, having convinced myself that just like the hummingbird with tiny drops of water, this thesis with its little contribution will give hope to an oppressed planet; however small the contribution, the change will be worth it.

As I conclude, it would be unfair not to mention the very important humans who offered me support throughout this journey. To my loving children, Gail, and your brothers and sisters, I dedicate this to you as my children, whom I love dearly, as a reminder to rise at the opportune time and take the stairs towards your path of success.

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Many have riches and among the royals, but I pride myself on a grandmother who prayed fervently, and that I say I continually stand on my grandmother's prayers.

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Chapter One: Introduction to the Study

1.1 Introduction

This study sought to investigate building a resilient, sustainable economy through green and closed-loop supply chain Management (GCLSCM) in the context of the circular economic model for manufacturing businesses in a Sub-Saharan African setting. Intrinsically, this chapter introduces pertinent issues around the subject matter anchoring the science of anthropogenic circularity and develops a problem case to formulate the research objectives. Against the backdrop, the chapter lays a solid foundation that evokes rich discussions in subsequent chapters toward answering the phenomena under inquiry. The chapter has twelve sections. Section 1.1 presents the introduction of the chapter. Section 1.2 provides a discussion on the background. Section 1.3 presents the research motivation. Section 1.4 provides the contextualization of the study, and section 1.5 provides the problem description. Section 1.6 shows the research objectives, and section 1.7 shows the research questions. Sections 1.8, 1.9, and 1.10 present the study's significance, scope, and limitations. Section 1.11 presents the thesis structure, and section 1.12 presents the chapter summary.

1.2 Background of the Study

The modern age of ecologically, socially, and economically conscious environment has awakened environmental protection, social equity, and economic growth to achieve sustainable development (SD). Also, the challenges of greater heights of enterprise turbulence, pathogenic mutations causing complex diseases, and global food and fuel crises allude to the urgency of building system resilience and sustainability. Chowdhury et al. (2021) argue that supply chain resilience (SCRes) has become a topic of interest since the outbreak of the COVID-19 pandemic. Also, supply chain sustainability (SCSus) continues to garner attention from governments, scholars, and practitioners. The World Economic Forum-WEF (2021) argues that businesses should continually seek ways to build resilient-reliable supply chains (SCs). Understanding how to build both SCRes and SCSus becomes essential for the growth of SCs and communities (Aming'a, et al., 2024).

However, comprehending the convergence of the two concepts remains challenging in extant literature with different definitions and philosophical viewpoints. Holling (2001) argues about the panarchy philosophy that explains a path to achieving healthy social-environmental systems. The author shows the importance of building systems that can innovate and test, gaining from discoveries that build chances while keeping safe from those threatening the system from their inherent natural features or extreme growth.

The debates of Holling (2001) underpin a primary complex adaptive reasoning philosophy based on the integrated theory of resilience and sustainability. Metaxas and Psarropoulou (2021), in their research on urban planning, argue that resilience is a part of sustainability as espoused by the United Nations in their efforts to redefine SD. Espiner et al. (2017) contend that it is essential to integrate resilience and sustainability even with few frameworks on their convergence; their fit may be imperfect, but it is a realistic foundation for complex adaptive systems. Holling (1973) argues that resilience is the capability of a system to bounce back after a disruption and move forward to a better-improved state. Such an understanding highlights a need for systems to build resilient capabilities to be sustainable (Marchese et al., 2018). SD is growth that seeks to improve the environment, society, and economy by utilizing resources well, not compromising future generations' access to such resources (World Commission on Environment and Development, 1987). SD definition continues to be viewed from a stability perspective (Marchese et al., 2018) of the triple bottom line.

However, such a view shows a static system dimension of sustainability disadvantaged by the need for assessment and response to the dynamism of this system. Such discussions indicate that the need to transition from a triple bottom line (ecological, social, and economic) to a quadruple bottom line (resilience, ecological, social, and economic) is more urgent than ever to arrest unsustainable turbulences. Upholding resilience and sustainability means that systems, whether firms, SCs, or economies, can cope with environmental, social, and economic disturbances. Against the backdrop, SD then calls for an ability to identify, assess, and respond to sustainability disruptions. Such discussions unfold the importance of combining resilience and sustainability and positioning such convergence as a productive argument worth developing toward SD. Building resilient and sustainable systems calls for efficient management of SCs (Aming'a et al., 2024). SCs remain the number one contributor to unsustainability and rigidity through their harmful activities, such as advanced manufacturing and other carbon-intensive activities (Mutingi, 2013).

This practice, termed the SC anthropogenic practice, calls for anthropogenic circularity science to promote sustainability. Even with these negative externalities, SCs form the backbone of global social-economic structures and the foundation of the natural environment. This means that proper management of SCs is key for building sustainability of economies. According to Cooper et al. (1997), SCM entails the administrative process of ensuring a product reaches the customer through the right procurement, operations, logistics, and return processes for goods, services, and works. This process entails a typical structure of suppliers, producer's/service providers, customers, and extended networks. Based on this definition, SCs remain an important aspect for every facet of the economy.

This highlighting their crucial role in societal development which should take first-line priority amid their harmful activities to the planet. According to Abendin and Duan (2011), compounded with the arguments of the World Bank (2020), international trade investments have always been significant determinants of economic growth in the past. However, in the 1990s, SCs necessitated an upward trajectory in global economic growth due to the interconnection of firms referred to as the rise of SCs (Organization for Economic Cooperation and Development- OECD, 2021). The argument of Goel et al. (2021) and the OECD (2017) further stresses that global economic growth has been slow since the global financial crisis in 2008 and 2009. This is due to sluggish international trade and supply chain (SC) expansion developments. Today, the conditions are not any different. The global financial system continues to face unprecedented disruptions. The global SC crisis of 2019-2023 provides evidence for this.

Between 2019 and 2021, the predominant factor influencing global dynamics was the outbreak of the COVID-19 pandemic and its far-reaching implications. Similarly, from 2022 to 2024, the persistent effects of the pandemic, compounded by the Ukraine-Russia conflicts, have intensified the shortage of essential supply chain (SC) components. Nevertheless, a significant portion of the world's economic infrastructure, consumption patterns, and international trade mechanisms rely on interdependent supply chains. These SCs serve as the backbone of global production systems and facilitate the exchange of goods, services, and works across borders. In this context, the ineffective management of SCs continues to engender adverse economic, social, and environmental consequences worldwide, impeding SD progress.

The availability of a simple commodity like fuel that enables the production of most items worldwide heavily depends on the production, logistics, and transportation tenets of SCs. This highlights the importance of global SC expansion towards an upward trajectory of resilient and sustainable progression. McKinsey and Company (2020) and Goel et al. (2021) argue about honing SCs toward achieving efficiency and responsiveness. However, with the changing climate, incremental continual disruptions, rising costs, civil wars, and political conflicts, an urgent need arises to manage SCs better for resilient-sustainable economies. Goel et al. (2021) further stress the importance of SCs for economic growth, denoting that high-functioning SCs are the hallmarks of any financial system. Modern SCs must embrace contemporary practices to manage risk disruptions toward resilient sustainability. Sarker et al. (2021) argue that current SC disruptions have delved deeper into social and environmental systems, posing concerns that have become a global threat to humanity. Echoing the sentiments of Sarker et al. (2021), global systems continue to prioritize economic performance at the expense of social and environmental growth.

From a policy perspective, the OECD (2017) points out statistics on global social concerns. For instance, 21 million people are in forced labor globally, and 168 million children are in child labor. The other population category is working under unfavorable conditions.

Such issues are directly linked to the complexity of SCs, highlighting a gap for an urgent mental shift for holistic system sustainability. In the arguments of Mutingi (2013), Khan and Qianli (2017), and the OECD (2017), SCs have a higher negative environmental effect on the ecological damage front. In support, the Global Environmental Facility, as cited in the OECD (2017), argues that beef, soy, and palm oil, mainly in the agricultural SC, contribute close to 80% of deforestation globally and 12% of the greenhouse gas (GHG) effect internationally.

Such statistics highlight the need for sophisticated methodologies for building resilient and sustainable systems. That said, resilience (Christopher & Peck, 2004; Silva et al., 2022), green supply chains (Sarkis, 2006; Sheng et al., 2022), closed-loop SCs (Guide & Wassenhove, 2009; Mishra et al., 2022), circular Economy (MacArthur Foundation, 2015; Yang et al., 2022), and sustainability (Siems et al., 2022; Silva et al., 2022) have become subjects of interest globally among governments, policymakers, practitioners and scholars, who continue to propound on responding to unsustainability challenges through such practices.

The current human population size, state of industrialization, and rapid technological disruptions continue to demand more use of natural resources (Shan & Wang, 2018; Yu & Solvang, 2020). Such consumption rates are detrimental (MacArthur Foundation, 2020) to Mother Earth. Such discussions stress the need to reverse the world ecosystems' anthropogenic effect, which is majorly caused by SCs (Mutingi, 2013), towards building resilient sustainability of systems. To reverse such harm, SCs need to go green and circular, close their loops, and build capabilities toward continuity as hastened measures for achieving resilient sustainability. Moreover, business as usual is not a language to uphold in this critical geological period. As our comprehension of the world changes (Krasny et al., 2011), a paradigm mindset from a mechanical reductionist philosophy to a worldview on complex adaptive system thinking (acknowledging the dynamism of ecosystems) becomes urgent.

To that effect, the argument of Singh and Trivedi (2016) validates that every firm should desire to be accountable and responsible for the biosphere and human societies through sustainable SC systems. Firms also need to contribute to system resilience through their SCs for long-term SD. For firms to achieve higher-level quality responsibility for their activities to the environment and society, a new philosophy for resilient sustainability from an ecological supply chain management (SCM) standpoint based on circularity and social justice is urgent. On economic performance, modern SCs suffer from volatility and high-velocity markets,

characterized by novel competitive moves and shorter product life cycles (Tanco et al., 2015). SCs are unstable and face large-scale risk disruptions that threaten business continuity. As companies respond to the upward ecological consumer expectation and pressure to uphold SD practices (Kumar & Chandrakar, 2012), enterprises are looking to collaborate toward the sustainability of SCs for the future (Mafini & Loury-Okoumba, 2018).

Therefore, the quest to attain sustainable industrial management systems rests on adopting such practices to recover the security and integrity of socioeconomic systems through re-modeling human industrial systems. Environmental risk disruptions are prominent due to a need for the practical embedment of environmental management philosophies in SCs. Dealing with risk disruptions and vulnerabilities with a focus on environmental risks is a gateway to achieving a resilient and sustainable community.

Similarly, Li et al. (2004) hypothesize that SC issues escalate as global competition intensifies. To that effect, firms realize the competition is no longer across enterprises but on competitive SCs. Understanding SC performance is essential in the global competitive race. That said, the performance of SCs is based on their capability to be resiliently sustainable towards global system sustainability. According to Krasny et al. (2011) and Marcheses et al. (2018), building sustainable systems depends on the resilient capabilities of such systems. Resilience, then, is a precursor to achieving sustainability. Building resilient sustainability calls for the embedment of regenerative, restorative, efficient, and adaptive philosophies with response capabilities to SCs. This embedment provides a platform for robust and sustainable SC models for an all-inclusive, resilient, and sustainable world ecosystem.

One of the most proficient SC models (Bhagizadeh et al., 2021) for handling sustainability challenges today rests on integrating green and closed-loop SCM, whose extensions anchor circular economy developments (MacArthur Foundation, 2020). Such methodologies continue to dominate policy, governance, and research agendas. The International Paris Climate Change Agreement of 1990, the United Nations Convention on Climate Change of 1992, and establishing the United Nations SD goals in 2015 provide evidence for such advancements. All these organizations agree on the significance of closing SC loops toward SD. Green and closed-loop supply chain management have their foundations in closed-loop and reverse logistics SC research. The work of Guide and Wassenhove (2009) argues that a closed-loop SC entails the management of SCs through optimal value creation across the entire life cycle of an SC with value-added recovery. According to Govindan et al. (2015), a closed-loop SC combines the forward and reverse SC.

A reverse SC, commonly referred to as "reverse logistics," is the management of product returns (Govindan et al., 2015). This is done through remanufacturing, recycling, and repair or re-use (Alkahtani et al., 2021). On the other hand, the forward SC entails the traditional connotation of SCM, taking a typical structure orientation. The works of Cooper et al. (1997) posit that SCM administers manufacturer-supplier and manufacturer-customer processes through value addition via information, material, and resources to ensure raw material conversion to final products. Muysinaliyev and Akitamov (2014) argue that SCM has its foundation in various aspects.

For instance, SCs are deeply founded on concepts such as logistics and transportation, and due to that, proper integration and coordination are imperative in SCM to yield value-based SCs. In addition, today, GCLSCM advancements call for extensions such as a circular economy for continual development. The circular economy model is an emergent concept (Aming'a et al., 2023) that provides a valuable avenue for GCLSCM extensions toward sustainability. Circular economy presents advancements to sustainability and closed-loop SCs to entail the embedment of restorative and regenerative practices (MacArthur Foundation, 2018) to SCs with the primary aim of waste reduction.

As green, closed-loop, sustainable, reverse logistics, and circular SCs (Guide & Wassenhove, 2009; Govindan et al., 2015; Saeed et al., 2017; Herrmann et al., 2021) continue to gain traction for both scholars and practitioners, an integrated model that goes beyond the traditional environmental management philosophies becomes urgent now than ever to offer a powerful synergetic combination for resilient-sustainable systems. In this study, GCLSCM integrates green, closed-loop, reverse logistics, and circular economy as a holistic thought process for building resilient, sustainable economies. Notably, for the successful implementation of GCLSCM, there is a need to practice internal environmental management (IEM). IEM as a SC eco-capability has foundations in dynamic capability theory (Souza et al., 2017).

Dynamic capabilities come about as a result of how firms respond to the world's dynamism. Zollo and Winter (2002) argue that dynamic capabilities can develop and adapt to changes that come through the efficient utilization of resources toward strategic value creation. Souza et al. (2017) further posit that with rising sustainability demands, firms must develop SC eco-capabilities to respond to such demands. According to Barreto (2020), to achieve a competitive advantage, SCs must develop strategic capabilities. Souza et al. (2017) contend that some eco-capabilities are top management support and building alliances and partnerships. Burki et al. (2019) argue about the importance of customer cooperation in achieving sustainability. SC eco-collaboration across the different SC partners is essential for upscaling the resilient

sustainability of SCs. Burki et al. (2019) argue that SC cooperation among SC partners is one of the critical factors in driving SCRes and SCSus. SC eco-capabilities, such as collaboration or cooperation, strengthen the relationship between GCLSCM and resilient sustainability (Burki et al., 2019). From systems thinking, ecological modernization, and dynamic capabilities theories, collaboration is a strong force in SCs that connect systems in an industrial ecosystem. To strengthen such ecosystems, symbiotic relationships among SC partners become essential with proper information-sharing. Investigating GCLSCM and resilient sustainability can yield valuable results when tested in practical settings. Contextualizing the study from a global, regional, and local perspective becomes vital for this study.

1.3 Contextualizing the Study: A Sub-Saharan African Manufacturing Context

1.3.1 Study Context Overview

Manufacturing is the leading carbon and greenhouse gas (GHG) emitter and, as such, a focus for decarbonization toward net zero (McKinsey & Company, 2021). Strategies such as GCLSCM become essential for manufacturing toward resilient sustainability. This section contextualizes a green growth agenda anchoring GCLSCM and resilience sustainability. The section has four parts. Section 1.3.1 provides a brief overview, section 1.3.2 discusses manufacturing globally, section 1.3.3 discusses manufacturing in Africa, and section 1.3.4 discusses manufacturing in a Sub-Saharan African manufacturing context.

1.3.2 Manufacturing Across the Globe

Since the global financial crisis of 2008-2009, the world recorded a declining growth in GDP by 2.9% in 2019 compared to 3.7% in 2018 (Kenya National Bureau of Statistics-KNBS, 2020). The KNBS further records that such decline in economic growth exhibited itself across economies (both developed and developing), which is majorly attributed to sluggish global trade, investment, and policy uncertainties. The United Nations Industrial Development Organization-UNIDO (2021) also argues that global manufacturing has experienced stagnation due to many factors, such as trade tensions between China, the United States, and the European Union. In addition, COVID-19 led to a significant decline in economic growth. Manufacturing has been the most hit globally (Kenya National Bureau of Statistics, 2020). Moreover, the COVID-19 effect led to the first decline in manufacturing growth after the financial crisis of 2008-2009. Manufacturing remains a treasure to investors, policymakers, and governments because of its significant contribution to economic development. According to UNIDO (2016), a financial manufacturing sector is vital in social and economic growth.

However, as per the current statistics (KNBS, 2020; UNIDO, 2021), the present global manufacturing sector plays a minimal role in economic development, which has raised fears. This is due to lower gross domestic product (GDP) and manufacturing benefits (African Development Bank Group-ADBG, 2014). The ADBG (2014) and the UNIDO (2016) posit that the manufacturing industry is pressured to re-engineer the sector's business model in line with global trends emanating from higher manufacturing firm failure rates. A significant percentage is attributed to outdated business models and international policy uncertainties. To that effect, and as economies work towards long-lasting recovery from COVID-19, it is paramount to look deep into the business process reengineering of the global manufacturing sector to boost its GDP and manufacturing added value. Also, to aid the attainment of global system resilient sustainability, design for sustainability, smart manufacturing-intelligent factories, smart logistics, sustainable procurement, and reverse logistics become essential.

1.3.3 Manufacturing in Africa

Africa still lags behind the rest of the world in terms of economic development (Africa Growth Initiative-AGI, 2018). Amid such statistics, Africa showed tremendous economic growth of more than 7% annually between 2005 and 2015 in select countries (Ethiopia, Rwanda, and Tanzania). Even though Africa still lags in the global economic curve, it calls for urgent manufacturing growth measures. Africa's plan for 2063, coupled with the United Nations Sustainable Development 2030 agenda, spurs the continent's program to institute a thriving region categorized by sustainable, all-encompassing advancements, sound governance structures, and peace (United Nations Environmental Program, 2016).

Africa continues to experience insurmountable challenges on its path to achieving sustainability. By 2050, the continent's population forecasts record that the population will reach 2.5 billion people. Due to industrialization and rapid urbanization, Africa's production and consumption patterns have continued to hit the environment and society hard. Africa records six out of 10 top countries whose activities are environmentally detrimental (United Nations Environmental Program, 2016).

As such, the African space displays an atmosphere struggling with pollution and anthropogenic and organic GHG emissions affecting its human race, the environment, and economic development. Under such observations, an all-inclusive model for SD becomes urgent for Africa. McKinsey and Company (2021) document that Africa records 440 megatons of carbon dioxide equivalent (mtco_{2e}), about 30-40% of Africa's total emissions. According to McKinsey and Company (2021), Africa is meeting its nationally determined contributions per the Paris climate change agreement.

However, this status prevents Africa from devising any mechanisms toward decarbonization. McKinsey and Company (2021) further argue that Africa's emissions will rise by 70% in 2050 compared to its emissions in 2018, leading to the continent lagging against other regions in GHG reduction. The arguments of McKinsey and Company (2021) add that Africa has more significant potential to contribute to the global decarbonization agenda. This can be done by localizing SCs and producing green commodities for its local African market. Africa continues to face insurmountable economic challenges in manufacturing (AGI, 2018). This is due to the limitation of domestic markets, fuel price increases, and decreased commodity prices. This again calls for its intentionality and higher ambition to build resilient-sustainable SCs.

1.3.4 Manufacturing in a Sub-Saharan African Context

The ADBG (2017) argues that Sub-Sahara Africa will have a larger share of the world's population, unfolding the need to develop manufacturing capability to feed its growing population. For the larger Africa that has seen inconsistent results in manufacturing economic development, Africa's stagnation in manufacturing is attributed to its early exposure to world markets at a young age (ADBG, 2017). In addition, the AGI (2018) argues that Sub-Saharan Africa has the potential to grow through its hotspot countries such as Ghana, Kenya, and Seychelles. For instance, Kenya has been ranked number four in Africa in terms of competitiveness in the international market, whereas Seychelles, Ghana, and Zambia have come first, second, and third, respectively. Also, according to a 2017 research, Kenya was named second in Africa, taking position forty-one in the world in terms of its innovativeness and sophistication, which continues to attract investment in the manufacturing space.

Besides, Sub-Saharan Africa has a dearth of factories which hinders the growth of the manufacturing industry. Even with few factories in the Sub-Sahara, the region faces the massive impact of climate change. As such, a move to green industrialization is urgent. The Intergovernmental Panel for Climate Change, as cited in Wei and Jin (2021), the temperature rises in Sub-Saharan Africa are anticipated to go higher than the world average, leading to a shortage of rainfall in the region. Sub-Saharan Africa records climate change effects in several countries, highlighting an urgent need to build resilient, sustainable economies. For instance, Sono et al. (2021) present statistics on some of the regions in Sub-Saharan Africa:

*Heavy rain falls in Mauritania, Niger, and South Sudan, causing heavy floods affecting many people. In particular, severe flooding due to heavy rainfalls in South Sudan in 2019 led to a serious humanitarian crisis in the sub-Sahara.

*The 2015-Elnino caused serious drought, leading to food insecurity affecting thousands of people in Ethiopia, Kenya, and Uganda. *

Tropical cyclone that hit Mozambique and neighbouring countries such as Zimbabwe and Malawi in March 2019 led to a massive humanitarian crisis. *

Climate changes in Sub-Saharan Africa (Sono et al., 2021) continue to cause lower levels of agricultural productivity. For instance, due to rising temperatures, a reduction in significant crop yields in cocoa, coffee, and cola wild production is experienced in Ghana. The International Monetary Fund (2022) asserts that climate change in the sub-Sahara will affect the region massively but more severely in the most fragile states. The International Monetary Fund-IMF (2022) further argues that areas in the Sub-Sahara with weak governance systems, heavy dependence on agriculture, and frequent conflicts will be the most affected. The United Nations Children's Fund-UNICEF (2020) anticipates rising sea levels in most of the hotspots of the sub-Sahara. Specifically, Kenya, Madagascar, and Mozambique, in their coastal regions and banks of their inland lakes with the most recent climate change disruptive occurrences as:

<p>*Severe Horn of Africa drought in Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, and Uganda). The drought affected at least 17 million people. *</p> <p>*Cyclone Idai and Kenneth in Mozambique in 2019 affected 1.85 million people. *</p> <p>*East Africa's battle with locusts (Kenya) due to a warming climate from the onset of 2020. *</p> <p>*Occasional flooding in Lake Victoria (Kenya) affects the communities around the lake. *</p>
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Within the Sub-Sahara, Kenya is among the hot-spotted countries with severe climate disruptions such as droughts, floods, and invasions of insects to crops. Among the four divisions of Africa (Central, East, West, and Southern Africa), Kenya falls under countries in the East African Community. The Kenya Association of Manufacturers-KAM (2018) argues that Kenya continues to face challenges in manufacturing, which have frequently given birth to fears of premature deindustrialization.

A stagnating GDP over the years is clear evidence of this. For instance, Kenya recorded an average GDP of 10% between 1964 and 1973 and a marginal rise of 13.6% between 1990 and 2007 (KAM, 2018). While Kenya envisions an annual GDP growth rate of 10%, the country has not been able to come close to this percentage in the past except for the years 1962 (9.46%), 1963 (8.78%), 1971 (22.17%) and 1972 (17.05%) as reported in <https://www.macrotrends.net/countries/KEN/kenya/gdp-gross-domestic-product>

To reiterate, Kenya's economy rose by 5.4% in 2019 (The Kenya Economic Report, 2020) in comparison to 2018, when Kenya's GDP grew by 6.3% (Kenya Economic Survey, 2020). On a sector analysis, it is worth noting that Kenya's economic growth was prominent in the service sector (Kenya Economic Survey, 2020). Looking into manufacturing, Kenya recorded an increase in the economy of 3.2% in 2019 and 4.3% in 2018 (Kenya Economic Survey, 2020). Such statistics show that Kenya is heavily dependent on the service economy and characterized as a consuming economy, with the recorded increase in the economy from manufacturing coming from the automotive, food, and pharmaceutical sectors (KNBS, 2020). Kenya, the East Africa manufacturing hub, has a larger manufacturing share (KAM, 2020).

The larger share of manufacturing positions the country as a point of reference, for investigating resilience and sustainability of SCs in Sub-Saharan African economies. The Green Climate Fund (2017) states that Kenya envisions manufacturing growth of 10% annually through its project flagship under the development of industrial zones. However, such a vision was envisioned during the previous government regime necessitating a need for more emphasis even within the current government regime. In addition, Kenya continues to experience many negative environmental and social externalities with the development of such zones and low social-environmental compliance (Green Climate Fund, 2017).

The Green Climate Fund (2017) also estimates an increase in emissions from 59 million tons of carbon dioxide equivalent (MtCO₂ e) in 2010 to 102 MtCO₂ e in 2030. The Kenya National Climate Change Action Plan (2018-2022) documents the changing climate. Statistics of changing weather patterns affecting the country's economic progression are also shown. In particular, Kenya National Climate Change Action Plan (2018-2022, pp.6-8) presents notable climate change effects in Kenya:

- *"Kenya was hit by a drought in February 2017, leading to food insecurity for about 3.4 million people and inaccessibility to water by 0.5 million people.
- *Mount Kenya glaciers are estimated to disappear in the next 30 years.
- *An estimated 45% reduction in crop yield production for maize, soybean, and rice is expected by 2100, leading to severe food insecurity in the country and neighboring regions.
- *Flooding in 2018 claimed 183 lives."

1.4 Research Motivation and Knowledge Gaps

As the human race is in the age of the Anthropocene, there is reason to understand that the same cohort can work towards environmental safety (Canadian Urban Institute, 2017) due to experiences of extreme climate change effects. Having also experienced social concerns and turbulent dynamic business environments, the same group can work toward SD. Also, recent preparations toward achieving milestones discussed in several conferences such as Rio+ 20, the United Nations SD Goals 2030 agenda, coupled with conversations in COP 27/28, and those under the World Circular Economy Forum in 2023/2024, among many towards a sustainable society supports the motivation for this study. Against this background, modern struggles such as food insecurity, modern pathogenic and dietary diseases, higher firm and SC failure rates guide the study's motivation. Sections 1.4.1 to 1.4.4 provide the motivation and knowledge gap discussions, highlighting the study's significant contribution in section 1.4.4.

1.4.1 Integrated Resilient Sustainability of Supply Chains

With myriad disruptive occurrences across the globe that have a sustainability connotation, a need for integrating resilience into sustainability becomes more urgent. Sustainability conversations have always followed the traditional model of the Brundtland Report of 1987. However, in achieving SD, efficient management of sustainability disruptions becomes a pre-condition to SD. Also, classical research has always presented resilience and sustainability as separate and distinct concepts (Marchese et al., 2018). However, with modernity and the challenges that come with it, combining resilience and sustainability presents an avenue for growing communities towards all-inclusiveness and top-notch progression. Achour et al. (2014) argue that, many decision-makers need more motivation, awareness, and resources to provide developments on Integrating resilience and sustainability.

Besides, Achour et al. (2014) further argue that the available datasets and information globally are first-line support materials in the seamless integration of resilience and sustainability. Interestingly, the connection between the concepts of resilience and sustainability struggle remains the most demanding issue confronting modern academicians, industry practitioners, and researchers. Notable gaps in the extant literature, as documented by scholars such as Espiner et al. (2017), Marchese et al. (2018), and Negri et al. (2022), provide evidence for this. Most of the frameworks in existing literature have a bias toward mathematical programming.

For instance, the works of Mari et al. (2014) have a bias towards sustainability and resilience from a locational-based risk perspective. While such approaches are instrumental in growing the discipline of sustainable SCM, it is essential to have frameworks that capture process steps to integrating resilience and sustainability, more so from an indicator perspective. According to Marchese et al. (2018), resilience is a significant pre-condition for sustainability, meaning that when a system becomes more resilient, it becomes more sustainable. Nonetheless, increasing the sustainability of a system does not make it more resilient (Marchese et al., 2018). According to Ahern (2013), comprehending cities as dynamic and inherently fragile changes the understanding of sustainability. As such, the integration of sustainability and resilience is essential to developing sustainable cities. Ahern (2013) asserts that such comprehension denies systems such as cities the capability to be adaptive to the changes that come.

The works of Ahern (2013) further document disturbances that affect urban sustainability, such as disease outbreaks, climate change, and political revolution, highlighting that the sustainability of cities needs to integrate resilience to deal with the dynamism that comes with these systems.

The arguments of Blackmore and Plant (2008) contend that the strength of a system can massively impact its sustainability. All systems are inherently vulnerable to shocks and exposures propagated by risk disruptions. Then, to build long-lasting sustainability, resilience integration into systems becomes essential and urgent. The work of Milman and Short (2008) presents a resilient sustainability framework by incorporating resilience indicators into sustainability. (Marchese et al., 2018), much of the resilience and sustainability interconnections are founded on adding resilience indicators to sustainability indicators.

The works of Saidi et al. (2021) posit minimal studies on integrating resilience and sustainability, which points out the need to go way above conventional SD frameworks to capture resilience as a significant pre-condition to sustainability. Besides, Saidi et al. (2021) present a framework combining resilience and sustainability by merging their building blocks. Such studies act as starting lines for the convergence of resilience and sustainability. Colontanio (2009) argues that SD has yet to grow fully in its conventional economic, social, and environmental pillars.

The European Parliament (2020) reports that there has been much bias toward sustainability's environmental and financial aspects in the past. Such a stance has always brought about confusion on integrating social sustainability into sustainability. SD in the Anthropocene epoch demands a view from a system perspective in which disruptions may affect the system and, as such, the need to inculcate resilience as a significant component of sustainability.

The debate opens up to integrating the resilience and sustainability of SCs from a dimension perspective. The works of Marchese et al. (2018) present a review of 37 documents on the integration of resilience and sustainability, which rests on three fundamental philosophies as outlined below:

*Resilience as a part or pre-cursor to achieving sustainability. *
*Sustainability as a part of resilience. *
*Resilience and sustainability are distinct concepts. *

Moreover, Marchese et al. (2018) posit that for a system to be sustainable, it has to be resilient. In support, Ahern (2013) argues that the absence of resilience only provides fragile systems sustainability. This argument brings forth a significant assumption in the definition of SD first seen in the Brundtland report of 1987. Considering such meaning, it is clear that sustainability continues to underpin an equilibrium perspective of the triple bottom line without considering disruptions. The world economy is massively disruptive, which calls for building resilience. Anderies et al. (2013) posit that resilience provides a platform to achieve sustainability and, as such, a precursor to achieving sustainability.

On the contrary, the arguments of Ahi and Searcy (2013) and Closs et al. (2011) stress that for a system to be resilient, it has to be sustainable, meaning that a sustainable system is resilient. However, a resilient system is not necessarily a sustainable system. This conceptual definition unfolds that the critical objective of resilience is to achieve some level of maintenance.

Nevertheless, achieving some level of maintenance calls for status quo achievements that seek to reach equilibrium. In this age of interconnectedness and the multi-leveling of SCs, coupled with the scramble to who becomes a superpower in the world economy, it is tough to attain equilibrium over some time. Systems face continual disruptions, contributing to their evolution. Such evolving then departs from symmetrical equilibrium positions of systems. The end goal of SD, as derived from the Brundtland report of 1987, is to achieve long-lasting development. Considering such a definition, it becomes challenging to conceptualize sustainability as a significant aspect of resilience. Against the backdrop, viewing resilience and sustainability as separate and distinct concepts has also reached its end of life.

As depicted in the Brundtland report of 1987 and the periods after, the SD definition does not factor in the possibility of disruptions affecting systems. The definition misses out on climate-related risks that can propagate across different societal facets.

Extant literature continues to present resilience and sustainability as distinct concepts, where the proponents of this philosophy (Ning et al., 2013; Meacham, 2016) argue that resilience does not contribute to sustainability, and sustainability does not contribute to resilience. This framework originates in civil infrastructure, which relies heavily on systems' structural capabilities. Since SCs are multifaceted and dynamic systems, bringing this notion to SCs does not hold.

This present study agrees with the first framework's proponents that resilience is a significant aspect of sustainability. Avala-Alcívar et al. (2020) provide a conceptual framework by combining resilience and sustainability indicators in which they strongly argue the need for more empirical research to validate such thinking. Negri et al. (2020) also present a review of the literature and say that there is a need for more empirical studies to integrate resilience and sustainability in SCs, where they propose the integration of indicators. From a sustainable SC network design perspective, Mari et al. (2014) proposed a resilient sustainability framework. Mari et al. (2014) used an optimization model of multi-objective goal programming that looks only at carbon emissions, the carbon footprint, and location-based risks. The framework of Mari et al. (2014) fails to provide holistic measurements for resilience and sustainability. Jabbarzaeh and Sabouh (2018) considered a hybrid methodology in enjoining resilience to sustainability through a mathematical program.

However, the study did not show process steps and was biased toward supplier selection risk disruptions. Mohammed et al. (2018) also developed a resilient sustainability framework considering only the supplier selection risks; hence, the framework is limited to the tenets of SCM and upstream SC risks. The works of Macdonald et al. (2018) developed a framework based on risk disruptions, SC ecosystem, and resilience-based investments. The framework does not have a sustainability connotation. Based on the above discussions, integrating resilience and sustainability, particularly in SCs, is still in its infancy. Most research within the literature review space calls for empirical investigation validation. It is interesting to note that most scholars are proposing integrating individual indicators of sustainability and resilience into a convergent framework in their areas for further research.

To provide more evidence, the works of Abson et al. (2021) present a review of the use of resilience in sustainability research between 2014 and 2018. Their research shows the slow progress of resilience research in sustainability, which could explain the slow progress of sustainable global systems. Corrales-Estrada et al. (2021) view resilience and sustainability from an organizational perspective. The researchers call for empirical testing and validating resilience and sustainability capabilities. These studies highlight that the enjoinder of resilience and sustainability is still a paradox for scholars and practitioners, which is a path rarely traveled, particularly in a win-win situation for SCs and climate resilience.

Most scholars consider reducing SC emissions without considering how climate-related risks affect SCs. Also, most scholars regard resilience and sustainability as standalone rather than integrated concepts. Their convergence requires a holistic system risk analysis. Policy arguments present a starting ground for attention to managing SC-climate-related disruptions. The IMF (2022) stresses that most research is biased toward managing economic and partly social disruptions (the OECD, 2021). This shows evidence of minimal attention to SC-climate-related risks (World Economic Situations and Prospects, 2020), which is particularly important for the scholarly community to contribute to an upward trajectory of managing and mitigating SC-climate-related risk disruptions.

Few scholars have examined resilience and sustainability from a combined dimension perspective. Also, only a few studies look at sustainability holistically from the triple bottom line. Most studies are biased toward the environmental and economic pillar of sustainability, disadvantaging the social pillar. Bostron (2016) emphasizes that social sustainability is a missing pillar affecting companies' sustainability performance. Furthermore, Metaxas and Psarropoulou (2021) posit the urgency to integrate resilience and sustainability for valuable development, which calls for convergent frameworks, more so from empirical investigations. Such arguments highlight the urgency of empirical investigations to show the practicality of

such convergence. For this study, resilient sustainability dimensions have been thoroughly investigated and tested through surveys by SC line managers, managing directors, and chief executive officers from manufacturing businesses in a Sub-Saharan African context.

1.4.2 Green-Closed-Loop Supply Chain Management Under Circular Economy

The Manufacturing Research Consortium of Michigan State University put up GSCM 1996 as one of the first proponents with a significant aim to minimize the environmental effects of manufacturing SCs (Jayarathna, 2016). Since then, research in this area has garnered attention in its various dimensions, such as adoption levels and the link between GSCM and performance. The MacArthur Foundation (2020), Guide and Wassenhove (2009), and Sarkis (2006) continue to expound on the concept of GSCM by proposing other notable avenues, such as the circular economy (Mac Arthur Foundation, 2015).

Also, Guide and Wassenhove (2009) and Sarkis (2006) stress the significance of closing the SC loop and GSCM, respectively. Such discussions highlight that it is time to shift to a new SC model anchored on GCLSCM (Mafini & Loury-Okoumba, 2018), by rethinking the SC anthropogenic practice. That said, it is interesting to note that previous literature has focused on individual models for building of sustainability. Seuring, (2012), Brandenburg et al. (2014) and Govindan et al. (2015) show evidence for this, where the studies have paid attention to either GSCs, closed-loop SCs, reverse logistics, circular SCs, or sustainable SCs.

Seuring (2012) looks into modeling approaches and sustainability dimensions. However, Seuring (2012) focuses only on the forward SC under the triple bottom line. Brandenburg et al. (2014) look into sustainable SCs with a bias to sustainability aspects, SC dimensions, and models used. The works of Brandenburg et al. (2014) look into sustainable SC from a forward perspective under quantitative models using the triple bottom line. The study of Brandenburg et al. (2014) also fails to capture closed-loop aspects in the SC. Govindan et al. (2015) present a review of reverse logistics and closed-loop SC, which is very exhaustive.

However, Govindan et al. 's (2015) paper is a systematic literature review that focuses only on closed-loop and reverses logistics without the circular economy. Karsak and Dursun (2016) consider reviewing quantitative models for supplier selection, where the study fails to capture the complete SC structure and closed-loop aspects. Notably, all the above studies are biased toward sustainable supply chain network design, where scholars have focused on specific practices in the larger concept of sustainable SCM. For instance, some scholars are looking at either circular economy, closed-loop SCM, or GSCM. Remarkably, such studies do not show a direct link between either practice to sustainability or resilience performance due to the nature of mathematical programming.

It is also worth noting that most studies have conducted review investigations. Prior scholars in the review space up to 2016 fail to offer more holistic and integrated approaches encompassing green, closed-loop, circular economy, larger sustainable SCM, and other emergent ecologies. The period 2015 (before 2016) marks the inception of the United Nations SD Goals Agenda, which spurred research in this area. Further evidence from studies such as Govindan et al. (2017) provides a review outlook in which the concentration is on SC sustainability with uncertainty considerations. However, the review does not capture closed-loop concerns. Goltos et al. (2019) look into uncertainty in remanufacturing. The review considered only one aspect of the closed-loop SC. Ambilkar et al. (2021) looked at one part of the closed-loop SC: product returns. Flores-Sigenza et al. (2021) review quantitative models for sustainable SCs.

However, Flores-Sigenza et al. (2021) focused only on the forward SC without considering the closed-loop SC. Empirically, Noparast et al. (2021) proposed an integrated, sustainable, closed-loop SC for the concrete manufacturing industry. From an empirical perspective in sustainable SC network design, Noparast et al. (2021) considered a closed-loop SC with modeling of GHG emissions. However, the research needed to capture the circular economy and the link between sustainable closed-loop SCs and resilient sustainability. De and Giri (2020) looked into a closed-loop SC. However, their paper did not capture circular economy embedments and the social aspect of sustainability. Using a numerical case study, Heidari-Fathian and Pasandideh (2018) designed a green blood SC network. Their paper concentrated only on the forward SC.

Clearly, before and beyond 2015, extant literature fails to offer thorough conceptual contributions on holistic GCLSCM, highlighting a gap in consideration of GCLSCM to build resilient sustainability in today's most fragile systems. There needs to be more literature linking GCLSCM to resilient sustainability, a novel avenue for this study.

Against the backdrop, it is also essential to look into empirical investigations that show a direct link between GCLSCM and the resilient sustainability of SCs. Starting with the works of Cankaya and Sezen (2019), it is notable that the study investigates the effect of GSCM on sustainability performance. Nonetheless, the study failed to capture the impact of such practices on combined resilience and sustainability since it only focused on sustainability performance. Cankaya and Sezen (2019) discovered that the relationship between GSCM and economic performance was different than expected and proposed future research to investigate such an association closely. In the study of Cousins et al. (2019), GSCM practices influence operating and environmental performance where SC traceability and ecocentricity moderate such a relationship.

The works of Cousins et al. (2019) fail to capture all the pillars of sustainability and look at GSCM practices from a single indicator perspective for each SC facet. Ullah et al. (2022) investigated the influence of GSCM practices on organizational resilience during the COVID-19 pandemic and found that GSCM practices can increase organizations' resilience.

However, the conceptualization of GSCM does not follow the SC structure, and the study fails to capture the relationship between such practices and sustainability. Also, the study has a bias towards the financial resilience of organizations. In the study of Baz et al. (2023) on SC resilience and social performance, the researchers find that social performance practices positively affect SC resilience. Also, the study of Baz et al. (2023) did not have an outlook on social practices across the SC. According to Gyabeng-Mensah et al. (2020), internal GSCM practices may negatively affect a firm's performance. However, green human resource management and environmental collaboration can strengthen such a relationship, which could explain inconsistent findings in such a relationship in the extant literature. Against the backdrop, such findings and discussions unfold the importance of making practices such as IEM viable capabilities to strengthen such a relationship. IEM has heavily been considered a GSC practice, driver, and mediator between GSCs and sustainable performance (Burki et al., 2019), with little attention to its moderating role (Pan et al., 2020).

The SC collaborative capability in adopting GCLSCM is significant in achieving resilient sustainability. Based on this study's arguments on extant literature, it is evident that apparent gaps exist in building a resilient and sustainable economy through GCLSCM under a circular economy. Most studies investigate the direct link between GSCM practices and sustainability.

However, such studies need to look at sustainable performance holistically and capture other aspects that could speak to the circular economy and closed-loop aspects. Seeing minimal evidence of the effect of GSCM practices and resilience is worrying. The works of Ullah et al. (2020) act as a pivotal study but fail to capture sustainability. Studies in the larger space of sustainable supply chain network design with mathematical programs are at the forefront of upholding resilient and sustainable supply chains. Nonetheless, most of such studies are within the review space, and even those within the empirical space need to be more holistic regarding the outlook of resilience and sustainability.

Then, the direct link between GCLSCM under circular economy for resilient sustainability proves a novel area. Studies such as of Negri et al. (2021) and Marchese et al. (2018) provide solid arguments for combining resilience and sustainability. With such convergence, the direct effect of GCLSCM and resilient sustainability becomes a vital avenue worth investigation and productive development for resiliently sustainable SCs and, by extension, economies.

In addition, studies such as those of Ullah et al. (2020) provide evidence for direct investigations of integrated green and closed-loop SCM under a circular economy for the resilience and sustainability of SCs. Moreover, a broader scope of practices defining GCLSCM must be examined. For instance, lean philosophies (Chin et al., 2015) encompassing total productive maintenance and the Japanese 5S approach must be integrated into green manufacturing. Incorporating such practices in this present study also provides a novel contribution to the study's motivation.

1.4.3 A Sub-Saharan-African Context

Studies on GCLSCM and resilient sustainability are minimal in the Sub-Saharan African region. However, according to prior scholars such as Barrett (2017), evidence of integrated resilient sustainability models could be more robust in the sub-Sahara. Barrett (2017) looks into the resilience and sustainability of agriculture in the sub-Sahara, concentrating on building agricultural value chains in Africa. Nonetheless, the study did not provide a convergent framework for resilience and sustainability. Mwangi et al. (2021) look into the resilience and sustainability of agricultural SCs. The study looks at resilience from the perspective of readiness, response, and adaptability. The study of Mwangi et al. (2021) leaves out key pertinent resilience building blocks such as agility, collaboration, and a risk management culture.

Wagengen's economic research (2021) looks into building resilience for Africa's food value chains. The paper has a bias toward the food chain and building resilience alone. The works of Nkrumah et al. (2020) looked at adopting GSC capabilities in Ghana with a bias toward the forward SC without a circular economy, closed-loop, and resilience aspects.

That said, Kenya and the larger Sub-Sahara face SC-climate-related challenges. The Kenya National Climate Change Policy Framework (2016) documents that Kenya relies heavily on the natural resource base for its economic progression. While Kenya's contribution to GHG emission globally is minimal, it has experienced vast SC-climate-related disruptions in the form of droughts, floods, rising temperatures, and the invasion of insects on crops. Kenya has prioritized green growth industrialization under its Climate Action Plan and Act, opening up a gap for this study. In addition, this study pegs its motivation on the United Nations Sustainable Development Goals 2030 agenda. The study is pegged explicitly upon sustainable development goals 12 (responsible consumption and production), 13 (climate action), and goals toward environmental safety and resiliency.

1.4.4 Summary of Research Motivation and Knowledge Gaps

As demonstrated in the background of the study, research motivation, and problem description and expounded upon in the literature review, numerous studies over the past two to three decades have delved into researching various aspects of GCLSCM and resilience sustainability. For instance, the studies of Cankaya and Sezen (2019), Negri et al. (2021), and Silva et al. (2022) are among a few that have investigated some of these concepts. Despite the evident advantages of GCLSCM practices, organizations and their SCs continue to grapple with performance challenges. This highlights the importance of integrating these practices and different performance dimensions to build SCRes and SCSus to explore new avenues for improved performance. This present study investigates the combined effect of GCLSCM on SCRes and SCSus, departing from the more commonly explored individual aspects.

Moreover, building upon the arguments made by Espiner et al. (2017), Marchese et al. (2018), and Negri et al. (2021), which advocate for the empirical integration of resilience and sustainability, the study contends that there is a dearth of research exploring these combinations. This present research contributes to the extant literature by employing a multifaceted approach to measure GCLSCM outcomes. These outcomes encompass resilience, adaptability, agility, robustness, a risk management culture, and environmental, social, and economic sustainability factors. A triadic-dimensional conceptual model with 83 factors, categorized as GCLSCM, resilient sustainability, and IEM, was developed and empirically tested to address literature gaps. The conceptual model was tested through a novel structured survey crafted based on an extensive literature review and distributed to 159 manufacturing organizations in Kenya, selected through a multi-stage judgmental sampling approach. Although the study primarily focused on the manufacturing economy of Sub-Saharan Africa, specifically Kenya, the tested framework is proposed for consideration by individual countries and regions within the Sub-Sahara and other emerging economies.

This research aligns with the sentiments expressed by Nkrumah et al. (2020) on the need for more studies investigating the relationship between GSCM and sustainability performance in Sub-Saharan African Economies. However, it distinguishes itself by exploring the link between these practices and resilience and sustainability while considering the entire SC from end to end, with additional practices such as closed-loop and circular economy. Furthermore, it addresses previously overlooked aspects within the lean manufacturing philosophy (Chin et al., 2015). Examples of the lean practices such as total productive maintenance and the Japanese 5S approach (Chin et al., 2015), oriented towards waste reduction, a fundamental tenet of the circular economy have been considered in this study.

In summary, this study makes several significant contributions:

1. As the discipline of sustainable supply chain management gains traction, particularly given our critical geological period, this research goes beyond the triple bottom line theory to address sustainability challenges by integrating resilience and sustainability. Drawing from the works of Marchese et al. (2018) and Espiner et al. (2017), it explores the empirical integration of resilience and sustainability in a Sub-Saharan African manufacturing context. This was achieved by investigating the resilient sustainability adoption levels amongst manufacturing businesses.
2. It explores the adoption levels of GCLSCM in the circular economy context, shedding light on a promising avenue for building more sustainable and resilient SCs. The study advocates for including lean supply chain practices like total productive maintenance and the Japanese 5S methodology in GCLSCM studies, emphasizing their role in cleaner production and SCSus.
3. It explores the combination of green, closed-loop, and circular economy-based practices and further investigates their combined direct effect on resilience and sustainability. While ample literature exists on GSCM and sustainability performance, minimal evidence on the combined GCLSCM and resilience sustainability is seen in the literature. The study of Ullah et al. (2022), which examines GSCM practices and resilience, acts as a starting line for linking GSCM to resilience. Moreover, this present study extends such investigations by exploring the synergetic combinatory effect of GCLSCM on resilient sustainability. To the best knowledge of the researcher, this present study is one of a kind to explore such direct investigation. Thus, this study developed and tested a triadic-dimensional framework based on GCLSCM, IEM, and resilient sustainability.

1.5 Problem Definition

With heightened global economic challenges such as trade tensions among China, the US, and Europe, COVID-19 effects, and the Ukraine-Russia wars cascading across world regions, compounded with social unrest and the ever-warming globe, the building of a resilient, sustainable economy becomes more urgent than ever. Against the backdrop, the WESP (2020) documents that, since the global financial crisis of 2008-2009, the world recorded the lowest gross product growth of 2.3% and the lowest global trade growth of 0.3% in 2019. Goel et al. (2021) present a higher impact of SC disruptions after the financial crisis of 2008-2009. Such global cross-cutting challenges, coupled with intensified political divergence and uncertainty on multilateral benefits, can impose severe and lasting harm to society, hindering SD.

Such eventualities continue to hit hard on global SCs, weakening their expansion. The International Monetary Fund (2022) argues that production challenges in one country have cascading effects on other countries. Such discussions speak to the magnitude of global SC disruption propagating effect from one SC partner to another, prioritizing building resilient sustainable SCs. From a climate change perspective, Chen et al. (2019) posit that unsustainable manufacturing in the current industrial setup can be equated to the grey/black factories at the beginning of the 20th century due to fumes from fired steam engines in the coal industry. While such a practice yields good economic returns, it is unsustainable (Chen et al., 2019) and leads to climate variability. Such variability calls for resilient capabilities for climate safety and SCs as a shield from climate disruptions. Mutingi (2013) and Shan and Wang (2018) argue that SCs remain the number one environmental and social polluter, which calls for greening and closing their loops toward SD.

Extant literature documents limited studies investigating the direct link between an integrated model of green and closed-loop SCs in the circular economy context and resilient sustainability. Studies showing upholding resilience and sustainability of SCs from a practical perspective are also limited (Marchese et al., 2018; Negri et al., 2021; Aming'a et al., 2024). The view of sustainability still anchors the triple bottom line from a static perspective. However, with continual disruptions, sustainability dynamics call for proactive measures for SD. Converging resilience and sustainability rests on the fact that climate changes have a ripple effect on SCs that house most climate-dependent activities. Such arguments highlight the importance of managing SCs for sustainability and mitigating SC-climate-related Risks for resilience. In this context, WESP (2020) emphasizes that climate risks are continually underrated, leading to decision-making that relies heavily on investment expansions around carbon-intensive assets. Such investments contribute to higher GHG emissions.

In response, a need for holistic models that go above economic solutions to integrate both social and environmental solutions for SD emerges for policy, scholarly and practice. For instance, the International Finance Corporation (2021) highlights the need to prioritize the reduction of the GHG effect in emerging markets like Sub-Saharan Africa. Scholarly discourse also shows the need to prioritize GHG emissions reductions across all world regions but with attention to the most fragile areas of the world economy (Kinda, 2021).

While green, closed-loop, and circular SCs (Guide & Wassenhove, 2009; Govindan et al., 2015; Chen et al., 2020) continue to be propelled by scholars, practitioners and policymakers as a promising a venue for resilient sustainability (Fahimnia & Jabbarzadeh, 2016; Abson et al., 2021), the investigations remain unexplored in emerging markets and more so their direct influence to both resilience and sustainability. The upholding of resilience and sustainability of SCs also remains unexplored, more so from an empirical perspective (Negri et al., 2021). According to Cankaya and Sezen (2019), their study on the effects of GSCM practices on sustainability performance found that GSCM did not influence economic performance and suggested the need for future research to investigate such effects closely.

The study of Cankaya and Sezen (2019) also found that GSCM practices did not have as much influence on social performance as environmental performance. Cankaya and Sezen (2019) did not factor in resilience and its combination with sustainability. Dzikriansyah et al. (2023) argue that GSCM would influence environmental performance. However, there is a need for more studies to consider more complex models for organizational performance. Even with these findings, the GSCM practices used are fewer and need to align with the structure of SCM. The practices used are the safety of products and materials, product availability information, efficient usage of fuel, optimal transportation capacity, reuse, recycled materials, and time and the number of customers who purchase from the company. Dzikriansyah et al. (2023) need to capture holistic GSCM practices and pillars of sustainability.

From a resilience perspective, GSCM practices can increase organizations' resilience (Ullah et al., 2022). This study argues that companies that invest in GSCM practices have higher survival rates from economic and financial crises than those that have not invested in the same. The study of Ullah et al. (2022) did not factor in sustainability and holistic GSCM practices. Jassim et al. (2020) state that GSCM practices influence firm performance, whereas green packaging does not. Green manufacturing and marketing influence firm performance the most. Even with these findings, Jassim et al. (2020) posit that it is essential for such investigations to be considered case by case concerning the country and region under investigation because different regions' adoption and awareness levels differ.

The study of Jassim et al. (2020) focuses on the forward SC and, thus, has no connotation to the closed-loop SC. In studies that argue about converging resilience and sustainability, Marchese et al. (2018) and Espiner et al. (2017) argue about combining resilience and sustainability from their indicators.

Negri et al. (2021) contend that the convergence of resilience and sustainability is a possible avenue for future research where the starting line should combine their indicators. All these scholarly discourses provide reviews on the convergence of resilience and sustainability without practical investigations from an empirical perspective. From a Sub-Saharan African perspective, there is still a need for more literature on studies of GCLSCM and resilient sustainability, which presents an opportunity in an underdeveloped context. For instance, studies such as Nkrumah et al. (2020) and Kinda (2021) provide a starting ground unfolding the need for more studies in the region. Hypothetically, such studies show that circular economy and closed-loop practices still need to be added to GSCM studies.

Sustainable Inclusive (2021) on circular economy trends in Kenya argues the need to embrace circular economy models beyond waste recycling and management. Also, the adoption and practice of GCLSCM depend on several SC eco-capabilities, such as IEM, top management support (Gong et al., 2021), and collaboration (Gurzawska, 2020). Most studies continue to treat IEM as a GSC practice. For instance, the study by Diaz and Ping (2018) argues that IEM can improve performance. However, with such capability, the relationship between GSCM and sustainability performance would be stronger under the contingent effect of IEM (Gong et al., 2021; Gurzawska, 2020). Drawing motivation from this discourse, some gaps are notable in extant literature.

The need to combine resilience and sustainability from a dimension perspective, the need to combine green and closed-loop SCs considering circular economy and the need to investigate the direct effect of GCLSCM on resilient sustainability under IEM. To show the practicality of these gaps in contexts in Sub-Saharan Africa, Kenya, and the larger Sub-Sahara continue to face SC-climate-related challenges which might hinder the development of SCs. For instance, while Kenya envisions a GDP of 10% on average and growth of its manufacturing sector, with low uptake of strategies to manage climate related risk disruptions, the country might not achieve its vision. This vision and past Industrial Production, GDP, and Manufacturing Added Value position Kenya as a significant part of the global economy. Also, with Kenya transitioning from a low developed to a middle-income country, its participation in trade agreements and as a member of the World Trade Organization highlights its involvement in advanced trade processes, which have a prospect to induce negative environmental externalities.

Even with these nascent circumstances, investigations into GCLSCM remain limited. Kenya prioritizes green growth industrialization under its Climate Action Plan and Act. Amid such efforts to achieve SD, Kenya and the larger Sub-Sahara still need to catch up in implementing policy frameworks. Such discussions show that GHG emissions from manufacturing in Kenya are ungoverned.

This is expected to triple by 2030 (Sustainable Inclusive, 2021). Also, this means that waste management and social well-being are equally ungoverned in this context. While it is promising with the upstarting of circular economy guidelines such as the Sustainable Waste Management Act of 2021 and the Extended Producer Responsibility Regulations of 2022, there is a need for an integrated framework towards building resilience and sustainability, more so from a SC perspective. Any effort that leads to long-term development in this region becomes a priority. To address these research gaps and advance research in sustainable SCM, this study contributes by investigating the building of a resilient, sustainable economy through GCLSCM under a circular economy for manufacturing businesses in a Sub-Saharan African context.

1.6 Research objectives

1.6.1 General Research Objective

To investigate building a resilient, sustainable economy through green and closed-loop supply chain management practices in the context of a circular economy for manufacturing businesses in a Sub-Saharan African context.

1.6.2 Specific Research Objectives

The study specifically sought:

1. To investigate the level of resilient sustainability adoption in manufacturing businesses in a Sub-Saharan African context
2. To determine the level of green and closed-loop supply chains adoption in manufacturing businesses in a Sub-Saharan African context
3. To investigate the effect of green and closed-loop supply chains on resilient sustainability for manufacturing businesses in a Sub-Saharan African context
4. To investigate the moderating effect of internal environmental management on the relationship between green and closed-loop supply chains and resilient sustainability of manufacturing businesses in a Sub-Saharan African context

1.7 Research Questions

1. What is the level of adoption of resilient sustainability dimensions in manufacturing businesses in a Sub-Saharan African context?
2. What is the level of green and closed-loop supply chain adoption in manufacturing businesses in a Sub-Saharan African context?
3. How do green and closed-loop supply chains affect resilient sustainability in manufacturing businesses in a Sub-Saharan African context?
4. What is the moderating effect of internal environmental management on the relationship between green and closed-loop supply chains and the resilient sustainability of manufacturing businesses in a Sub-Saharan African context?

1.8 Significance of the Study

1.8.1 Practical Significance

Practical aspects of any research are instrumental in guiding practitioners and policymakers. This present study will benefit manufacturing business organizations, service business organizations, humanitarian organizations, the home economy, government organizations, policymakers, regulators, and trade associations such as the Kenya Association of Manufacturers, and development partners such as the World Bank, among many others. For manufacturing business organizations, particularly in the Sub-Sahara, this study will be beneficial through the practicality of upholding supply chains' resilience and sustainability (Marchese et al., 2018). The study highlights the importance of using GCLSCM business models to transition manufacturing businesses into greener hubs and toward green economies in Sub-Sahara Africa.

This study further sheds light on the importance of building manufacturing capabilities in the Sub-Sahara by increasing the number of factories to boost manufacturing and through the uptake of closed-loop and circular economy business practices to strengthen the resilience and sustainability of SCs in the region. According to the Global Food Security Index (2021), Sub-Saharan Africa continues to face food insecurities due to the effects of climate change. By upholding SD practices such as GCLSCM, which was investigated in this study, Sub-Saharan manufacturing contexts are likely to benefit by reversing their anthropogenic food SC practices toward food security. As economies progress from COVID-19 effects and the Ukraine-Russia wars, organizations such as Universities realize the importance of prioritizing resilience capabilities to sustain education.

Universities will benefit by learning to uphold resilience and sustainability for sustainable education (Aming'a et al., 2023) since education remains a motor of change (United Nations

Decade for Sustainable Education, 2005-2014). The study will also benefit humanitarian and government organizations in terms of closed-loop and circular economy SC management, together with resilient capabilities for risk management. On SDG goal 12_responsible consumption and production, the home economy will also benefit through consumers who are a part of the public learning on consumption and production choices at the home level.

Buying home items with recycling capability and using resources such as water and energy efficiently can be drawn from some of the study's practices. For regulators and policymakers, the study will benefit several players. For instance, the study will benefit KAM by teaching them how to map and profile manufacturing businesses best to take up GCLSCM. The study will also help ministries such as the Ministry of Education and the Institute for Curriculum Development. Also, the study will benefit the Ministry of Environment and Forestry on which practices to embed in various policy guidelines to build SC resilience and sustainability.

1.8.2 Scholarly Significance

Scholars and academicians will gain from this study, as it will contribute to the body of knowledge by building on conceptual gaps and providing solutions. This study will also benefit students in building on their knowledge base on GCLSCM, a resilient circular-based sustainable economy, and the importance of being environmentally and sustainably conscious for sustainable risk-tolerant societies. It would be necessary for scholars, academicians, and researchers to welcome the convergence of resilience and sustainability, as upholding both in SCs could be a game changer for enhanced development. It is also worth noting that such stakeholders will benefit from the suggestion and practicality of converging resilience and sustainability.

The integration of resilience and sustainability might seem an uphill task; however, the findings of Espiner et al. (2017) and this present study argue that the fit may be imperfect. However, such integration provides a starting line for complex adaptive systems like SCs. The scholarly community will yet again benefit from the practical empirical contributions on the direct influence of GCLSCM and the resilient sustainability of SCs. Interestingly, even with the maturity of concepts in resilience and sustainability, more so in SCM literature, the direct effect of GSCM and resilience and resilient sustainability is still in its infancy, which could be influenced by the triple bottom line philosophy that traditionally has not acknowledged systems to be dynamic.

The arguments of Marchese et al. (2018) contend that, for systems to be sustainable, they must be resilient. Resilience capabilities provide the strength for systems for their long-term survival and thus contribute to their sustainability. Such arguments highlight the importance

of investigating the direct effect of practices such as GSCM on resilience and sustainability. This study will also benefit the scholarly community from a context perspective, where studies such as this are minimal in Sub-Saharan Africa. As such, this study might jumpstart the minds of scholars to give attention to GCLSCM and resilience sustainability in Sub-Saharan African manufacturing economies.

1.9 Scope of the Study

The study had a bias toward a Sub-Saharan African context. In particular, the study looked into the assessment of 329 multi-sectoral manufacturing businesses in Nairobi, Kenya. The businesses are listed under the KAM (2019-2021) under the Nairobi industrial area within the food, chemicals, pharmaceuticals, cosmetics, metal, energy and construction sectors.

After an inclusion/exclusion assessment, the sample size for the study sat at 159 mixed manufacturing businesses under the above sectors in pure production, which had existed during the research period and for at least one year, with evidence of some GCLSCM practices.

1.10 Summary of the Study's Limitations

This thesis has limitations. For example, the study investigated the phenomena under inquiry in a single manufacturing context in Sub-Saharan Africa. While, the findings can be replicated to similar contexts in the region, it would be important for future research to consider expounding to other contexts in the region.

Moreover, given the few factories in these region, the research was only able to study 159 manufacturing businesses. The data collection was conducted during the COVID-19 pandemic when a more significant percentage of companies had to close down due to the impact of the COVID-19 pandemic. However, even with these limitations, the study got a helpful response rate of 100 responses that was utilized for the study. In the Sub-Saharan African Manufacturing context used as a setting for this study, it was noticed that the manufacturing businesses were not willing to partake in sustainability studies. The companies continuously stated that the researcher could be an agent of the government spying in the form of research. The usage of the research permits made the companies to be responsive. However, the majority were hesitant to partake in environmental management-related studies. This necessitates the intentionality of governments to strengthen research policies, particularly regarding sustainability.

1.11. Organization of the Thesis

This thesis shows how the practice of GCLSCM can help SC managers uphold the resilience and sustainability of SCs by investigating the influence of GCLSCM on resilient sustainability. The thesis has seven chapters. Chapter One lays a foundational ground through an introduction. The introduction provides a synopsis of the study by giving pertinent debates in the background, which inform a problem case for the study. Chapter One still presents the study's objectives, the research motivation, and the contextualization of the study.

The contextualization of the study reflects the global, regional, and local perspectives unfolding on the importance of building resilient sustainability for global economic systems. Chapter two provides discussions on the definitions of critical constructs guiding the study. Here, primary constructs are defined: resilient sustainability (dependent variable, GCLSCM (independent variable), and IEM (moderating variable). Chapter Two still provides a detailed literature review from an empirical perspective. Chapter three presents the theories, hypotheses, and conceptual model guiding the study.

Chapter three still opens the theoretical framework through a multi-theoretical perspective of three prominent theories. Chapter four discusses the research methodology anchoring the research philosophy, design, strategy, approach, data collection, data analysis, and quality. Chapter five presents the data analysis and interpretation of the research findings. Chapter six delves into the discussion of the research findings, and chapter seven presents the research's conclusion.

1.12 Chapter Summary

In this chapter, we introduce the investigation of building a resilient, sustainable economy through GCLSCM based on the circular economic model for manufacturing businesses in a Sub-Saharan African context. The chapter starts by outlining the purpose of the study and the chapter's structure. The chapter then provides a background of the study, delineating key constructs and the motivation for the study. The chapter further describes the problem and gaps that define the formulation of the research objectives, as shown in sections 1.6 and 1.7. Finally, the chapter discusses the study's scope, justification, limitations, thesis organization, and a chapter summary. The chapter provides a foundation for comprehending the scientific basis for building resilience and sustainability. The following chapter is the literature review, which discusses the phenomena under study based on extant literature.

Chapter Two: Literature Review

2.1 Introduction

This study sought to investigate building a resilient, sustainable economy through green and closed-loop supply chain Management in the context of the circular economic model for manufacturing businesses in a Sub-Saharan African setting. As such, the main objective of this chapter is to provide a comprehensive literature review towards the achievement of the phenomena under study. A literature review is an essential arm of research as it allows for the basis for investigating a phenomenon under inquiry. According to Snyder (2019), a literature review is the foundation of all research components. A literature review provides developments and gaps from extant literature, which opens up further developments in a discipline's growth.

The works of Mudavanhu (2017) state that a literature review significantly justifies specific research questions. Intrinsically, it is essential to start with conceptual discussions to comprehend the key constructs and their measures. For this study, the foundations of the study's key variables (endogenous variables-resilient sustainability; economic, environmental, social, and resilient sustainability), (exogenous variables-GCLSCM; design for the environment, green procurement, green manufacturing, and reverse logistics) and (moderating variables-IEM; environmental collaboration capability) are discussed. The discussions offer a base and justification for investigating the phenomena under inquiry.

2.2 Literature Review

2.2.1 Main Concepts

2.2.1.1 A Preliminary Outlook on Resilience

To understand the concept of resilience, it is essential to start by comprehending the present atmosphere of risk disruptions that call for building resilient, sustainable economies. With globalization and today's impatient customers, different global systems face unprecedented disruptions, exposing the vulnerabilities of modern SCs that contribute massively to economies. The current international system continues to face massive SC-climate-related risk disruptions. This is an Anthropocene, where man's industrial activities are more detrimental to Mother Earth than any other geological epoch. Besides, the present global business atmosphere faces tough competition. Such competition continues to force firms to uphold operative processes that address the uncertain dynamic international environment relationships and dependencies (Erol et al., 2010).

As a result, it is notable that firms must be able to deal with evolving threats, adapt to fast, turbulent times, and still sustainably meet the needs of the customer and other stakeholders. That said, myriad occurrences, such as natural disasters, terrorism, food insecurity, and inequality, are continual fears of social, ecological, and economic resilience and sustainability (Ernst & Young, 2010). In addition, low levels of productivity across businesses and unsustainable consumption and production patterns (Shan & Wang, 2018) remain a challenge to the building of resilient, sustainable systems. Also, as the world business space commonly referred to as ‘the global village’ continues to grow smaller, myriad disturbances beyond food insecurity, such as political divergence and scramble for power, emerge.

The works of Christopher and Peck (2004) state a need to build resilient SCs to manage continual SC disruptions. A SC disruption is a disruptive occurrence that hinders the SC's normal functioning and propagates across SCs. Son (2018) posits that risk is a possible loss to SC through variations that affect the normal functioning of SCs. Carter and Rodgers (2008) argue that risk is a degree of variation that affects the result of something. Christopher and Peck (2004) assert that, with disruptions such as natural catastrophes and civil wars, business as usual in SCs is not an option. According to the European Commission (2014), climate-related occurrences have cascading effects on society and the more extensive global economic system. For instance, the European Commission (2014) documents a few examples of SC-climate-related risk disruptions and their impact on societies and economies:

“After the Tohoku-pacific earthquake of 2011, the Economic Times reported that “Japan’s Toyota Motor will cut production at its Indian subsidiary by up to 70% between April 25 and June 4 due to disruption of supplies” The New York Times reported that “auto production in Japan is at only half the normal level for Honda. That is mainly because many of the 20,000 to 30,000 parts that go into a Japanese car come from the earthquake-stricken region in northeast Japan, where numerous suppliers were knocked offline” (EU, 2014, p. 8).

For efficient management of risk disruptions, assessing vulnerable points is essential for building resilient and sustainable SCs. Also, the United Nations Environmental Programme (2007) posits that climate change challenges have a far worse disruptive effect than other disruptions in the economic space due to their massive cascading effects. The works of Freise and Seuring (2015) argue about managing risks beyond economic SC risks to environmental and social risks. This means that achieving SD calls for proper resilience strategies. Xu et al. (2020) posit that disruptions in the SC in terms of natural disruptions (hurricanes, floods, and earthquakes, human-induced disruptions (terrorism, civil wars), and legal disruptions (sustainability laws and regulations) continue to cause massive disturbances within SCs.

Such disruptions affect the entire SC through their ripple effects, commonly called disruption propagation (Xu et al., 2020). SC disruptions are a significant threat to the continuity of SCs and, its global expansion. SC risk disruptions call for re-engineering the SC network by building resilient SCs (Peck & Christopher, 2004) for long-term business continuity.

To understand the resilience of SCs then, it is essential to comprehend SC risk management. The works of Carter and Rodgers (2008) argue that SC risk management is the capability of an organization to deal with economic, social, and environmental disruptions. Such conventional reasoning highlights that modern thinking needs to inculcate the management of risks as a significant sustainability component.

According to Vanany et al. (2009), SC risk management entails a process SCs follow to reduce risks and their impacts. This is usually depicted in several strategies that SCs and companies devise to stay afloat when a disruption occurs and remain competitive. Also, Fan and Stevenson (2017) posit that SC risk management is a process of identifying, assessing, treating, and monitoring risk disruptions with the assistance of internal SC capabilities and the collaboration of SC partners toward reducing vulnerabilities to achieve profitability and competitive advantage.

According to Shishodia et al. (2021), SC risk management usually is reactive rather than proactive. A proactive mechanism to manage and react to risk disruptions, especially disruptive risks, becomes essential. Disruptive risks are complicated to predict and rare, having a low degree of occurrence but a high impact (Shishodia et al., 2021). Besides, disruptive risks vary in scale and magnitude; usually, their effects could be short-term or long-term (Shishodia et al., 2021). More than SC risk management as a reactive strategy is needed to respond and react to such disruptive occurrences to build resiliently sustainable SCs to attain sustainable, long-lasting development.

In addition, beyond risk management, there is a need to understand the vulnerability of SCs to develop capabilities toward a renewed better state. SC risk vulnerability is the force behind risk-disruptive occurrences (El-Baz & Ruel, 2020). In developing resilience capabilities for SCs, it is essential to consider a combinatorial approach that looks into the vulnerable and exposure points for risk disruptions, risk disruptions themselves, their management, and long-term resilience capabilities towards sustainably long-lasting development.

2.2.1.2 Conceptualizing Resilience

Resilience emanates from engineering, ecology, and psychology prints. Resilience, a multi-disciplinary concept stretching from ecology to mathematics, engineering, psychology to business, has different understandings and definitions (Holling, 1973; Erol et al., 2010). For instance, from a mathematical point of view, resilience is the capacity of a system to pull through disruption and return to its original state (Erol et al., 2010). In the works of Ledesma (2014), resilience from a leadership perspective denotes the ability of a leader to get back to stability after facing harsh conditions, obstructions, and mishaps.

Psychological resilience is the capability to recover from misfortunes and bear such adversities (Wolin & Wolin, 1993). Psychiatry literature argues that resilience is man's ability to deal with change through the help of psychosomatic and genetic strengths (Flach, 1988), which are determining factors in achieving resilience. Correspondingly, the social sciences mirror resilience as the ability to recuperate from undesirable life experiences and become stronger while overcoming them (Henderson & Milstein, 1996). In addition, scholars have given different outlays of resilience per other disciplines and key elements defining resilience from those disciplines. For instance, Ruuter (1993), Maguire & Hagan (2007), Meador & Hild (2007), Pettit et al. (2010), Folke et al. (2010), Henry & Ramirez (2012), Vitanen & Kingston (2014), Walah, (2015) and Cai et al. 2018 present aspects that underpin resilience from different disciplines. For instance, aspects such as adaptability of social systems (social resilience) and disruption in supply and demand (SC resilience).

Other aspects such as recessionary shocks (economic resilience), adaptability of the environment (environmental resilience), regaining original conditions (engineering resilience), avoiding family breakdowns (family resilience), disturbances in a system (system resilience), survival of eco-system (ecological resilience) and evolutionary responses (biological resilience) define resilience. The discussions on resilience from different disciplines show a static-based approach to resilience.

Such an approach only indicates the ability of a system to bounce back. The growth of systems goes beyond their static nature. Instead, it focuses on their continuous development, which brings forth the aspect of constant learning from the disruptions for systems to improve continuously towards stability and sustainability. In addition, the bouncing back to an original position delineates the traditional viewpoints of risk management that are reactionary. Resilience is a proactive capability beyond returning to an original state for systems facing disturbances.

In the arguments of Gunasekaran et al. (2015), traditional systems embraced the idea of risk management to deal with disturbances and disruptions. However, the risk management game plan is a challenging model for uncertainties, as it can only deal with foreseeable occurrences that disrupt a system. Therefore, resilience was born to cope with foreseeable and unforeseeable events to encompass a holistic worldwide view of risk disruptions and vulnerabilities, together with their management towards sustainable SCs and economies.

2.2.1.3 Supply Chain Resilience: Meaning and Measurement

Supply chain resilience is usually viewed from an equilibrium perspective that brings forth tensions between SC and firm resilience, unfolding critical gaps in resilience views in the past (Novak et al., 2019).

The works of Novak et al. (2019) argue that an equilibrium-based approach of just bouncing back is not viable in complex adaptive systems like SCs, which means that SC resilience needs to be viewed from a scale perspective, which Novak et al. (2019) posit to be a standard reference point of resilience. Novak et al. (2019) further contend that SC resilience involves many actors beyond the firm level, including social actors such as non-governmental organizations.

Notably, such actors pose dynamic interactions on the scale to which SC resilience should be measured. For instance, risk disruptions and their propagative effects occur at different times and magnitudes and impacts, posing a challenge in conceptualizing SC resilience. Measuring SC resilience from multiple scales alone could be misleading. In the context of Novak et al. (2019), multiple scales look into every facet of the SC with interactions with all social actors of the world ecosystem. For instance, interactions with actors such as non-governmental organizations are essential in building resilience. While this notion provides a basis for scientific arguments toward the right trajectory for building SC resilience, the notion needs more scope, relevance, and criticality in measuring complex systems such as SCs. This means that building resilience by looking into all social actors of society calls for different systems from the home economy to the firm level, SCs to economies.

Considering all these social actors, it might not be easy to achieve by looking at SCs as an end rather than a means to an end. Against this background, the arguments about not measuring SC chain resilience from a firm level (Novak et al., 2019) point out gaps in SC comprehension. SCs are defined from their critical node that opens up to their branching either upstream or downstream. In addition, traditionally and even within modern times, SC comprehension is viewed from a typical structure perspective (supplier-manufacturer/service provider/work contracting-customer) perspective.

The modern era of globalization that brings about the extensions and tiering of SCs provides a further branching on the leveling of the upstream and downstream SC. Building SC resilience is more practical from their central node in this context. This means that understanding of the SC partners can only be drawn from their central node (focal firm level). Under such discussions, it is crucial to differentiate economic resilience, firm resilience, and SC resilience. Economic resilience sits at the macro level and can be viewed from an economic perspective.

Many facets contribute to economic resilience, such as SCs and firms. On the other hand, firm resilience can be viewed from a micro perspective. This looks into the ability of an organization to respond, adapt, and recover towards an improved state after disruptions. SC resilience also could be viewed from a meso perspective as the ability of SCs from their focal firm level to respond to disruptions, enhancing stability, agility, adaptability, and a risk management culture.

Further, SC resilience is the capacity of a SC to react to unanticipated disturbances. This revolves around a SC's capability to bounce back to its original or new state after undergoing risk disruptions; and avoiding the occurrence of happenings that lead to failure (Carvalho & Cruz-Machado, 2011; Bhatia et al., 2013; Arani et al., 2016; Ruiz-Martin et al., 2018).

Table 2.1: Meaning of Supply Chain Resilience

Resilience Meaning	Authors & Year
The capacity of a system to bounce back to its original position and move forward to a new state.	Christopher and Peck (2004)
The capability of a supply chain to survive amid disruptions, adapt, and grow.	Fiksel, (2006)
The ability of supply chains to prepare for disruptions, respond, adapt, and recover.	Ponomarov and Holcomb, (2009)
The ability of supply chains to bounce back, respond, and restore operations after a disturbance.	Datta et al. (2007)
The ability of supply chains to proactively plan for unexpected adverse events, adapt, and become more robust.	Ponis and Koronis, (2012)
Ability to restore a supply chain to a robust state by planning and responding to disruptions effectively.	Kamalahmadi and Parast (2016)

To emphasize, defining SC resilience as the avoidance of happenings that lead to failure shows perspectives that view SC resilience from a static perspective. SCs do not operate in a vacuum. SCs are a part of the world's ecosystem, meaning SCs may not have control over the world's happenings but can build capabilities to achieve their resilience. Holling, the father of ecological resilience, discusses resilience as the capacity of a system to persistently absorb change and disturbances while maintaining its position to move forward to a better-improved state (Holling, 1973).

While this definition is still anchored on SCs as static systems, it brings out an essential aspect of persistence, highlighting the significance of continuous learning and development that responds to the ever-changing circumstances within the world ecosystem and through its components. Based on the above observations and those of Table 2.1, SC resilience could be viewed from its central node denoting the focal firm and its networks as;

The ability of SCs viewed from its central node to continuously and persistently respond, adapt, and build beyond their original position by picking up lessons and learning from them towards continually developing their systems with the primary goal of growing economies, societies, and communities.

Unpacking the concept of SC resilience points to the arguments of Holling (1973) that demonstrate resilience debates resting on two commonly confused terms: stability and resilience.

The works of Holling (1973) posits that the latter is founded on systems being able to pull through when faced with a disturbance and move forward to a better state, while the former concentrates on being able to bounce back to the original state. Moreover, it is worth noting that stability is a significant component of resilience but not itself. In the contention of Erol et al. (2010), resilience is characterized by robustness and reliability, where reliability keeps a system in check during disturbances to ensure systems do not fall, while robustness provides system functionality without extreme destruction. In the same vein of reasoning, Hu et al. (2015) define resilience through redundancy, absorbing capability, and recovery capability. McManus et al. (2007) also look at resilience in terms of situation awareness, management of vulnerabilities, and adaptive capacity. Van Opstal (2007) considers resilience as the ability to be risk-intelligent, flexible, and agile.

The works of Hollnagel and Woods (2006) focus on preparedness, flexibility, and capacity as significant resilience attributes. Fiksel (2006) states that resilience is essential for efficiency, cohesion, diversity, and adaptability. Christopher and Peck (2004) look at resilience in terms of the risk management culture, SC design principles, SC engineering, visibility, collaboration, and agility. Kumar et al. (2017) looked at 13 measures: adaptive capacity, technological capacity among partners, uncertainty reduction, a risk management culture, supply chain agility, supply chain visibility, market sensitiveness, SC structure, information sharing, sustainability, risk and revenue sharing and collaboration. Wagenberg (2018) looks at resilience-building factors encompassing a SC risk management culture: visibility, velocity, flexibility, agility, redundancy, robustness, adaptability, and transformability. That said, robustness, adaptability, agility, collaboration, and a risk management culture are common resilience factors across scholarly discourse and thus pose curiosity for further inquiry in building resilient SCs.

Wieland and Wallenburg (2012) argue that redundancy is a significant aspect of robustness, and flexibility is a primary component. Consistently, this study looked at resilience from the lens of adaptability, robustness, agility, collaboration, and a risk management culture as the most critical metrics defining SCRes and in agreement with prior scholars such as Juan et al. (2021). In the arguments of Swafford et al. (2006) and Juan et al. (2021), agile resilience (agility) is the SCs' ability to adapt and respond with speed to the changes within the business environment. Christopher and Lee (2004) postulate that agility is described by the speed of response, which works towards balancing the demand and supply aspects of SCs. Gligor et al. (2019) provide five building blocks of agility: speed to change direction, speed to accelerate operations, capability to anticipate, ability to empower customers, and ability to be flexible. Defining SC resilience from an agile perspective underscores the importance of flexibility and quick response capability. A robust SC is a resilient SC (Ozdemir et al., 2022).

Robust SCs can anticipate changes, prepare for the changes, and have the capabilities to adapt to the new changes. Agile and robust SCs can then build stable SCs. Alshahrani and Salam (2022) argue that to build SC resilience, there is a need to have a culture of handling risks. While this practice is considered reactionary, it is an essential mechanism in combination with other proactive mechanisms, such as agility, adaptability, and robustness, to build stable SCs. According to), for SCs to have the adaptive capability, they should be able to have contingency plans for any changes, be able to act in response to any anticipated and unanticipated occurrences, and have the capacity to recuperate by upholding sustainable operations (Singh et al., 2019). Against the backdrop, SC resilience is argued to be built on agility, adaptability, robustness, and risk handling as significant building blocks through continuous learning and development. Table 2.2 presents a brief outlay of the SC resilience measures as per the context of this study.

Table 2.2: Supply Chain Resilience Measures and their Meanings

No.	Resilience Dimension	Resilience Dimension Meaning	Authors & Year
1	Adaptability	The capability to plan for uncertain occurrences, respond to risk disruptions, and recuperate by upholding sustainable operations.	Wieland and Wallenburg, 2012; Singh et al.2019
2	Robustness	Ability to calculate and carefully select capacity and inventory space usage for managing crises to deal with demand surges and shortages of supplies.	Christopher and Peck, (2004). Wieland and Wallenberg, 2012; Stevenson et al., 2015; Singh et al., 2019; Ozdemir et al., 2022.
3	Agility	The ability to respond fast to volatile disruptions in supply and demand. It is measured through visibility and velocity, where visibility is the capacity to understand the status of a supply chain environment and assets. In contrast, velocity concentrates on the speed of flexibility on the capacity to adapt and, hence, a determinant of the resurgence speed of a supply chain from a disturbance. Flexibility is the capacity of a system to absorb the change of whichever kind with a minimum attempt to time.	Christopher & Peck,2004, Tukamuhabwa et al., 2015 Fiksel et al. 2013; Erol et al.2010; Wieland and Wallenburg, 2012; Singh et al. 2019; Gligor et al. 2019.
4	Risk Management Culture	The ability of a system to cope with foreseeable occurrences that can disturb operations.	Christopher and Peck, (2004). Erol et a. 2010; Gunasekaran et al.2015; Singh et al.2019.

2.2.1.4 The Science of Sustainability

Resilience that is not sustainable is a short-term, reward, and as such, resilient sustainability for the going concern of operations is vital in translating to resilient SD. Notably, Kates et al. (2016) postulate that to bring the concept of SD into understanding, what needs to be sustained and what needs to be developed must be clear. For that reason, Kates et al. (2016) further attest that the people, society, and economy need to be developed while sustaining the natural environment to reap economic benefits. According to Martens (2006), the fundamental tenet of SD is the endowment for the necessities of humankind without harming the natural systems, hence saving them. It is also worth noting that SD is geared towards a future with healthy humans and a healthy biosphere coupled with well-utilized resources for eradicating poverty and diseases. In agreement, Giddings et al. (2002) attest that SD as a paradigm is pegged on the human, natural, and social capital as the central views that should be sustained over time. The United Nations Report (1997) states that the sustenance period of 25 years and forever is the threshold for defining sustainability. In the same fashion, SD mirrors the state of the future generation through the preservation of today's affordability.

Giddings et al. (2002) further state that SD rests on some principles driving its agenda for a shared future that is not threatened by economic growth at the expense of social systems and the environment. As such, it is achieving sustainability as the goal through the process of SD becomes essential. In addition, to yield good results, it is imperative to dig deeper for sustainability principles, as shown in Table 2.3: inter-generational, geographical, procedural, and inter-species equity principalities.

Table 2.3 Principles of Sustainable Development

Principles of Sustainable Development	Stance
Futurity	Inter-generational equity
Social-Justice	Intra-generational equity
Trans frontier responsibility	Geographical Equity
Procedural equity	Open and fair treatment of people
Inter-species equity	Importance of Biodiversity

Source: Giddings et al., 2002

In the works of John Elkington in his 1998 book, 'Cannibals with Forks,' the principles of SD are purely pegged on its definition that touches on the pursuit to balance the triple bottom line (environmental, social, and economic). Emas (2015) expounds on the Brundtland definition of SD through the perception of needs as the vital needs of the world deprived for which the primary concern should be accorded and the constraints touching on the shape of technology and societal organization on the capability of the atmosphere to meet the needs of future generations.

Emas (2015) provides a decomposition on the SD principles; intergenerational equity is concerned with the pure safeguarding of resources for the future cohort and the substitutability of capital to encompass the unique nature of environmental resources that can never be substituted with manufactured resources. In addition, on SD principles, the polluter pays principle requires the relevant bodies to impose regulations on polluters to pay and the precautionary principle to look at threats of irreversible environmental harm. According to Marinova and Raven (2006), sustainability is the long-term continuity of man's natural, social, and financial capital activities. This definition is consistent with the Brundtland definition anchored on the capability to meet the current needs of humanity without compromising the capacity of the future human race to meet their own needs.

2.2.1.5 Conceptualizing Sustainability

In search for an operational meaning of SD, the collaboration of the environmental quality (low carbon emissions, zero waste, zero other pollutants, energy saving, and efficient resource usage), social equity (safety and health of workers and beneficiaries of products) and economic prosperity (reduction in the total cost of ownership) define sustainability. Metaxas and Psarropoulou (2021) argue that SD encompasses economic, social, environmental, and governance pillars. Okeniyi et al. (2020) present SD pillars as financial (reduction of costs), social (cultural, religious, and healthy systems), and ecological.

Moldan et al. (2011) argue that economic sustainability is purely dependent on economic growth, which captures the capacity to be as efficient as possible. In the SC space, economic growth can be argued to be founded on the total lowest cost of ownership (Ferrin & Plank, 2002) across the SC, from procurement to distribution for economic progression and resource utilization and efficiency that defines economic systems. Moldan et al. (2011) further argue that social sustainability looks into the well-being of humanity in a safe and healthy environment. Moldan et al. (2011) further posit that environmental sustainability should consider climate resilience, reducing carbon GHG emissions, and waste generation. With such discussions.

In addition, Spangenberg (2005) also argues about economic sustainability as economic progression. In this study then, sustainability capabilities have been viewed from the triple bottom line pillars of economic, ecological, and social and measured as capabilities; economic sustainability was measured through economic (total cost of ownership) and resource utilization, social (safety, health, and fairness) and ecological (reduction of carbon emissions, climate resilience and reduction of wastes).

The choice of these measures is founded on prior research such as Responsible Research and Innovation Learning-RRIL (2021), UNEP (2020), and UN (1987). Besides, with the upward surge in environmental degradation, SD comes in handy to assimilate regions to employ the best ecological and circular economy principles for resilient sustainability. Under such circumstances, Arani et al. (2016) postulate that sustainability and resilience are interrelated concepts, as a resilient system leads to attaining a sustainable system. The ever-escalating issues on the environment, economy, and society that rotate around inequalities, poverty, and concerns about a shared future of healthy individuals have forced humanity to coexist with the biosphere for economic growth (Hopwood et al., 2005). Hopwood et al. (2005) further argue that the basic existence of the human species and its well-being depends on the environment.

Notwithstanding, the Earth system is one; nonetheless, the world is not. Humanity depends on one biosphere for the sustenance of life. However, different sections of the world, such as communities, countries, and regions, strive for existence and fortune with minimal regard to their activities and detrimental environmental effects. According to Shan & Wang (2018), life is sacred, and it rests upon the relationships between humans, the physical environment, and the systems of economy. Moreover, the future is uncertain in supporting such relationships due to rising pollution records and a severe imbalance of scarce resources amounting to poverty and wealth in some areas and not others. The fragility of the Universe and its associated systems and the world at large need solutions to such eventualities. The provision of lasting and workable solutions to the instability of planet Earth calls for activities geared towards growth and progression that is developmental.

Development refers to man's activities to improve the environment, society, and economic well-being (Kates et al., 2006). Development needs to be resilient and long-lasting, giving birth to SD, first seen in the Brundtland Commission in the 1980s. Under the United Nations (1987, Pg.3) in the Brundtland report titled "our Common Future", SD is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." These needs touch society, environment and the economy.

It is important to note that the environment is a support system for man and is considered the social system of other inhabitants of planet Earth. It is the social system that supports the economic system. Upholding economic well-being at the expense of social equity and environmental quality will bring the whole sustainable system down with no economic benefit, no society, and a failed environment where species become extinct.

That is not a desirable scenario for man and other inhabitants of planet Earth. Subsequently, SD provides a powerful rationale for environmental protection that supports social systems and, in turn, economic well-being (Emas, 2015). Gallopin (2003) contends that SD is driven by production and consumption patterns. Gallopin (2003) further argues that in SD, what matters is what has to be sustained as the progression of man's conditions or the improvement of the social systems that man relates to. Sustaining production and consumption patterns to yield an eco-efficient society is paramount. For economies and societies to be resiliently sustainable, they must be able to fight back disruptions to achieve their stability. Such understanding points out the need to consider the integration of resilience and sustainability from a system perspective, which calls for an understanding of the economy.

The term economy emanates from concepts of being efficient in the use of resources, such as economic systems and economic growth, which looks at the conservation of resources efficiently in the processes of production and consumption and the supply of money to achieve growth (Kamitake, 2009; Fieldman et al., 2016).

In the context of this study, an economy is a SC system and, by extension, the state of nations, regions, and communities involved in the supply of money through trade. Building an economy translates to economic growth or economic progression of economies and communities. According to Sarkis et al. (2017), sustainability encompasses economic, social, and environmental pillars. In the arguments of Labuschagne et al. (2005), sustainable social development can be viewed from the perspective of external populations, internal human resources, stakeholder participation, and macro-performance issues. Such indicators of social sustainability bring out the perspective of being cognizant of the health, safety, and well-being of all stakeholders of society. Supply chains and business firms should consider the impact of their activities on planet Earth's stakeholders, whether those that buy from them (customers), their regulators, or the larger society. According to Friedman (1962), there is only one model to measure social sustainability. Friedman (1962) argues that businesses' sole purpose is to be profitable with fair competition and not engage in fraud or corruption.

Looking into Friedman's (1962) reasoning about the social responsibility of companies, it is clear that before the advent of intense globalization and the notion of active campaigns on the notion of sustainability, social responsibility was viewed from a profit-making perspective. Considering such thinking, it is not surprising that sustainability started gaining momentum after the discussions in the Brundtland Commission of 1987. While businesses need to be profitable, considering other facets of development beyond the economic aspect is significant. According to McGuire (1963), an essential perspective of social sustainability is seen through corporate citizenship. McGuire (1963) argues that the responsibilities of businesses are not only based on economic and legal aspects, but they have extensions to societal responsibility.

Corporations exist for society. This means that the customers of businesses are actors of society, may it be man, animals, or vegetation. In other words, companies exist to support and sustain life. In this context, it is selfish for companies only to guard their benefits from society (economic) and ignore the well-being of society and, more so, the impact of business activities on society. The claims of Carroll (1979) bring forth a more pronounced measurement of social sustainability. Carroll (1979) argues that businesses must consider society's economic, discretionary, legal, and ethical expectations.

Companies need to be as human as possible and view life as sacred, meaning that considering businesses as mechanical systems is outdated. According to Labuschagne et al. (2005), as cited in Sarkis et al. (2010), social sustainability by looking into internal human resources is significant. This is because the first line of business contact is the internal customers.

The health and safety of these internal customers is paramount for business success. Labuschagne et al. (2005) look at social sustainability indicators from a health, safety, capacity development, diversity, discrimination, and equity perspective of internal human resources. The works of Labuschagne et al. (2005) further contend that social sustainability includes external populations (human capital, productive capital, and community capital), stakeholder participation (information provision), and macro social issues (stakeholder influence and social-economic-environmental performance).

This study viewed social sustainability from the perspective of fairness (no discrimination), the safety of employees and customers, and the health of employees and customers as part of manufacturing businesses' mandate to take care of society. Environmental sustainability looks into meeting human needs without affecting the planet's health (Morelli, 2011). Morelli (2011) further contends that environmental sustainability encompasses keeping the Earth safe, such as reducing emissions, reducing waste, enhancing climate resilience, and embracing the culture of recycling and reuse. In the contentions of Morelli (2011), economic sustainability is all about allocating resources so that future generations can access such resources.

This means that economic sustainability can be measured through resource utilization or efficiency. It is a world of scarce resources and, more importantly, one planet for humanity and other inhabitants for the continuity of life, and such calls for efficiency in resource use. Morelli (2011) also argues that achieving economic sustainability requires minimizing social costs. Unpacking the social costs could mirror all expenses that support activities in a given societal system. For instance, minimizing ownership costs becomes essential for achieving economic sustainability within SCs.

2.2.1.6 Integrated Resilient Sustainability Frameworks and Dimensions

On integrated resilient sustainability frameworks, the works of Marchese et al. (2018) present a review of 37 documents on integrating resilience and sustainability. According to Marchese et al. (2018), the convergence of resilience and sustainability rests on three fundamental philosophies:

¹Resilience is a component of sustainability

²Sustainability is a component of resilience

³Resilience and sustainability are two distinct concepts

The works of Marchese et al. (2018) on resilience as a significant component of sustainability states that, for a system to be sustainable, it has to be resilient. The absence of resilience only provides fragile sustainability of systems (Ahern, 2013). This argument brings forth a significant assumption in the definition of SD first seen in the Brundtland report of 1987.

Considering such a definition, it is clear that sustainability has been viewed from an equilibrium perspective without considering disruptions. The world economy is massively disruptive, which calls for building resilience to achieve long-lasting sustainable development. Anderies et al. (2013) posit that resilience provides a platform to achieve sustainability and, as such, a precursor to achieving sustainability. Looking into the arguments based on sustainability as a significant component of resilience, Ahi and Searcy (2013; Closs et al., 2011) argue that for a system to be resilient, it has to be sustainable. This means that a sustainable system is resilient, but a resilient system is not necessarily sustainable. This conceptual definition unfolds that the critical objective of resilience is to achieve some level of maintenance. However, achieving some level of maintenance calls for status quo achievements that seek to reach equilibrium.

In this age of interconnectedness and multi-leveling of supply chains, coupled with a scramble to who becomes a superpower in the world economy, it takes much work to attain equilibrium over time. This means that systems are continuously disrupted, contributing to their evolution. Such evolving then departs from symmetrical equilibrium positions of systems. In addition, the end goal of sustainable development, as derived from the Brundtland Commission report of 1987, is to achieve long-lasting growth. Development that seeks to satisfy the needs of future generations. Growth that is beneficial to the current and future generations. Considering such a definition, it becomes difficult to perceive and conceptualize sustainability as a significant aspect or pre-condition to achieving resilience.

Against the backdrop, the notion of also viewing resilience and sustainability as separate and distinct concepts has reached its end of life. The coining of SD frameworks in 1987 and the periods after did not factor in the possibility of disruptions affecting systems. More importantly, the definition should have included climate-related risk disruptions that can propagate across different facets of society. This means that, as much as resilience and sustainability emerged from other disciplines, the convergence of their practicality is more urgent than ever. The proponents of this philosophy (Ning et al., 2013; Meacham, 2016) argue that resilience does not contribute to sustainability, and sustainability does not contribute to resilience.

This framework originates in civil infrastructure, which relies heavily on systems' structural capabilities. Bringing this notion to supply chains does not hold since commonalities are usually experienced in building resilience and sustainability. Marchese et al. (2018) posit that the convergence of resilience and sustainability is achieved through such commonalities.

In definitive measure then, this study agrees with the proponents of the first framework that resilience is a significant aspect of sustainability or a precursor to achieving sustainability. From the discussions on the integrated resilient sustainability frameworks, it is evident that most scholars propose a combination of their indicators. However, minimal studies are seen in this context. For instance, the works of Chari et al. (2020) argue that past scholarly research has a bias toward static capabilities. However, dynamic capabilities become essential with the changing times and disruptive occurrences affecting SCs. Chari et al. (2020) looked into dynamic capabilities, touching on integrating resilience, circular economy business models, and sustainable competitive advantage. In this research, how sustainability was embedded to achieve a sustainable competitive advantage is unclear. Besides, this study did not have a bias on the convergence of sustainability and resilience. Souza et al. (2017) argue that dynamic capabilities can transition resilient and sustainable systems. This is supported by Su et al. (2014), who posit that resilience is an efficient eco-capability in addressing environmental management demands.

That said, resilience and sustainability, which have been argued to be distinct concepts, present possible avenues for their convergence toward resilient, sustainable SCs. From a resilience capability perspective, Chari et al. (2022) looked into several resilience competencies from prior scholars, such as agility, flexibility, efficiency, alertness, change management, and robustness.

According to Chari et al. (2022), such resilience capabilities were mined from a myriad of authors such as (Pettit et al., 2010; Ates & Bititci, 2011; de Sousa Jabbouret al.,2019; Prosman & Wæhrens, 2019; Ünal & Shao, 2019; Shin & Park,2020; Diaz-Chao et al.,2021; Fabbe-Costes & Ziad, 2021; Shayganmehr et al., 2021) and validated through interviews and surveys from experts.

In this context, it is evident that prior scholarly discourse is biased toward the distinct path of resilience and sustainability with no evidence of their convergence from a dimension perspective, even though many scholars propose their convergence. Looking into these nascent circumstances on the combination of resilience and sustainability in the extant literature, this present study defines a resilient, sustainable economy as systems, may they be organizations, SCs, or economies at large, that can have a balance or an acceptable trade-off among the pillars of the bottom line. Moreover, systems that can respond, adapt, mitigate, and build capabilities that make them absorb shocks, adapt, recover, and build back better.

Per se, a resilient, sustainable economy calls for a convergence of resilience and sustainability of firms and SCs. It has an intelligent transition from the triple bottom line to the quadruple bottom line through adaptability, agility, robustness, risk management culture, and economic, environmental, and social sustainability.

2.2.1.7 Supply Chain Management

SCM has its roots in the works of Oliver and Webber, who coined the word during an interview in the Financial Times in 1982. SCM was first documented in the literature in the mid-1980s (Cooper et al., 1997). Nevertheless, SCM rests on its fundamental tenets that were born earlier than the 1950s in channel management research (Gonzalez & Souza, 2010). The assertions of Habib (2014) confirm that SCM was in practice before the 1950s as a logistics concept, which developed into a matured logistics concept between 1970 and 1980. In the advent of 1980, the concept of SCM developed from a logistics concept to SCM, which advanced to SCM in manufacturing in the 1990s and progressed to service SCM in the 2000s (Habib). After that, several improvements came up. For instance, SC improvements constituting value-based SCs, such as the lean, agile, resilient, and green philosophical SC frameworks of the present times, coupled with the green closed-loop supply chain pegged on the circular economy. Hence, it is imperative to realize that competition has moved from individual firms to SCs. Thus, upscaling SCs is necessary to build social equity, environmental quality, and economic prosperity and, in turn, realize resilient sustainability in its fullness.

In the global competitive landscape, enterprises recognize that SCM is a primary contributor to sustainable operations and to gaining a competitive edge. According to Chin et al. (2015), SC is a network of all the parties (supplier, manufacturer, and distributor) involved in translating the voice of the customer into production requirements and transferring the products and services as a result of the operation processes to the ultimate customer. Correspondingly, a SC depicts a group of enterprises connected by the flows of products, processes, services, information, and resources from the source of raw materials to the consumption of the final product.

In addition, Muysinaliyev and Aktamov (2014) and Tanco et al. (2015) state that an SC is a systematic production cycle with inherent procedures whereby materials are sourced from suppliers and converted to final products for customers with the main aim of meeting the need of customers. In essence, then, SCM involves the act of production and distribution of a final product to the ultimate customer. In the pursuit of understanding the concept of SCM, scholarly literature provides an array of definitions of the supply chain concept.

Supply chain activities refer to the undertakings from sourcing raw materials to distributing the product or offering the service to the customer at the right quality, delivery time, cost, and quantity (Mitra & Dattla, 2013). SCs and SC activities play a tighter role in ensuring products reach the customer.

For that to happen, management of the complex networks is critical in giving rise to the management of SCs with no definite accepted model. Given the ever-increasing surge in the uncertainty and confusion of the understanding of SCM, the Council of Supply Chain Management Profession (CSCMP) contends that SCM involves the process flow of raw materials through conversion to produce an ultimate product through coordination with SC partners (Stock & Boyer, 2009). Also, Lummus and Vokurka (1999) postulate that SCM encompasses all activities involved to ensure a customer gets the product, including the information technology, resources, and people employed to harmonize all these activities.

The different explanations of the concept of SCM pose a conceptual confusion that leaves many scholars and industry practitioners muddled. This is primarily a misunderstanding on which path of SC understanding school of thought to uphold. To that effect, to unlock SC understanding confusion, Stock and Boyer (2009, pg.18), under a review of 173 journal articles, present SCM as; “The management of a network of relationships within a firm and between interdependent organizations and business units.

These business units consist of “material suppliers, purchasing, production facilities, logistics, marketing, and related systems that facilitate the forward and reverse flow of materials, services, finances, and information from the original producer to the final customer with the benefits of adding value, maximizing profitability through efficiencies, and achieving customer satisfaction” (Stock & Boyer, 2009, pg.18).

According to Chin et al. (2015), SCM encompasses the administration of a firm’s activities to ensure the enterprise gets the right goods and services in time, with quality, quantities, and satisfactory cost. Muysinaliyev and Aktamov (2014) and Tanco et al. (2015) contend that SCM involves the designing, examining, and coordinating activities required to ensure a raw material becomes a product for consumption by the ultimate customer. With the complex and evolving nature of SCM, and with the different arrays of its definition, this study provides an all-inclusive definition of SCM pegged on its fundamental tenets, its historical and conceptual development as: “The administration of the different parties (Supplier-Manufacturer-Distributor-Customer) involved with the flow of materials, information, resources, and related SC activities from the cradle stage of raw material all through to the grave stage of a final product whereby the cradle signifies the birth process (supplier) and grave signifies the death process (customer) including the aspect of post-consumer processes (to include the reverse flow); which is achieved through coordination of SC players.”

The assertions of Mena et al. (2013) confirm that the structure of a SC in terms of its complexity and length is worth considering due to its impact on a resilient circular economy in the face of sustainability for enterprises and economies.

Mena et al. (2013) further ascertain that the present emphasis is on multi-tier relationships due to globalization and technological advancements and the risks that come with such complexities that connect the world in an SC ring. To build competitive SCs, looking at their structural issues to yield the highest performance is essential. Because of that, today’s focus is not just on SCs but value-based SCs that can rotate the world to achieve resilient sustainability. As manufacturers, suppliers, wholesalers, and retailers across the globe scramble to meet the needs of the customers, it is within these companies to master the art of the game in improving the management of their supply chains to get a larger share of the cake.

Notwithstanding, the contention of Muysinaliyev and Akitamov (2014) further states that value-based SCs are desirable business internetwork connections in the management of challenges of demand and supply to prosper in the present climate of competition across SCs, organizations, and economies and for business continuity at large.

The works of Mbuthia and Rotich (2014) postulate that effective SCs have become a valuable tool for enhancing competitive advantage and that the sole aim of SCs is to enable collaborations on material and information flow as a weapon for competition. Presently, most value-based SCs rest on the LARG (lean, agile, resilient, and green) philosophical framework. For instance, Cabral et al. (2012) posit that LARG is the foundation of competitive SCs that enhance organizational performance.

As a result, improved organizational performance leads to business continuity and, thus, circularity in the arms of sustainability-based resilience. Cabral et al. (2012) further argue about the LARG framework on the foundations of its constituent tenets: lean, agile, resilient, and green. The lean framework rests on the principles of cost and waste minimization. According to Govindan et al. (2015), the lean concept emanates from the works of Ohno (1988) at Toyota Motor in Japan, which forms the basis of the Toyota Production System. The Toyota Production System rests upon the foundations of just-in-time production and autonomy.

According to Stock and Boyer (2009), lean practices fail to incorporate ecological concerns into their implementation. For example, environmental risks are not incorporated in the minimization of wastes targeted by the lean philosophy. According to Van Hoek et al. (2001), agility has its roots in flexibility. Agility has been linked to manufacturing only, thus ignoring the other side of the SC and, therefore, not a holistic idea of SCM developments. It does not look at environmental issues concerning flexibility in response to demand. Resilience is deep-rooted in the concepts of agility to enhance flexibility and adaptability for sustainability enhancement (Christopher & Peck, 2004). Christopher and Peck further contend that resilience entails returning to an original state in case of disruptions and vulnerabilities.

In addition, the green philosophy incorporates achieving utmost performance to enhance the continuity of business operations. This is through reducing environmental risks to yield ecological efficiency and their effects while maintaining the organization's social performance and economic well-being. Looking deeper into building resilient, sustainable economies beyond the LARG framework is essential to provide a broader spectrum of SCRes and SCSus.

2.2.1.8 Green Closed-Loop Supply Chain Management

Globally, the heavy burden of environmental degradation is deeply felt across different economic stakeholders, coupled with social and economic challenges. As such, Kumar and Chandrakar (2012) argue that the SC fabric needs to be greened.

This is to cleanse the base of the natural environment and scale the heights of resilient circular-based sustainability. GCLSCM has its foundations in studies that capture reverse logistics, GSCM, closed-loop SCs, sustainable SCs, and the general area of industrial ecology. Hassangaviar et al. (2022) provide evidence on the investigation of the design of a GCLSCM. Hassangaviar et al. (2022) start off with the understanding of open-loop SCs, which entail scenarios in which materials are recovered by components other than the major manufacturers (Hassangaviar et al., 2022).

Moreover, the works of Hassangaviar et al. (2022) stress that the major manufacturers of these materials must have the capacity to reuse the products or materials. Abbasi et al. (2023) argue that a GCLSCM is the integration of environmental and economic principles into the supply chain. The thinking of Abbasi et al. (2023) extends the comprehension of GSCM as coined by Sarkis (2006) to incorporate economic aspects besides environmental aspects to SCs. According to Sarkis (2006), GSCM is the incorporation of environmentally conscious reasoning into SCs. The arguments of Huang et al. (2019) contend that GCLSCM is a combination of green and closed-loop SCM practices. In addition, the works of Govindan et al. (2015) stress that a closed-loop SC is a combination of the forward and reverse SC.

A closed-loop SC Extends from the forward SC to the reverse SC, including reverse logistics (remanufacturing, recycling, reuse, repair, and renovation) (Hassangaviar et al., 2022). Hassangaviar et al. (2022) also argue that in understanding the concept of a closed-loop SC, it is important to understand what does not include the closed-loop SC, something Hassangaviar et al. (2022) refer to as a ring SC. A ring SC entails reusing materials or products from the downstream SC by returning them to the original producer to extract value from those products by reusing parts of the product or the entire product. Against the backdrop, Hassangaviar et al. (2022) further argue that to differentiate between the open-loop and closed-loop SC, it is vital to assess the manufacturer's ownership of the materials.

Here, Hassangaviar et al. (2022) argue that for open-loop SC, value addition for different materials is from different manufacturers, while closed-loop SC focuses on specific manufacturers. Under the circumstances, combining both GSCM and closed-loop SCM to have GCLSCM proves a significant approach for reviving the natural resource base that supports the planet's systems (Guide & Wassehove, 2009; Abdallah et al., 2012; Ahuti, 2015). In addition, looking into the specific aspects of GSCM and closed-loop SCM, their interrelationships bring forth an economic model that attempts to move away from the linear model of take-make disposal to a more circular system that encourages zero waste.

This is through the 4R strategy of reduce, reuse, recycle, and remanufacture through closing the loop of SCs (Lahti et al., 2018; Otero et al., 2018) referred to as the circular economy. The circular economy model looks into creating value at waste generation and resource use for the environment's well-being.

As such, Abu Seman et al. (2012) attest that GSCs and their management started when the concept of quality was revolutionized in the 1980s and the revolution of SCM phenomena in the 1990s. According to Kumar and Shekhar (2015), GSCM involves incorporating ecological thinking into SCM, from sourcing raw materials to getting the product to the customer and up to the point of product returns for serviceability. In the same vein of reason, a closed-loop SC encompasses the phases of forward and reverse SCs to manage waste disposal for the well-being of the environment, society, and the economy (Talbot et al., 2007; Kumar & Kumar, 2013). In light of the words of Mutingi (2013), GSC initiatives are fundamental to achieving resilient sustainability. In agreement with the contentions of Mutingi (2013; Ahuti, 2015), GSCM aims to restore the degraded environment. In addition, the focus is on managing pollution at the cradle stage rather than the management after pollution (Ying & Li-Jun, 2012).

Also, Kumar and Chandrakar (2012) posit that GSCM incorporates finding a mix between the SC journey of a final item and the ecological issues about the effects of such supply chain activities. Kumar and Chandrakar postulate that GSCM aims to develop methodologies to minimize waste and improve SC inefficiencies. Such reasoning underpins the fundamentals of the circular economy. According to Abdallah et al. (2012), GSCM should be geared towards minimizing location, transportation, and carbon emission costs due to incorporating environmental principles into the SC. Assessing extant literature discussions on green, closed-loop SCM, and circular economy, it is clear that green supply chain management rests on environmental incorporation into SCs to attain environmental performance. Closed-loop SCM has also been argued to incorporate environmental and economic integration into SCM to realize economic and environmental performance.

Other scholars have argued that closed-loop SCM extends to reverse logistics, defining an SC that combines both the forward and the reverse SC. The MacArthur Foundation (2020) reported that the Circular economy focuses on designing out waste. In addition, the circular economic model is founded on keeping materials in the loop for longer and regenerating natural systems. These principles interact with those of GSCM and closed-loop SCM. All these debates point to the integrated green and closed-loop SCM model based on the circular economic model.

In particular, while studies looking into the broader field of sustainable SCM argue that the concept means the integration of environmental, social, and economic principles into SCM, it is right to argue that GSCM, GCLSCM, and circular economy can be argued to form sustainable SCM. However, such arguments need to consider the extent of the incorporation of social aspects to such models, if any. For those reasons, this study agrees with the arguments of Huang et al. (2019) that GCLSCM is a combination of green and closed-loop SCM with extensions on other methodologies, such as circular economy and incorporating some social considerations. Given the analysis of the concept of green closed-loop supply chains pegged on different authors' understanding of the concept, this study will look at the concept of GCLSCM and their management as the incorporation of ecological, lean, social, and economic reasoning into every stage of the SC including reverse logistics and coupled with the assessment of the impacts of SC activities on the natural environment, society, and economy for sustainability. GCLSCM encompasses all stages, from design for the environment, green procurement, cleaner production, and green logistics to reverse logistics with internal environmental management as a contingent element.

Section 2.4.3 provides an in-depth discussion of these practices. Liu (2019) brings forth an exciting discussion on the role of top management in adopting GSCM. Liu argues that it is important to assess the particular characteristics of top management in support of GSCM, such as environmental and social responsibility awareness. Abu Seman et al. (2012) put forth green supplier practice, green innovation, compliance with existing green regulations, internal environmental management, customer ecological cooperation, and reverse logistics as the GCSM practices that must be used to attain top-notch organizational performance leading to sustainability. Geng et al. (2017) argue that GCLSCM entails intra-organizational environment management, reverse logistics, green supplier integration, and customer cooperation. On the contrary, Tippayawong and Supaidang (2015) argue that the practices should focus on manufacturing technology and present green manufacturing, green procurement and logistics as the central practices to support green production technology.

Accordingly, Masoumik et al. (2014) state that GCLSCM ranges from eco-product design to upstream SC greening, green production, downstream SC greening, and greening post-use. The works of Srivastava (2007) emphasize green design, green operations, and reverse logistics. Further, Sarkar (2012; and Rahim et al., 2016) contend that the importance of these practices cannot be left unrecognized, and thus, SCs need to include green purchasing and inbound logistics, green distribution and outbound logistics, green marketing, and reverse logistics.

Given the analysis of the different assortments on GCLSCM, this present study looks at GCLSCM to encompass eco-design (design for the environment), green procurement, green manufacturing, green logistics (green warehousing, green distribution, eco-labeling,) reverse logistics and green supply chain collaboration as the significant building enablers for the achievement of a resilient, sustainable economy. Table 2.4 provides a detailed analysis of the in-depth understanding of GCLSCM from different authors' perspectives.

Table 2.4: Meaning and Measurement of Green Closed-Loop Supply Chains

GCLSCM	Meaning	Author
Design for the Environment/Green Design	Incorporation of environmental standards in the choice of unique attributes for product design.	Saeed et al. (2018) Cankaya and Sezen (2019) Michelli et al. (2020)
Green Procurement	Obtaining raw materials has a less harmful effect on the environment.	Govindan et al. (2014) Cankaya and Sezen (2019) Michelli et al. (2020) Huma and Siddiqui (2022)
Cleaner Production/green manufacturing	Conversion of raw materials to final items with the use of processes and technologies geared toward safeguarding the environment, including the Japanese 5S methodology (Shine, Sort, Set in order, Standardize, Sustain) and total productive maintenance.	Chin et al. (2015) Mohamed et al. (2018) Jaca et al. (2015) Chen et al. (2019)
Green Logistics	The management of the movement of goods, resources, people, and information in a manner that meets environmental principles for safeguarding the same.	Saeed et al. (2017) Cankaya and Sezen (2019) Michelli et al. (2020)

Green Packaging	Green packaging is the use of materials that are friendly for the environment for packaging.	Chin et al. (2015) Cankaya and Sezen (2019)
Eco-Labeling	Labeling of products in an ecological standard.	Chin et al. (2015) Cankaya and Sezen (2019)
Reverse Logistics	Getting product returns by incorporating environmental principles to touch on reusability, reducibility, remanufacturing, and recycling.	Souza (2013) Govindan (2014;2015)
Internal Environmental management	Customer and Supplier collaboration on green training for the use of products and the production of raw materials for safeguarding the environment, including top management support, transparency, and professionalism	Beamon (2005) Angus-Leppan& Metcalf (2010) Mafini & Loury-Okoumba (2018) Huma and Siddiqui (2022)

Source; author (2024)

The study further provides comprehensive debates on individual GCLSCM practices. Design for the environment seeks to choose attributes that go to a product to minimize environmental impacts throughout the product life cycle (Clark et al., 2009). Clark et al. (2009) further indicate that design for the environment should capture materials and products of longer life spans, the easy disassembly of parts, materials, and products that can be recycled, and a higher form of material sourcing for ecological safety. Kumar and Chandrakar (2012) mirror design for the environment as improvements to products in its various product design stages (new product design and redesigning) for environmental safety.

Green procurement determines an overall GSCM encompassing both green sourcing and purchasing. Dubey et al. (2014) argue that green procurement entails an environmentally conscious selection of materials, increased resource efficiency, and an integration of green sourcing. Appoloni et al. (2014) classify green procurement into three significant components: product standards, behavior standards, and collaboration. Product standards are defined within the confines of purchasing ecologically conscious materials (that can be recycled and have less toxic ingredients), and behavior standards touch on the supplier's behavior for disclosure of

ecological practices coupled with pollution discharges. Green et al. (1998) argue that green procurement entails supplier audits, ISO standards, and collaboration. Similarly, yang and Zhang (2012) posit that green procurement encompasses a green product, reverse logistics, social responsibility, and eco-design.

Equally, Cheng et al. (2018) state that green procurement aims to minimize product environmental aspects by employing ecologically friendly procurement technologies. These products lead to resource conservation (less energy and water use) and material efficiency. Moreover, Islam et al. (2017) contend that green procurement is the practice that focuses on the selection of materials with the ability to be recycled and reused, materials that are safe for the users, materials that do not compromise on labor rights of the workforce, an initiative for the reduction of carbon emissions during the flow of materials from suppliers to facilities and the will of suppliers to commit to waste minimization objectives and other environmental initiatives within their operations. Green manufacturing or cleaner production is the focal point of a greener SC.

Green manufacturing seeks to apply production strategies to minimize the ecological impacts of such products and the processes used (Mafini & Loury-Okoumba, 2018). A green manufacturing system should properly recycle waste within production, properly dispose of hazardous waste, provide safety and protection for the labor force, and provide a conducive working environment for employees (Mafini & LouryOkoumba, 2018). Rehman and Shrivastava (2013) proposed a conceptual frame that mirrors green manufacturing under an eight-lens strategy for ecological well-being. This denotes Product innovation, use of resources efficiently, energy saving and usage of renewable energy, efficient use of raw materials, employing the 4R strategy (recycling, reuse, reducing, and remanufacturing), closed-loop manufacturing, inventory reduction, and substitution of raw materials. Also, cleaner production is characterized by the Japanese 5S methodology that looks into a spotless working environment and total productive maintenance that considers autonomous machine maintenance for sustainability (Jaca et al., 2015; Chen et al., 2019).

Green logistics seeks to deliver goods straight to the user without unnecessary stoppages, encourage vehicles that use less harmful fuels, group orders for the total efficiency of vehicles and other transportation modes, and plan vehicle routes for efficient delivery (Chin et al., 2015). Green logistics promotes using temperature-controlled technologies for efficient management and transportation of cold chain products for their well-being. Chin et al. (2015) argue that green distribution encompasses green packaging that seeks to downsize packaging,

encourage recycling and reusing, encourage the use of green packaging materials, reduce the unpacking time for the user, cooperate with suppliers for standardized packaging that is environmentally friendly, material usage minimization and the use of recyclable pallet systems. Green distribution encompasses eco-labeling. Green warehousing is an environmental initiative for the supply chain to reuse older facilities, use space efficiently to increase its utilization rate, save energy and promote green buildings.

This is through material selection and minimization, and improve indoor air quality (Chin et al., 2015). In addition, green warehousing needs to encourage safety in material handling. Accordingly, reverse logistics is founded on product investment recovery using the 4R strategy: reduce, reuse, recycle, and remanufacture (Kumar & Chandrakar, 2012; Chin et al., 2015). Furthermore, reverse logistics can be experienced in the entire journey of a reverse SC. For instance, under eco-design, to design products that allow for recycling, procure materials that will enable the 4R strategy, manufacturing processes and equipment that promote the 4R strategy, and finally, distribution in a manner that encourages the use of the 4R approach.

Environmental supply chain collaboration seeks to train the customer and the supplier about reducing environmental impacts through choices of raw materials and proper disposal of the used products. Against this background, this study looked at green closed-loop supply chains based on a circular economy from a green procurement-based design for the environment, cleaner production, green logistics, and reverse logistics perspective as the main components that inform GCLSCM. The works of Mafini and Loury- Okoumba (2018) look at GSCs, including green purchasing, collaboration, product recovery, reverse logistics, and eco-design. This does not touch on closing the loop, as it misses reverse logistics.

Equally, Mohamad and Kuilpillai (2018) postulate that a green supply chain includes green purchasing, eco-design, and reverse logistics, which do not mirror a complete closed-loop supply chain. Under such circumstances on the various practices defining GCLSCM, this study will look into SC stages from the supplier to the point of product recovery to encompass eco-design, green procurement, green manufacturing/cleaner production, green logistics (green warehousing, green packaging, eco-labeling), reverse logistics and green customer and supplier collaboration. Also, 5S Methodology (Shine, set in order, standardize, sort, and sustain) and total productive maintenance are vital for attaining resilient sustainability (Beamon, 2005; Jaca et al., 2015; Angus-Leppan & Metcalf, 2010; Chen et al., 2019). The 5S methodology seeks to achieve continuous improvement for the stability of the job floor. Total productive maintenance is a lean management methodology looking into autonomous

maintenance for machine stability and sustainability. Against this background, in assessing the impact of GCLSCM on the resilience and sustainability of SCs, it is imperative to be cognizant of moderating variables such as internal environmental management.

2.2.1.9 Internal Environmental Management

Internal environmental management refers to practices that emanate from the internal supply chain that advocate for the uptake of green supply chains. In the arguments of Burki et al. (2019), cooperation with customers is an excellent internal environmental management practice as it assists in developing robust, sustainable systems. Burki et al. argue that customer cooperation entails the willingness of supply chain customers to work towards the sustainability of the supply chain. In addition, Su et al. (2020) argue that environmental leadership catalyzes adopting and practicing green supply chains such as innovations. Environmental leadership entails top management support for the uptake and practice of green supply chains. Top management and cooperation among supply chain partners are vital for implementing green supply chains to achieve resilient sustainability. Also, Ardakani et al. (2022) argue that supply chain collaboration with internal and external stakeholders is pertinent and motivating towards adopting and practicing green supply chains. Against the backdrop, it is notable that few studies are looking into internal environmental management from a moderator perspective, which points out a gap in this study.

2.2.2 Previous Studies

2.2.2.1 Adoption Levels of Resilient Sustainability Dimensions

Integrating resilience and sustainability in short-food SCs is important (Michel-Villarreal, 2022); resilience is classified into five themes (flexibility, redundancy, collaboration, visibility, and agility) and their adoption levels across three cases. All the resilience dimensions had higher adoption levels, with the exception of agility, which showed adoption in only one case. The findings of Michel-Villarreal (2022) reveal that all sustainability dimensions were well adopted across the three cases. The study by Michael-Villarreal (2022) failed to capture other resilience dimensions, such as adaptability, robustness, and a risk management culture, which are essential in building holistic system resilience. The study of Michel-Villarreal (2022) shows that agility would have been the least adopted resilience dimension because flexibility, a significant aspect of agility, had already been adopted. This means that the understanding and awareness of these dimensions would have contributed to these findings, necessitating the need to include flexibility and redundancy under agility.

The study of Cherrafi et al. (2022) agrees that building resilient and sustainable SCs is significant, especially after the COVID-19 pandemic. The study of Cherrafi et al. (2022) looked into digital technologies and circular economy as vital for building resilience (planning, response, and recovery dimensions) and sustainability of SCs. The results of Cherrafi et al. (2022) reveal that Planning to detect risks, tracking to enhance visibility, and collaboration with suppliers are among the adopted resilience dimensions. The study, however, fails to recognize the strength of being adaptive beyond planning to detect risks, being agile and robust, and inculcating a culture of risk management.

The study of Cherrafi et al. (2022) still shows that social sustainability was the most adopted sustainability dimension in terms of the health and well-being of employees. The study reveals that companies adopted employees' health and well-being by developing hygiene programs and providing employees with personal protective equipment. Moreover, Cherrafi et al. (2022) argue that companies adopted stability as a resilience dimension by creating a response team that was always on standby to make quick decisions toward stabilizing their SCs. Silva et al. (2022) agree somewhat with the findings of Cherrafi et al. (2022) regarding companies having differing adoption levels for both resilience and sustainability. The findings of Silva et al. (2022) reveal that 10/12 companies adopted both resilience and sustainability dimensions, while 4/12 companies built SCRes without considering all the sustainability capabilities. For instance, two companies considered social sustainability alone in building SCRes, and two of the companies considered institutional sustainability alone in building SCRes. Further, two companies were not able to build SCRes at all. This could be explained by their lack of considering holistic SCSus dimensions.

In essence, the study of Silva et al. (2022) advocates for the holistic uptake of both resilience and sustainability of SCs for improving performance, more so during overstretched disruptions like COVID-19. According to Jessin et al. (2022), most SCs pretend to be doing well during minor disruptions but get surprised when they get overwhelmed with overstretched events like COVID-19. This argument brings forth an essential aspect of pseudo-resilience, which should rest on the authenticity of SCs in sustaining their resilience. The study of Jessin et al. (2022) reveals that higher levels of inventory and outsourcing are the most adopted adaptive resilience dimensions classified under pseudo-resilience. In their study, higher inventory levels and outsourcing are argued to help boost the companies' confidence and increase flexibility. According to Achour et al. (2014), significant decision-makers' lack of motivation, awareness, and resources has delayed the integration of resilience and sustainability.

Besides, Achour et al. further argue that the available datasets and information globally can be utilized for the seamless integration of resilience and sustainability. It is then noticed that the connection between the concepts of resilience and sustainability struggle is the most demanding issue confronting modern academicians, industry practitioners, and researchers. As such, the resilient sustainability framework based on GCLSCs is presented in this section. Notably, extant literature lacks an established framework for such a convergent framework towards theory development. For instance, Mari et al. (2014) proposed a resilient sustainability framework through an optimization model of multi-objective goal programming looking only at carbon emissions and the carbon footprint together with location-based risks. On the same note, Tabibian and Muvahed (2016), on a lane toward resilient and sustainable city, looked at a resilient city from the lens of social, economic, environmental, and institutional grounds and a sustainable city from the mirror of social, economic, and environmental, physical and urban governance. Tabibian and Muhaved's work is not the achievement of an integrated framework for resilient sustainability as is evidenced by the individual frameworks.

Such findings unfold gaps in developing an integrated framework for resilience and sustainability. Accordingly, Jabbarzaeh and Sabouh (2018) considered a hybrid methodology in enjoining resilience to sustainability through a mathematical program. However, they did not show process steps and had a bias toward supplier selection risk disruptions. Also, Mohammed et al. (2018) developed a resilient sustainability framework considering only supplier selection; hence, the framework is limited to the tenets of SCM and thus inefficient.

The works of Macdonald et al. (2018) develop a framework based on risk disruptions, supply chain ecosystems, and resilience-based investments. The framework is based on the development of supply chain resilience and, as such, has no sustainability connotation. Such discussions have argued resilience under different frameworks for its enjoinment and as distinct concepts. However, this study aligns with frameworks that debate the enjoinment of resilience to sustainability. According to Marchese et al. (2018), resilience is a significant pre-condition for sustainability.

This means that when a system is more resilient, it becomes more sustainable. However, increasing the sustainability of a system does not make it more resilient (Marchese et al., 2018). According to Ahern (2013), comprehending cities as dynamic and inherently fragile changes the understanding of sustainability. As such, sustainability as a concept is confronted to develop the resilience of cities. Looking into the understanding of sustainability, Ahern (2013) asserts that such comprehension denies systems such as cities the capability to be adaptive to the changes that come.

Ahern further documents disturbances that affect urban sustainability, such as disease outbreaks, climate change, and political revolution, highlighting that the sustainability of cities needs to integrate resilience to deal with the dynamism that comes with these systems. Blackmore and Plant (2008) contend that the resilience of a system can massively impact its sustainability. This means all systems are inherently vulnerable to shocks and exposures propagated by risk disruptions. Then, to build long-lasting sustainability, resilience integration into systems becomes essential and urgent. Milman and Short (2008) present a resilient sustainability framework by incorporating resilience indicators into sustainability indicators.

Looking into prior literature, much of the resilience and sustainability interconnections are founded on adding resilience indicators to sustainability indicators. Critically analyzing the presented discussions on extant literature, it is evident that minimal studies combine resilience and sustainability from a dimension perspective in the discipline of SCM. However, the few studies available offer a foundation to kick-start conversations investigating the possible benefits of combining resilience and sustainability. The studies in the literature still show critical gaps in the nature and type of dimension considered.

For instance, most studies fail to capture adaptive resilience, robust resilience, and a risk management culture as major resilience dimensions. A few studies look at agile resilience, highlighting gaps in the literature on the significance of responding quickly to attack a disruption. From a sustainability perspective, all the available studies approach sustainability from the triple bottom line, with a few that are not holistic. For instance, while the works of Cheraffi et al. (2022) show the adoption levels of resilience and sustainability dimensions, a more prominent dimension in their study is social sustainability, but only from an employee perspective. It is essential that social sustainability also considers the customers, who are equally essential stakeholders for businesses. Such studies also view economic sustainability from a profit perspective and environmental sustainability from reducing carbon emissions only. While such considerations are essential in building resilient and sustainable SCs, it would be necessary to investigate a wider pool of resilience and sustainability adoption levels.

2.2.2.2 Adoption Levels of Green and Closed-Loop Supply Chain Management Practices

According to Mitra and Datta (2014), the adoption levels of GSCM are still deficient. This is explained by the fact that the concept of GSCM is still young in India. The works of Balasubramanian and Shukla (2017) posit that green design, green transportation, green purchasing, and end-of-life management are the least adopted practices among different stakeholders in the construction industry, including developers, suppliers, and consultants. Moreover, the low uptake in Indian firms can also be explained by a lack of understanding and awareness of the GSCM concept. In agreement, Govindan et al. (2015) argue that while GSCM is essential for Indian firms, it is yet to be accepted by firms within the mining industry. The works of Govindan et al. (2015) agree with the study of Mitra and Datta (2014) on low adoption levels for GSCM through the investigation of drivers for the adoption of GSCM. The works of Nkrumah et al. (2020) argue that Ghanaian firms are at the forefront in the adoption of GSCM.

Here, the majority of the green supply chain practices are being adopted with higher adoption levels: green manufacturing, green purchasing, green marketing, and green supplier development. Looking at the study of Mitra and Datta (2014) and that of Govindan et al. (2015) against Nkrumah et al. (2020), it is interesting to note that a country in the Sub-Saharan African region having higher adoption levels than those in Asia. A probable reason would be the low emissions from firms in Sub-Saharan African regions due to low industrialization levels and a dearth of factories. This means that the level of policy and guidelines would be minimal, meaning companies are willing to adopt, and their implementation yields positive fruits compared to Asia.

A study by Abdellatif and Graham (2019) in Jordan contends that most manufacturing organizations in Jordan are interested in adopting GSCM practices, where they begin with internal practices, green production, waste management, clean energy, then external practices, and green supplier development. While this is a good reflection on the uptake of GSCM practices, such firms need to consider holistic practices capturing both the upstream, downstream and return stream supply chain. According to Laosirihongthong et al. (2013), legislation and regulations seem to be the most adopted practices, followed by eco-design, green purchasing, and reverse logistics. Thai manufacturers do not see the sense of reverse logistics. This could be explained by the process and costs of returning and processing returned products.

According to Debnath et al. (2023), companies are more interested in green technologies, waste management, sustainable logistics and inventory management, energy management, green procurement, and sustainable training and development. This shows that technologies as enablers of SC performance are the most adopted, and training and development are given the least attention. Looking at this carefully, training and development should be on top of the list. However, it could be that these manufacturers are unaware of the role of training and development toward the successful adoption of GSCM practices.

According to Vijayvargy et al. (2017), Indian manufacturers are interested in GSCM, but their adoption levels are relatively low due to a lack of awareness of the new concept. In the study of Vijayvargy et al. (2017), green purchasing seems to have low adoption levels. However, on a broader scale of GSCM, large firms seem to be at the forefront of adopting GSCM practices compared to smaller firms. This poses a challenge since most firms are small and medium-sized (Vijayvargy et al., 2017). The Namagembe (2018) study argues that Ugandan firms have higher rates of GSCM adoption levels.

Even with the country being in the early stages of industrialization, the companies are more aware of the benefits of these practices. Namagembe (2018) posits that eco-design and investment for recovery seem to have higher adoption levels. These findings reveal the importance of education and awareness in implementing GSCM practices. Against this background, it is notable that different regions and industries have different adoption levels depending on their awareness levels and training and development on the importance of GSCM practices. It is also interesting to note that most of the adopted practices sit at the focal point of the SC, which is production, with intersections to energy usage and waste management.

The circular economy deeply engraves practices to deal with waste management, design, and energy management. Also, practices relating to the forward supply chain seem to be the most adopted, except green procurement. The findings on green procurement show a lack of understanding of the confines of green procurement since studies such as the works of Abdellatif and Graham (2019) show different green procurement practices as standalone. Besides, while ample literature exists on the embedded circular economy and closed-loop, such practices are not widely adopted. Most manufacturers perceive reverse logistics as hard work with minimal benefits, leading to low adoption levels.

2.2.2.3 Green Closed-Loop Supply Chain Management and Resilient Sustainability

In line with the arguments presented by Souza (2013), Mutingi (2013), and Meera & Chitramani (2014), the adoption of green supply chain practices is a crucial element for enterprises, societies, and economies as they strive towards sustainability and resilience. Several studies emphasize the significance of green initiatives in diverse industries to achieve sustainability and resilience. For instance, Kumar & Chandrakar (2012) and Mafini & Loury-Okoumba (2018) argue that sustainable procurement practices, design for the environment initiatives, reverse logistics capabilities, and green manufacturing strategies had an impact on waste reduction and pollution elimination, thereby contributing to environmental safety and supply chain performance in general, ultimately leading to sustainability.

The emphasis on waste reduction and pollution elimination aligns with the philosophy of the circular economy, serving as a catalyst to transition supply chains towards sustainability and, by extension, resilient, sustainable economies and communities. Similarly, implementing reverse logistics contributes to waste reduction, promoting sustainability. Additionally, GSCM exerts an influence on the sustainability of operations (Tippayowong & Supaidang, 2015; Shan & Wang, 2018). While existing literature suggests that GSCM leads to sustainability and improved performance, there is limited research on closed-loop SCs.

This is particularly with regards to their contribution to resilient sustainability, emphasizing the need for more investigation into the integration of GCLSCM for the resilient sustainability of SCs. Applying GSCM contributes to sustainable efforts, enhancing overall enterprise performance (Kumar & Shekar, 2015). Similarly, Kumar and Kumar (2013) posit that green supply chains significantly impact the improvement of production processes and products, reducing anthropogenic effects such as waste and pollution and enhancing resource usage. Also, sustainability practices aimed at achieving sustainable consumption and production patterns result in reduced SC costs, translating into enhanced SC performance and sustainability as the ultimate goal (Gouda & Saronga, 2018; Govindan, 2018).

Furthermore, environmental leadership, environmental supply chain ethics, environmental 5S methodology, and total productive maintenance are identified as essential factors for achieving sustainability (Beamon, 2005; Angus-Leppan & Metcalf, 2010; Jaca et al., 2015; Chen et al., 2019). While practices like the 5S approach and total productive maintenance have been extensively discussed in quality management and lean practices literature, integrating these philosophies into GCLSCM is essential. This is because of the lean philosophy's emphasis on waste minimization, a fundamental tenet of circularity.

A study by Alraja et al. (2022) on technological innovation, green practices, and sustainable performance in SMEs in Oman reveals that green human resources management, green innovation, and green marketing strongly influence the sustainable performance of SMEs. Another study by Alraja et al. (2020) indicates a positive relationship between technological factors and green innovation, organizational factors and green human resources, and environmental factors and green marketing.

However, the study found no impact of green supply chain practices on sustainable performance, suggesting a need to investigate each functional practice individually for meaningful results (Aming'a et al., 2024). This is supported by the works of Fok et al. (2022), who looked into quality management practices, organizational culture, green supply chain practices, and sustainable performance. Fok et al. (2022) found that green supply chain practices positively impacted economic, social, and environmental performance. In the study of Fok et al. (2022), green practices were measured from a green culture perspective on reducing pollution and waste. Thus, a need for practices traversing SC, such as environmental supplier audit, green manufacturing, green logistics, reverse logistics, and green procurement, is essential for meaningful GSC results. Abdul-Rashid et al. (2015) researched sustainable manufacturing practices on sustainable performance, concentrating on product design and development, manufacturing, and end of life on economic, social, and environmental.

In the paper of Abdul-Rashid et al. (2015), sustainable design was found to have an impact on environmental performance but not on economic and social performance. Also, sustainable manufacturing was noted to positively influence all the indicators of sustainable performance. In addition, SCSus was realized to affect social performance but without impacting environmental and economic performance. Besides, sustainable end-of-life was found to impact economic performance without affecting social and environmental performance. It is possible that with much scholarly discourse on sustainable supply chains and green closed-loop philosophies, a sufficiently established model on a combination of indicators feeding each part of the SC is lacking to contribute meaningfully to holistic, sustainable performance. Cankaya and Seizen (2019) conducted a study on green supply chain practices (green purchasing, green manufacturing, green logistics, green distribution, green marketing, green packaging, internal environmental management, environmental education, and investment recovery on sustainable performance and found out that green supply chain practices lead to improved environmental performance and not so much effect on social and economic performance.

Specifically, Cankaya and Seizen's (2019) study noted that green production, distribution, and environmental education positively impacted financial performance. Moreover, green production, marketing, internal environmental management, investment recovery, and distribution positively impacted ecological performance. It is also noted in the study of Cankaya and Sezen (2019) that green production, green distribution, internal environment management, and investment recovery positively impact social performance. Looking into the findings of this present study, it is notable that green production is a worthy investment that enhances holistic, sustainable performance based on the triple bottom line. A study conducted by Afum et al. (2020) on the mediating role of GSC integration on green manufacturing practices and sustainable performance showed a positive influence and a further mediation role of green supply chain integration on green manufacturing and sustainable performance. This indicates that integration could be an essential defacto towards upscaling sustainability performance in the context of green manufacturing practices.

According to Chin et al. (2015), environmental collaboration as a moderating variable between green supply chains and sustainable performance can facilitate these relationships. Chin et al. (2015) argue that past literature has examined environmental collaboration as a leading green supply chain practice. Looking into the discussions of Chin et al. (2017), ecological collaboration creates synergy among supply chain partners, encouraging the uptake of green closed-loop supply chains and contributing to the resilience and sustainability of SCs.

2.3 Summary of Literature

Resilience and sustainability seem to be concepts that have yet to reach maturity regardless of their long-standing within scholarly discourse. The chapter provides discussions from a conceptual foundation to an empirical investigation perspective. The leading practices forming research hypotheses are green procurement, design for the environment, cleaner production/green manufacturing, green logistics, reverse logistics, and internal environmental management. It is also realized that there is limited literature that combines resilience and sustainability from a dimension perspective based on a SC orientation.

Chapter Three: Conceptual Framework and Hypotheses Development

3.1 Introduction

This study sought to investigate building a resilient, sustainable economy through green and closed-loop supply chain management in the context of the circular economic model for manufacturing businesses in a Sub-Saharan African setting. Against this background, the core purpose of this chapter is to present the theories underpinning the study, hypotheses that guide the study, and a conceptual framework. According to Kivunja (2018), a theoretical framework is a composition of theories developed by subject experts that provide a theoretical basis for research. The theoretical basis then acts as a guide towards meaningful research interpretation. A theoretical framework is the cornerstone of any research (Grant & Osanloo, 2014). Also, a theoretical framework is a well from which all research sources are drawn and, thus, a blueprint for the research.

Selection and construction of a theoretical framework are essential to draw meaning from the investigations under study. In addition, such theoretical underpinnings anchor the development of hypotheses. First, a multi-theoretical foundation for this study underpins its multi-disciplinary nature, for which a single theoretical perspective will not suffice. In this context, this chapter is organized into nine sections. Sections 3.1, 3.2, and 3.3 present the introduction, theories, and a multi-theoretical perspective. Sections 3.4, 3.5, and 3.6 present variable selection criteria, theoretical reasoning, and the development of hypotheses. Sections 3.7, 3.8, and 3.9 present the conceptual framework, operationalization of variables, and chapter summary, respectively. Figure 3.1 presents the theories used in this study. A multi-theoretical framework is essential in developing a theoretical framework in SCM that integrates with other disciplines, such as GCLSCM and resilient sustainability.

This study is founded on three prominent theories (ecological modernization theory, dynamic capabilities theory, and system thinking theory), coupled with a discussion of other valuable theories in SCM. Besides, these theories are founded on different disciplines in more extensive business management. For instance, stakeholder theory is borrowed from the social sciences, resource-dependent theory from strategic management, dynamic capabilities from strategic management, and network theory from several disciplines, specifically operations research. Also, systems thinking from different disciplines, resilience from resilience studies, ecological modernization, SOLA model from sustainability, and total cost of ownership (TCO) model from the SC. Such a depiction demonstrates the importance of a multi-theoretical framework in interdisciplinary studies, such as investigating GCLSCM for resilient sustainability.

3.2 Theoretical Framework

Several scholars continue to debate a myriad of theories underpinning the concepts of SD, the circular economy model, GSCM, GCLSCM, supply chain performance, organizational behavior, and systems resilience as fundamental concepts for this study. For instance, Alexandar and Walker (2013) theorized five classical green supply chain management theories to encompass stakeholder, resource-based view, systems, network, and industrial organization theories. Rezaee (2018) argues that agency, institutional, signaling, stakeholder, and stewardship theories are the central reference points for the green supply chain theoretical base. Equally, complexity theory, resource-based view theory, transaction cost analysis theory, knowledge-based view theory, strategic choice theory, agency theory, institutional theory, systems theory, network perspective theory, ecological modernization theory, information theory, resource-dependent theory, social network theory, dynamic capabilities theory and social capital theory have been put forth as the classical 15 in the attainment of sustainability through green supply chains (Dubey et al., 2017; Chu et al., 2017; Govindan, 2018).

The works of Zimmerman (2013) and Breda (2018) put forth a resilience theory as a significant theory underpinning resilience studies. Pieper et a. (2019) utilized the SOLA model for social sustainability. Also, Jedlinski and Sowa (2021) applied the total cost of ownership model to account for reusable wooden flat pallets in its operations. That said, stakeholder, resource dependency, network, systems thinking, resilience, ecological modernization, SOLA, and TCO theories are the primary theories underpinning the building of SCRes and SCSus. Drawing motivation from extant literature theoretical underpinnings in the subject of SC sustainability and resilience, this present study aligns itself to the use of systems thinking theory, dynamic capability theory and ecological modernization theory as the most prominent theories, while being cognizant of other relevant theories. This section therefore is organized into two parts. Section 3.2.1 discusses the three prominent theories, and section 3.2.2 discusses other relevant theories.

3.2.1 Prominent Theories Underpinning this Study

3.2.1.1 Ecological Modernization Theory

This theory emanates from the works of Joseph Huber 1982 and Janicke 1985 in their search for a remedy for ecological crisis (Huber, 1982; Janicke, 1985, as cited in Gibbs, 1998). According to Janicke (2008), the ecological modernization theory was first seen in a study for the Berlin Centre.

However, the term seems to have been coined in the 1980s to bring an understanding of the interfaces between the environment and the economy (Huang & Huang, 2022). Ecological modernization refers to solutions to environmental problems mainly from industrial processes (Gibbs, 1998). According to Spaargaren (2000), ecological modernization theory rests on the tenet of an environmental problem being a real issue that needs solutions. This theory further examines the need to achieve equilibrium levels for our world ecosystems from an environmental safety perspective. In the context of this study, this theory underpins the study in the sense that building a sustainable, resilient system results from the rising cases of anthropogenic SC activities that have depressed the environment, leading to environmental degradation.

To find a balance between social, environmental, and economic sustainability for the reversal of harm caused to the environment, ecological modernization theory tends to look into issues of modern society through the provision of sustainable solutions for sustainable communities and economies. According to Huang and Huang (2022), the ecological modernization theory examines how modern industrial systems can identify and react to emergent social and environmental challenges. In addition, ecological modernization theory can be felt by implementing GCLSCM to counter SC anthropogenic effects that taint the environment, posing environmental degradation, social unrest, and economic sabotage. Here, Joo and Min (2022) argue that environmental degradation is the main driver for economic reforms. Hence, the green closed-loop supply chain is vital in remedying such an environmental-sustainable crisis.

According to Mol et al. (2013, p.2), “Within the social sciences of environmental reform, ecological modernization stands out as the strongest, well-known, most used and widely-cited and constantly debated concepts.”

The arguments of Mol et al. (2013) posit that, despite the growing importance of ecological modernization theory as an environmental reform approach, the theory has shortcomings. For instance, the theory has been argued to concentrate on production with a neglect of the consumption patterns, is eurocentric, and lacks an assessment of social inequality and power. Such criticisms necessitated modern ecological theorists to offer contemporary contributions to the classical ecological modernization thinking.

According to Marsden et al. (2011), ecological modernization theory has been applied in regions such as China in developing ecological policies and, as such, can be applied in other regions too. Ecological modernization theory underpins this study by providing solutions such as GCLSCM for building resilient sustainability of SCs. Considering such arguments, integrating practices such as GCLSCM depends on the dynamic capabilities of these SCs.

The works of Zhu et al. (2011) argue that ecological modernization theory highlights that companies that have environmentally friendly technologies have a higher capability to improve their performance. Zhu et al. (2011) further argue that most of the ecological challenges in the world today can be solved by utilizing resources well and, at the same time, if producers can adopt cleaner technologies. In agreement, the works of Mckingsley and Roseline (2022) state that firms that employ green supply chain management practices have higher chances of improving performance.

Against this background, modern manufacturers and their supply chains, even the service providers and contractors are called upon to recognize that the challenges they face result from a lack of harmony in balancing system benefits for both the environment and the economy. This means that these manufacturers must be cognizant of their practices to benefit society, the environment, and the economy. GCLSCM, in building resilience and sustainability of supply chains, emerges as one of the best modern technologies with a quadruple interplay of economic, social, environmental, and resilience. Fundamentally, each oGCLSCM practices proven to be a modern technological capability in building SCSus and SCRes.

3.2.1.2 Dynamic Capabilities Theory

The works of Teece et al. (1997), in their research on dynamic capabilities and strategic management, argue that organizations need to go beyond traditional resource-based view strategies to capture the dynamic capabilities in achieving competitive advantage. Teece et al. (1997) describe dynamic capabilities as practices that firms need to embrace that are transformative, resonating with the changing times of business environments. Kirci and Seifert (2015) posit that firms require internal and external dynamic capabilities to stay abreast of the business environment. Beske (2012) asserts that SCs face dynamism from time to time, and integrating sustainability into the SC calls for building dynamic competencies for proper integration toward achieving competitive advantage.

The works of Bari et al. (2022) contend that organizations must take sustainability as a dynamic capability to reconfigure their networks and transform towards achieving competitive advantage. Bari et al. (2022) further assert that the dynamic capabilities, as Teece (2018) argued, are essential but fail to show the interrelationships of dynamic competencies of firm sustainability. To strengthen the SC networks, building dynamic competencies calls for understanding the SC partners.

This is towards achieving resilient, sustainable systems as strategic competitive weapons. Isnaini et al. (2020), in their study on the moderating effect of dynamic capabilities on the relationship between sustainable SCM practices and organizational performance, argue that with emergent issues such as environmental protection and transparency in supply chains, firms need competent supply chain models. Competency supply chain models are built on dynamic capabilities that transform the supply chain competencies to newer levels as time changes for long-lasting competitive advantage. This study's dynamic capability theory is vital in adopting and practicing green and closed-loop supply chains for resilient sustainability. Besides, in adopting such a critical practice, dynamic capabilities such as top management support and supply chain collaborative efforts become significant to achieve resilient sustainability.

In addition, few studies have shown SC capabilities as moderators on sustainable supply chain practices and sustainable performance. Also, SC networks become important for properly integrating dynamic capabilities across the different supply chain networks to achieve efficient power of dynamic capabilities. In Smith et al.'s (2009) arguments, dynamic capability theory is usually disadvantaged by its central proposition of coining capabilities as dynamic without regard to the nature of capabilities. In that perspective, Smith et al. (2009) assert that it is essential for researchers to assess the development of the area they are looking at and consider dynamic capabilities related to value creation for organizations and supply chains. In that perspective, systems thinking theory becomes essential to enable organizations and supply chains to understand their network partners externally and internally and comprehend the inter-departmental networks to build on dynamic capabilities in response to the dynamics of the business environment.

3.2.1.3 Systems Thinking Theory

Jay Forrester, known as the father of systems thinking, first put forth systems thinking theory in his contributions to system dynamic modeling under the Middlebury School of the Environment (Dangerfield, 2014). According to Barton et al. (2004), systems thinking is based on the fundamental concept of a system that Braton et al. (2004) argue is a set of components that work towards a common goal. Evagorou et al. (2009), as cited in Verhoef et al. (2018), systems thinking is the thought process for the cognitive processing of complex and dynamic systems. The underpinning of systems thinking in this study is twofold. One, from a sustainability perspective, is where a resilient, sustainable system can be developed. This is through efficient, sustainable development practices and resilience structures.

From a SC perspective, a SC is perceived as a sub-section of the larger world ecosystem with its different components that work together toward an overall system sustainability. Chreoner and Mirijamdotter (2009) argue the importance of integration and collaboration among organizational partners to drive the success agenda. SCs being complex systems, their management calls for a systems thinking approach to the embedment of GCLSCM across the entire chain for resilient sustainability. Holmann et al. (2018) argue that systems thinking is the new norm for sustainability supply chain and logistics management. Holmann et al. argue about moving from traditional to modern reductionist systems thinking. The traditional reductionist systems thinking considers a system as a contribution from individual parts. However, Holmann et al. (2018) argue that modern reductionism systems thinking looks at a system as the totality of its items and whose interactions result in a system objective whose extra features maximize performance beyond the contribution of individual components. Baz et al. (2019) argue about the importance of holistic thinking.

Moreover, the arguments of Baz et al. (2019) contend that scholars have continuously considered individual elements of GSCM in the past, forgetting the systemic nature of SC networks as a web. Baz et al. (2019) strongly argue the need to utilize systems thinking to boost the performance of SCs through GSCM. With such comprehension, systems thinking captures the tenets of collaborative efforts in supply chains toward the embedment of green closed-loop supply chain practices for a whole supply chain system to become resiliently sustainable. The works of Alhamstron et al. (2019) assert that the interdependence between firms and the planet is significant for sustainable management. To that effect, creating a symbiotic relationship between supply chain firms and the natural biosphere through the embedment of green closed-loop supply chains enhances the road map toward resilient sustainability. Systems thinking encompasses a model where supply chains are viewed as a sub-section of the more extensive system that entails economic, social, and environmental systems.

The interaction of SCs with the more extensive system then calls for sophisticated ways of embedding sustainability principles into the SC for a symbiotic interaction where the supply chain supports the planetary system and the social system, which in turn supports the SC and the more extensive system leading to resilient sustainability. Collaborative efforts in SC stakeholders are a critical avenue to provide a path for seamless interactions between the supply chain, nature, and the larger world ecosystem. In this context, the embedding of GCLSCM calls for a holistic SC system embedded with collaborative efforts to yield SCSus. With systems thinking, analyzing risk disruption becomes essential for developing resilience

strategies as an enabler of resilient, sustainable systems. As individual items contribute holistically to overall system success, disruptive occurrences hinder the achievement of resilient sustainability, and integrated design thinking interwoven with systems thinking assists in improving overall SC performance.

3.2.2 Interrelationships Among the Prominent Theories

Critically analyzing the three prominent theories presented in this study, it is notable that they are complementary rather than competing and interwoven in a web towards the adoption of GCLSCM for building both resilience and sustainability of supply chains. It is essential to begin with the systems theory to show the interrelationships and their criticality. A system is a composition of various related parts working towards achieving a common goal. A supply chain is ideally a web of different components that work together in harmony to sustain the economies of the world ecosystem. This begins with identifying the needs of the various facets of the world ecosystem, which usually starts from the consumption pipe, ideally termed procurement. Depending on the nature of the need, the materials procured could be transported for conversation or consumption purposes, bringing forth other components of the supply chain, such as logistics and production. Against this background, the adoption of GCLSCM for resilience and sustainability across all supply chain system members becomes important in achieving the different dimensions of resilience and sustainability.

Besides, GCLSCM adoption insinuates the relevance of the ecological modernization theory through practices such as design for the environment, green procurement, cleaner production, green logistics, reverse logistics, and internal environmental management. These innovations that work towards responding to the modern ecological crisis also become capabilities that respond to the dynamism of the world ecosystem. Utilizing the ecology of modernization across the different facets of the supply chain and its cascading effect on the larger society, ecological modernization needs to be holistic for both supply chain and societal sustainability. These modern innovations to ecological and societal crises need to be dynamic in nature to respond to the dynamism of the world ecosystem towards building both resilience and sustainability. In this regard, the three theories borrowing from design thinking are interrelated. Table 3.1 provides a summary of scholars who have applied the prominent theories in their studies.

Table 3.1: A Summary of Previous Literature Using the Prominent Theories

No	Theory	Theoretical Arguments	Author & Year
1.	Systems Theory	A supply chain is a complete system in which GSCM practices should be considered as an umbrella. Supply chains that embed holistic practices for their performance and that of society and the environment have higher capability to perform better.	Teece, 2018 Isnaini, 2020
2.	Ecological Modernization Theory	Technological innovations such as green and closed-loop supply chains should be developed to arrest the ecological crisis that modern society faces. Supply chains with well-developed green capabilities for modern challenges are more likely to perform better.	Zhu et al. 2011 Mckingsley & Roseline, 2022
3.	Dynamic Capabilities Theory	Supply chains that continuously develop dynamic capabilities with several evolutions have greater chances of improving their performance.	Baz, 2019 Alhastrom, 2019

Source: Author, 2024

3.2.3 Other Relevant Theories

3.2.3.1 Stakeholder Theory

According to Parmar et al. (2010), stakeholder theory thinking was first seen at the Stanford Research Institute in 1963, and later, the theory was shaped by Edward Freeman and other scholars in the 1980s and 1990s. Under Karimi and Rahim (2015), stakeholder theory emphasizes that organizations consider other enterprises' activities and strategies to develop institutional practices. Furthermore, a firm has much to gain through integrating multiple stakeholders (both primary and secondary) in its decision-making (Awan et al., 2017). In that regard, Castillo et al. (2018) assert that enterprises need to look into the input of a large percentage of their stakeholders when making decisions. In the case of implementing green closed-loop supply chains for resilient sustainability, it is prudent for the different parties of a supply chain regarded as stakeholders to be included in the decision-making of adopting green

initiatives in the different stages of a supply chain. This is vital because if one stage fails the system, the performance of green closed-loop supply chains will be in vain.

In addition, it is also crucial for the different supply chain organizations to manage and mitigate risks at their point of occurrence for a resilient SC, resulting in a sustainable supply chain. The works of Castillo et al. (2018) further argue that it is not at all times that both primary and secondary stakeholders exert equal influence in decision-making. As such, supply chains need to check where most stakeholders lie. The assessment of where most stakeholders lie also highlights the importance of evaluating the organizational and supply chain capabilities and their importance towards performance. In this regard, stakeholders with well-developed capabilities might have a higher hand in decisive decision-making, leading to enhanced performance. With such understanding, resource dependency levels of the different stakeholders then become critical toward successful implementation and practice of initiatives such as GCLSCM.

3.2.3.2 Resource Dependence Theory

According to Hillman et al. (2009), resource dependency was put forth by Pfeffer and Salancik in 1978. The resource dependence theory describes the muscle of an enterprise to get primary resources crucial for its well-being in an external environment (Glover et al., 2014). This theory also suggests a game plan for coordinating with suppliers and customers for survival and benefit sustainability (Glover et al.). Under similar circumstances, Donato et al. (2015) argue that resource dependency theory applies many strategies to acquire resources at different levels of an SC to gain access to inadequate resources and capabilities. Correspondingly, Donato et al. (2015) attest that organizations are likely to gain in choosing partners that contribute valuable and equivalent resources to the relationship. Dependency dictates that each partner has a valuable contribution to the organization's network to make it a mutual dependency with benefits that bring different partners together in search of valuable exchanges.

The different parties of a supply chain in implementing green closed-loop supply chains bring on board valuable benefits as each stage relies on another for successful implementation of the green closed-loop supply chain for resilient sustainability. For instance, suppliers need to collaborate with manufacturers to factor in the kind of raw materials to be supplied to manufacturers to meet environmental standards through the eye of the manufacturer. Equally, the distributors must be perfectly integrated with manufacturers to employ green distribution mechanisms such as green packaging and eco-labeling.

Besides, customer integration is vital for the manufacturers to translate the consumer's green voice to the green producer's requirements and capabilities for the well-being of all the parties in the supply chain. This creates a mutually dependent relationship that leads to healthy SCs, translating to sustainability. In this context, resource dependence theory lays a foundation for dynamic capabilities theory since the dynamism of systems affects the resource dependency levels.

In addition, Hillman et al. (2009) contend that organizations must plan on how to respond to external pressures for survival. In this study, with rising regulatory pressure towards upholding sustainability practices, organizations and supply chains need to develop resources such as GCLSCM to achieve sustainable development. Nienhuser (2008) stresses that central to the resource dependence theory is the power imbalances where organizations that have control of the needs of actors have power over those actors, creating a dependence relationship where one actor will be meeting the demands of another. Such a shortcoming in resource dependence theory is one where the network through integration across partners and dynamic capabilities (through the development of capabilities across partners) emerge as complementary models for the success of organizations.

3.2.3.3 Network Theory

Network theory can be traced to Harland (1996). Edward et al. (2011) argue about utilizing network theory for supply chain research. Edward et al. further assert that very few studies in the supply chain have considered the usage of network theory despite its significant underpinning to the different supply chain partners. Edward et al. argue that supply chains are networks encompassing different business units that are relational and, in working together, enhance their overall supply chain performance. In addition, unlike business firms with dyadic relations, supply chains are triadic in that they are composed of multiple partners that enable the transformation of products and their distribution to customers. Network theory underpins this study on the importance of adopting green closed-loop supply chains across different stakeholders for valuable, resiliently sustainable supply chains and, by extension, holistic world ecosystems. Humphries and Mena (2012) argue about the importance of network theory in the discipline of a fragmented supply chain for a properly efficient theoretical base for its enhanced performance. Humphries and Mena (2012) further document the need to consider network theory with relational dependencies exhibited in supply chains rather than traditional network theories like transaction-based economic theories. Pathak et al. (2007) posit the importance of network theory for efficient decision-making for supply chains.

However, Pathak et al. argue about the need to be adaptive in the networks of supply chains for efficient decision-making that goes beyond the normal relations among supply chain networks. In this study, network theory is significant in closing the SC loop by bringing aboard other supply chain partners typically left out of the structure in decision-making. For instance, the reverse logistics aspect of closed-loop and circular economy supply chains heavily depends on the interrelations between supply chain manufacturers, distributors, and customers for reverse logistics to offer real value. Under the circumstances, network theory opens up to resilience thinking theory, whereby supply chains are viewed as vulnerable to disruptions in the global ecosystem.

3.2.3.4 Resilience Thinking Theory

The resilience thinking theory can be traced back to the works of Holling (1973), commonly referred to as the father of resilience. Hollings describes resilience as the capability of a system to bounce back after disturbance and forge forward to an even better state. Ponomarov and Holcomb (2009) contend that SCs are inherently risky networks, so there is a need to develop resilient strategies for their management and continuity. Beyond economic vulnerability, Ponomarov and Holcomb argue that resilience thinking theory has its underpinnings in ecological and social vulnerabilities. When viewed together, such vulnerabilities (economic, social, and ecological) highlight the importance of upscaling strategies toward achieving SD.

Besides, long-lasting sustainable development calls for building resiliently sustainable systems. Kochan and Nowicki (2018) assert that risk disruptions are the basis for resilience thinking. As such, it is essential to understand a system disruption for efficient, resilient strategies and capabilities' Nightingale (2012) contends that resilience thinking results from dissatisfaction with the philosophies within the dynamics of ecosystems in ecological sciences in the 1970s. Most ecological science philosophies, including sustainable development, do not view the world ecosystems as structures that can be disrupted; thus, resilience is viewed as a completely distinct philosophy from ecological-related philosophies like sustainability. To that effect, resilience thinking theory underpins this study not only from a resilience perspective but also from building sustainable systems that are both resilient and sustainable. That said, it is essential to understand how to solve ecological challenges together with their management of disruptions.

3.3 A Multi-Theoretical Perspective

This study argues that it is almost challenging to conceptualize and debate the GCLSCM phenomenon and its effects on the resilience and sustainability of SCs using a single theory. Against this backdrop, this study provides three prominent but complementary theories: ecological modernization, dynamic capability, and systems thinking. Under such discussions, the multi-theoretical lens for this study shows three critical levels of power toward adopting green closed-loop supply chains for resilient sustainability. The first level starts from the consumption pipe. Essentially, customers drive business, which is the same for SCs. SCs must be integrated as a system through their collaborative capabilities to satisfy customers.

The second level of power emanates from the internal appetite of the supply chain through its various partners. Such appetite to perform well and be the best in the market is driven by dynamic capabilities theory and a systems thinking perspective. Organizations and supply chains exist intrinsically to make profits and fulfill stakeholders' intentions. Such an understanding then proves the importance of the combinatory power of a multi-theoretical lens for the subject of GCLSCM for resilient sustainability. Finally, it looks into the third level of influence, the government. Across world economies, and as the advancement of a myriad of practices in different disciplines emerges, governments are also working towards an upward trajectory of enhancing gross domestic product, manufacturing added value, trade investments, and SC expansion. As a result, SCs must embrace the pressure from such advancements in the third level of influence through a multi-theoretical perspective of GCLSCM on resilient sustainability.

Building upon these arguments, the three prominent theories provide an interrelated framework for supply chains on how to use systems thinking to understand how supply chain can adopt sustainable and resilience capabilities, while at the same time be able to contribute to society and environmental sustainability. This calls for sustainable revolution technologies and innovations to improve the supply chain and society in general. In this regard, supply chains need to embrace technological innovations within emergent ecologies for a win-win scenario for supply chains and the planet. In addition, such technological innovations need to be dynamic to respond to the dynamism of the world ecosystem and that of supply chain and therefore utilizing the dynamic capabilities theory in developing the dynamic capabilities of the supply chain to improve both supply chain and societal resilience.

3.4 Research Variables Selection Criteria

The study hypothesized a relationship between GCLSCM and resilient sustainability. The selection of variables for this study is based on the extant literature on commonly agreed measures of green and closed-loop SCM (green procurement, design for the environment, cleaner production, green logistics, and reverse logistics). Also, the dependent variable is defined by resilient sustainability, where resilience is measured through (adaptability, agility, a risk management culture, and robustness). sustainability is equally measured as (economic, social, and ecological sustainability). In addition, internal environmental management is equally measured through collaboration. Three control variables, including gender, business size, and industry type, were used. Based on the third research objective with five sub-objectives, several hypotheses were developed to test GCLSCM and resilient sustainability.

3.5 Theoretical Reasoning

The theoretical philosophy for conceptualizing the research model is at the heart of this study. As previously debated, scholarly discourse points out the importance of assessing the practice of green closed-loop supply chains in achieving resilience sustainability. The practice of GCLSCM has been found to rest on the circular economic model based on three fundamental pillars: designing out waste, keeping materials in the loop and regenerating natural systems (McArthur, 2015). This has been depicted under the four latent variables with their indicators, as shown in the research model. In addition, prior scholarly reasoning has focused more on the GSCM without integrating circular economy and closed-loop aspects for driving resilience and sustainability.

3.6 Hypotheses Development

According to Ullah et al. (2022), GSCM affects organizational resilience. Ullah et al. validated the effect of GSCM practices using Thomson Reuters data. They found that firms that had adopted GSCM practices had an enhanced capability to recover from disruptions during the COVID-19 era. While Ullah et al. note that this is an underexplored relationship, this study pegged its hypotheses development for testing and validating GCLSCM on resilient sustainability. A significant assumption in developing hypotheses for this present study is founded on Layder (1988), who emphasizes outcome scenarios of hypothesis testing. This means that hypothesis testing could be true or false. Chin et al. (2015) studied green procurement, manufacturing, distribution, and logistics on sustainability performance following the triple bottom line under the moderating effect of environmental collaboration.

The study of Chin et al. (2015) reports that GSCM affects sustainability performance. Esfahbodi et al. (2017) found no relationship between green procurement and green distribution on sustainable economic performance. In the findings of Cankaya and Sezen (2019), GSC management practices (green procurement, manufacturing, distribution, and logistics) positively affected environmental performance. However, they did not have a relationship with social and economic performance. Such studies reflect the extant literature on a contrast among scholars on green and closed-loop supply chains and resilient sustainability. Due to this fact, this study formulates several hypotheses as a guide for future studies on how to treat this subject and, at the same time, a contribution to sustainable and resilient supply chain management.

3.6.1 Green Procurement, Design for the Environment and Resilient Sustainability

According to Pereira et al. (2014), procurement continues to evolve as functionality to manage resources through the acquisition of the organization's needs and further evolves to deal with turbulent scenarios, leading to the building of supply chain resilience. Besides, procurement as a function within organizations has a more significant role in achieving business value. Procurement is the first line of contact for supply chains, and with that, efficient and responsive procurement is significant for achieving top-notch SC performance. Lysons and Farrington (2006), procurement has evolved from just a purchasing functionality to an all-encompassing functionality that entails the management of resources and supplier relationships (Ellram & Carr, 1994). Against this background, the works of Bergendhal et al. (2018) posit that ecological modernization theory looks into technological innovations that can improve human conditions and environmental sustainability.

The works of Bergendhal et al. (2022) argue that technological innovations are significant in improving the world's ecosystem. Considering GCLSCM practices such as green procurement and design for the environment as technological innovations for the SC have been argued to contribute to the sustainability and resilience of SCs, thus technological innovations. Also, Zhu et al. (2011) argue that the ecological modernization theory recommends that producers mitigate risks by employing sustainable practices. Hermann and Smith (2018) argue that businesses that embed green procurement are more likely to gain value with the changing times that call for environmentally sustainable practices within business operations. Green procurement has massive benefits for SCs and business operations. In agreement, such innovations can continually improve the operations of systems.

The ecological modernization theory argues about the capacity of such innovations to assist in eliminating and reducing waste, dematerialization, and reuse, practices deeply engraved within the design for the environment, and green procurement tents of SCSus. Hosseini et al. (2022) posit the importance of collaboration with SC partners for improved competitiveness. In the case of green procurement, collaborating with suppliers enhances the resilience and sustainability of SCs. For instance, Dubey et al. (2013) highlight cost reductions and environmental performance benefits.

According to Mitra and Datta (2014), while green purchasing may reduce pollution at source, there is no evidence of it leading to enhanced economic performance. Golicic and Smith (2013) highlight inconclusive findings on green procurement and performance. Rasit et al. (2019) highlight the importance of design for the environment and green procurement in improving sustainable performance (Dubey et al., 2013).

The works of Hsu et al. (2023) reveal that developing green sourcing plans can improve SCSus. Previous literature shows a lack of consensus on green procurement and sustainability. From a design for the environment perspective, Garza-Reyes et al. (2018) found that design for the environment can improve the performance of SCs by influencing the procurement process sustainably. The findings of Marti et al. (2015) reveal that design for the environment helps customers to reduce their environmental impact. This leads to improved SC performance through increased market share, enhanced customer loyalty and confidence in the products and price tags of the products offered to the customers. This will act as a buffer for the SC, improving its resilience and making SCs more stable and reliable. Design for the environment encompassing the reduction of harmful materials, design remanufacturing, design for reuse, design for recycling, and design resource efficiency found that design for the environment was highly adopted and significantly affected performance (Abdallah et al., 2019).

This shows that SCRes and SCSus challenges can be tackled at the design stage. In addition, design for resilience and sustainability calls for stringent policies, government support, company leadership support, and collaboration among SC partners for effective design practices for resilient sustainability. The arguments of Hosseini et al. (2022) through the systems thinking theory reasoning state that focal companies need collaborative strategies to harmonize the entire SC network to enhance seamless operation among their networks. Strong collaborative capabilities among the procurement, production, and logistics units of supply chains can strengthen the uptake of design for the environment toward achieving resilience and sustainability. Against the backdrop, procurement being the SC consumption pipe,

combining green procurement with design for the environment becomes essential, especially in developing the specification and coming up with procurement and sourcing plans.

This assists SCs in examining the ecological material impact of the product before the raw materials are received. This lessens the time for production, improving SC agility and adaptability, enhancing Sc robustness. Therefore, the combined effect of green procurement and design for the environment has more power to build SCRes and SCSus. While both green procurement and design for the environment are argued to enhance sustainability performance, very few studies combine the two practices towards the achievement of sustainable performance and, by extension, resilience.

Furthermore, minimal studies have investigated the relationship between either green procurement or design for the environment and resilience. Most GSCM studies neglect the social aspect of sustainability. (Cankaya & Sezen, 2019) From a resilience perspective and to the best knowledge of the researcher, the study of Ullah et al. (2022) provides a starting line conversation on the assessment of GSCM on resilience. However, the study does not show how individual GSCM practices improve the resilience of SCs. That said, green procurement and design for the environment can improve SC's environmentally, resilient, social, and economic performance, thus leading to the following hypotheses:

H1a: Green procurement and design for the environment have a positive relationship with resilience.

H1b: Green procurement and design for the environment have a positive relationship with economic sustainability.

H1c: Green procurement and design for the environment have a positive relationship with social sustainability.

H1d: Green procurement and design for the environment have a positive relationship with environmental sustainability.

3.6.2 Cleaner Production/Green Manufacturing and Resilient Sustainability

According to Rao and Holt (2005), cleaner production catalyzes competitive advantage but has no apparent relationship to enhancing economic performance. Sezen and Cankaya (2020) argue that adopting cleaner production processes can lower an organization's costs. According to Zhu and Sarkis (2004), the benefits of practicing cleaner production are towards both social and environmental performance. Cleaner production is a solid dynamic capability since it sits at the company's forefront of building resilience and sustainability. Also, the works of Bergendhal et al. (2018) argue that technological innovations that improve the sustainability of systems are pertinent to be held by firms. Cleaner production practices define technological innovations such as total productive maintenance and raw material substitutability for

enhanced resilience and sustainability of SCs. Previous studies have focused solely on adopting cleaner production for sustainable performance without incorporating resilience as a major pre-condition to achieving sustainable performance. Also, prior studies do not include the lean concept of the green philosophy, such as the Japanese 5S approach and total productive maintenance that essentially contribute to social, environmental, economic, and resilient sustainability. Besides, prior studies are seen to provide contrasting findings on this subject. Such discussions then give rise to the following hypothesis:

H2a: Cleaner production has a positive relationship with resilience.

H2b: Cleaner production has a positive relationship with economic sustainability.

H2c: Cleaner production has a positive relationship with environmental sustainability.

H2d: Cleaner production has a positive relationship with social sustainability.

3.6.3 Green Logistics and Resilient Sustainability

Green logistics entailing (green transportation, packaging, and warehousing) has been shown to improve firm competitiveness but with inconclusive findings on improving financial performance (Rao & Holt, 2005). Also, Choi (2012) argues that many studies have presented positive relationships between green logistics and sustainable performance. However, others have presented mixed findings. The works of Vienažindienė et al. (2021) posit that green logistics has a capacity for organizations and their supply chains to achieve sustainable performance from the triple bottom line as a dynamic capability based on dynamic capability theory (Kirci & Seifert, 2015). Here green logistics is viewed as a dynamic capability through the different dynamics across green transportation, warehousing and packaging that can continuously be improved for resilience and sustainability. Besides, green logistics as per the ecological modernization theory (Zhu et al., 2011) is considered a modern innovation through green inventory management, transportation and eco-labelling towards promoting the sustainability of SCs. Looking into these past scholarly debates, it is notable that the findings have mixed results and thus need further investigation. Also, it is notable that prior literature has concentrated more on economic and environmental performance and minimal focus on achieving resilience. Such findings highlight the need for further investigations through the following hypothesis:

H3a: Green logistics has a positive relationship with resilience.

H3b: Green logistics has a positive relationship with economic sustainability.

H3c: Green Logistics has a positive relationship with environmental sustainability.

H3d: Green logistics has a positive relationship with social sustainability.

3.6.4 Reverse Logistics and Resilient Sustainability

In the arguments of Binalla and Mateo (2022), reverse logistics is an essential component in supply chain management in handling sustainability challenges and contributing to a circular economy. Also, Kazancoglu et al. (2022) argue that SCs continually face disruptions that call for building resilient reverse logistics systems beyond sustainability challenges. According to Sarkis et al. (2010), sustainability dimensions are gaining importance in reverse logistics. The focus of sustainability in reverse logistics research has historically been anchored on economic and environmental performance without consideration of the social dimension. Alnoor et al. (2019) argue that reverse logistics can enhance sustainability performance from the triple bottom line. Specifically, Alnoor et al. (2019) found a positive relationship between reverse logistics as a technological innovation and sustainable manufacturing.

The works of Sarkis et al. (2010) argue that there are many benefits to accrue from reverse logistics. This is from its individual practices such as recycling, remanufacturing, repurposing, reusing among many which McKingsley and Roseline (2022) argue under the ecological modernization theory. For instance, Sarkis et al. (2010) posit that establishing return processes like reusable containers may benefit businesses, such as eliminating stapling using pallets and cutting boxes, which commonly cause injuries to people. This then boosts the social sustainability of businesses and their networks through the enhancement of the safety and health of society.

Fundamentally, such a practice supports the circular economy philosophy of keeping materials in the loop. This means introducing and using reusable containers also has environmental benefits to businesses, their networks, and the larger society. This is because the reuse practice discourages the continual extraction of virgin materials and encourages the closing of SC loops, whereby items are disposed of when they reach the end of their life. In addition, there is scanty evidence on the role of reverse logistics in achieving resilience. Gilgor and Holcomb (2012) argue that integrated logistical capabilities can lead to agile resilience. In support, Mandal et al. (2017) posit that integrated logistical capabilities are positively associated with supply chain resilience. Based on these discussions, it is notable that there are very few studies that look into reverse logistics and social sustainability, minimal studies that show the effect of reverse logistics and SC resilience, and a mixture of findings on reverse logistics on environmental and economic performance which gives rise to the following hypothesis:

H4a: Reverse logistics has a positive relationship with resilience

H4b: Reverse logistics has a positive relationship with economic sustainability

H4c: Reverse logistics has a positive relationship with environmental sustainability

H4d: Reverse logistics has a positive relationship with social sustainability

3.6.5 IEM on GCLSCM and Resilient Sustainability

According to Chen et al. (2015), external environmental management, such as customer cooperation, positively moderates the relationship between green supply chain practices and competitiveness. Also, Dubey et al. (2020) argue that sustainable supply chain practices could enormously enhance sustainable performance through Environmental SC visibility. This could be through customers and suppliers through the focal company's collaborative capability. Kirci and Seifert (2015) state that dynamic capabilities reflect how firms strategically achieve competitive advantage.

This argument anchors the resilience capability of SCs. In the current age of advanced technologies and a more aware customer, SCs are continuously leveraging emerging technologies, such as internal environmental capabilities, to be successful. Achieving both resilience and sustainability can position supply chains for a competitive advantage. Besides, the works of Bergendhal et al. (2022) argue that the new technological innovations that can arrest an ecological crisis underpin the ecological modernization theory. This reflects how SCs can relate and correlate among the different SC network partners. This is towards achieving a more coordinated supply chain that can adopt and practice internal environmental management to building resilient and sustainable SCs. Extant literature shows minimal evidence of the role of collaboration as capabilities from an internal environmental perspective toward sustainable performance.

Besides, there is no trace of internal environmental management on the relationship between GCLSCM and resilience. It is also realized that most scholars have looked at internal environment management as a driver of adopting GSC. For this study, environmental collaboration has been examined to define internal environmental management with regards to cleaner production, reverse logistics and resilience. Looking at prior literature such as Dubey 2020, collaborative capability from the focal company (anchoring cleaner production) enables SCs to be more competitive. Also, given that SCs do not have much control on customers like they have with suppliers, exploring the moderating role of IEM on reverse logistics and resilience proves significant to see if collaboration can enhance the performance of reverse logistics, more so on the returns. Building upon this foundation, this section presents the following hypotheses:

H5a: Internal environmental management affects the relationships between cleaner production and resilience

H5b: Internal environmental management affects the relationship between reverse logistics and resilience.

3.7 Conceptual Framework

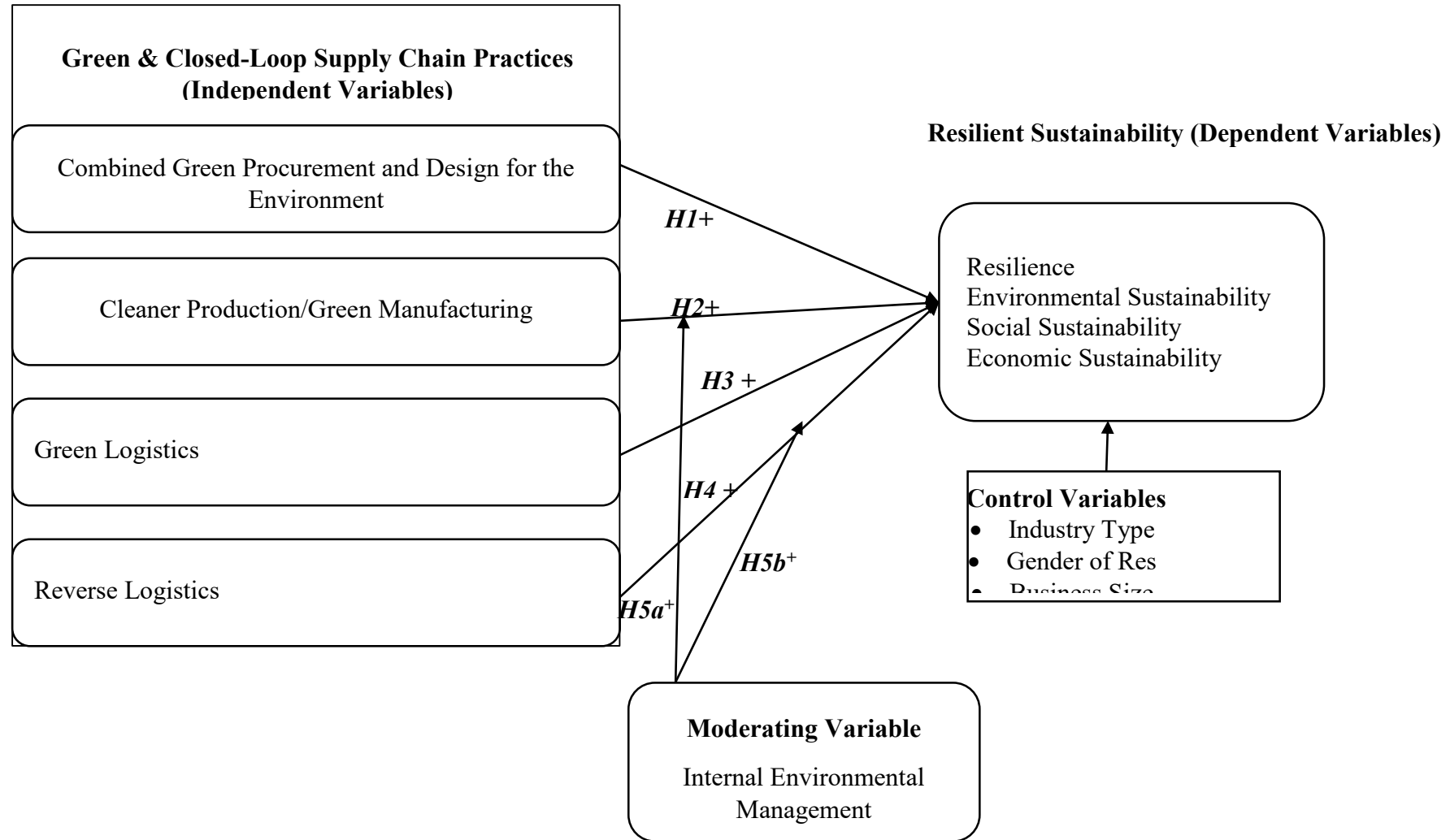


Figure 3.1: Conceptual Framework

3.8 Operationalization of Variables

This present study operationalized the phenomena, utilizing 83 measurement items tested in a three-dimensional conceptual framework. Resilience was operationalized using adaptability, agility, robustness, and a risk management culture. Manufacturing supply chains remain particularly pre-disposed to vulnerabilities due to the nature of their activities encompassing a complete supply chain. These are the most prominent and common in building resilience. Besides, green and closed-loop supply chains considering circular economy practices, green procurement, design for the environment, cleaner production, green logistics, reverse logistics, and internal environmental management have been used to show the importance of systems thinking in mapping out the supply chain for resilience and sustainability.

Table 3.2: Operationalization of Variables

No.	Variable	Type	Measurement	Source	Supporting Theory
1	Resilience	Ordinal	Adaptability, agility, robustness, and a risk management culture.	Hosseini et al. (2022)	Systems thinking theory
2	Economic Sustainability	Ordinal	Resource Utilization, reduction of total cost of ownership.	Bergendhal et al. (2018)	Ecological modernization theory
3	Social Sustainability	Ordinal	The health of employees, the safety of employees, and fairness (no discrimination against employees).	Bergendhal et al. (2018)	Ecological modernization theory
4	Environmental Sustainability	Ordinal	Reduction of carbon emissions, reduction of waste, and climate resilience.	Bergendhal et al. (2018)	Ecological modernization theory
5	Green Closed-loop Supply Chains	Ordinal	Green procurement, design for the environment, cleaner production, green logistics, reverse logistics.	Kirci and Seifert (2015) Bergendhal et al. (2018) Hosseini et al. (2022)	Ecological modernization theory, dynamic capabilities theory, systems thinking theory
6	Internal Environmental management	Ordinal	Environmental collaboration.	Kirci and Sefert (2015) Bergendhal et al. (2018) Hosseini et al. (2022)	Systems thinking theory, ecological modernization theory, dynamic capabilities theory

3.9 Chapter Summary

This chapter provides in-depth theoretical, hypotheses, and conceptual development debates. Notably, a single theory does not suffice in a complex multi-disciplinary study like this one, and as such, a multi-theoretical perspective has been presented. Moreover, hypotheses have been developed based on extant literature that informs the conceptual framework for the study.

Chapter Four: Research Methodology

4.1 Introduction

According to Melnikovas (2018), research methodology is integral to any study. It provides a firm foundation for properly answering research questions. In any study thereof, proper structuring of a research methodology becomes essential. Besides, its appropriateness enables the further development of a discipline. This study sought to investigate building a resilient, sustainable economy through green and closed-loop supply chain management in the context of the circular economic model for manufacturing businesses in a Sub-Saharan African setting. Since the first three chapters have laid a concrete scientific conceptual foundation, this chapter presents the methodology of transitioning the research questions into practical answers underpinning the subject of inquiry. The chapter explains how the philosophical viewpoint of this research underpins the research design and the methodology utilized. The chapter provides discussions on the population targeted and the sample size explored.

The chapter presents 11 sub-sections in detail. Section 4.1 depicts the introduction, 4.2 demonstrates discussions on the research onion, and section 4.3 outlines the research philosophy. In addition, section 4.4 describes the research approach; section 4.5 presents the inquiry strategy and the research method. Also, section 4.6 provides a narrative on the target population, and 4.7 depicts the data collection methodology. Moreover, section 4.8 demonstrates the data analysis, section 4.9 discusses research quality, section 4.10 describes the ethical considerations, and section 4.11 presents the chapter summary. Given such an outlay, it is essential to refer to Saunders et al. (2019) research onion to make the research methodology chapter valuable. The arguments of Melnikovas (2018) posit that the methodological basis should have a firm foundation depicting strategies and philosophies towards inquiry of a phenomenon. Such strategies and philosophies have a basis in various research models, such as the research onion of Saunders et al. (2019).

4.2 Research Onion

The works of Melnikovas (2018) argue that a research onion is a theoretical concept for constructing a research methodology with practical stages for accomplishing an effective method and research by extension. In business management research, a research onion is a widely acceptable research model (Al Zefeiti & Mohamad, 2015; Melnikovas, 2018). This study adopts Saunders et al. (2019) thinking based on the research onion.

The research onion helps to delineate a proper methodical strategy. This is towards accomplishing the objectives of the phenomena under inquiry. Figure 4.1 shows a diagrammatic representation of Saunders et al. (2019) research onion. The outer parts of the onion show the philosophical considerations, and the inner parts show the practical considerations (Saunders et al., 2019). This chapter discusses each layer of the onion in the subsequent sections, indicating its significance to the study.

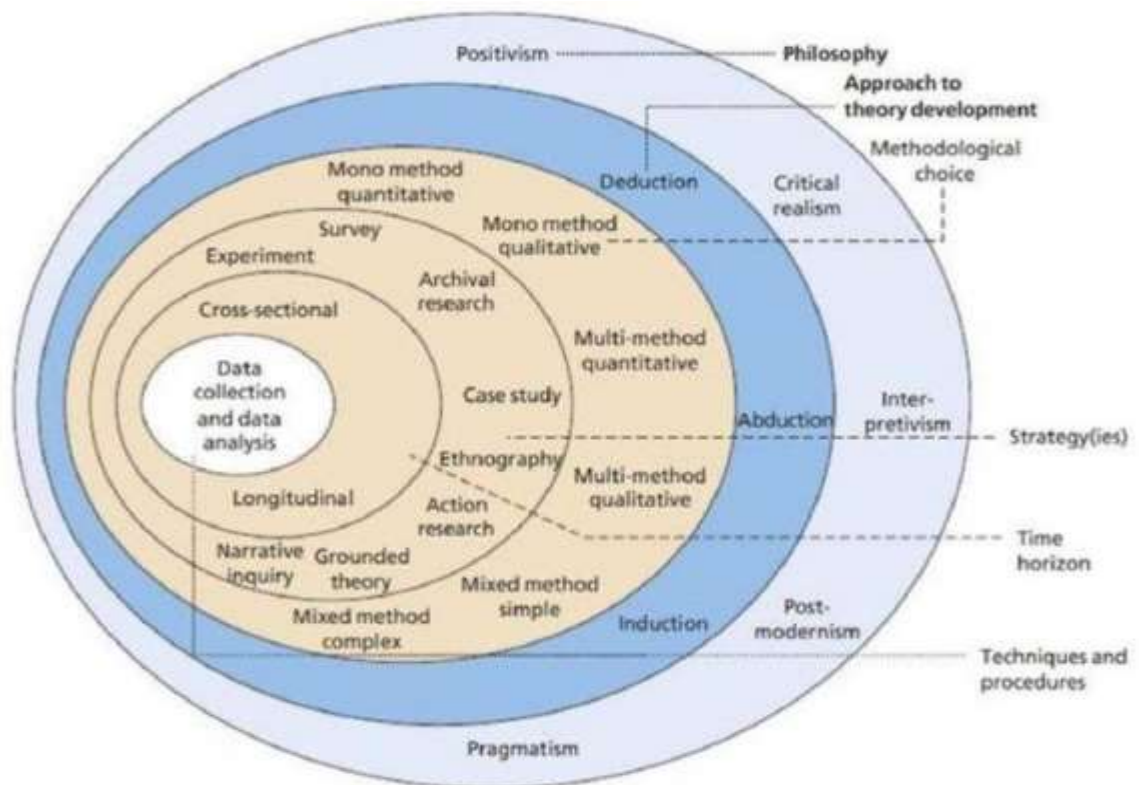


Figure 4.1: Research Onion (Saunders et al., 2018, as cited in Saunders et al., 2019, p.130)

4.3 Research Philosophy

The contention of Ihuah and Eaton (2013) affirms that the philosophical perspective of things is imperative to the real meaning of research methodology. Research philosophy mirrors the worldview of things and acknowledges the conventions that reinforce the research design and the approaches selected as part of the research model (Saunders et al., 2016). Al Zefeiti and Mohamad (2015) contend that a research philosophy is a set of beliefs and assumptions on collecting and analyzing research data for meaningful interpretation. Saunders et al. (2009), Mills and Birks (2014) and Creswell (2014) argue that a research philosophy can be comprehended through different worldviews: epistemology, ontology, and axiological.

Ontology explains an individual's perception of the existing assumptions on reality and the worldview of things (Creswell, 2014). In addition, Pessu (2019) argues that ontological assumptions are based on the belief that our observations are based on the nature of understanding realism. Epistemology describes the phenomenon's knowledge, meaning, and reality concerning what the researcher knows and how the researcher seeks to gain such knowledge (Mills & Birks, 2014; Creswell, 2014). Besides, Crotty (1998) asserts that epistemology is about what we know as truth and how we know it. Axiology is immersing oneself in the value and ethical system of the research process (Saunders et al., 2009). Each of these philosophical stances has philosophies attached to them.

According to Al Zefeiti and Mohamad (2015), positivism, realism, interpretivism, and pragmatism are the most common. Saunders et al. (2019) show extensions of these philosophies to reflect positivism, critical realism, interpretivism, postmodernism, and pragmatism. Also, Saunders et al. (2019) argue that these philosophies are seen in the first part of the research onion (figure 4.1), depicting the importance of first processing the research philosophy for an effective research methodology. In the context of this study, comprehension of the research philosophy is a defining guide to the choice of the strategy of inquiry. Figure 4.2 presents a comprehensive summary of positivism, critical realism, and interpretivism, as Saunders et al. (2019) depict. Beyond these philosophies shown in Figure 4.2, the postmodernist and pragmatic ideologies are equally crucial in comprehending a methodology structure for research. Postmodernism underpins what counts as truth through in-depth investigations and primarily qualitative studies (Saunders et al., 2019). Pragmatism looks into value-driven research and seeks the practical meaning of inquiries (Saunders et al., 2019).

4.3.1 Ontological and Epistemological Concerns in Business Management

The works of Antwi and Hamza (2015) argue that most research has been anchored on either positivism or interpretivism in business research. Antwi and Hamza (2015) further postulate that such thinking exposes the shortcomings of each paradigm and thus calls for a combination of both in business research. Also, the quality assessment is divergent for the positivists and interpretivists. The choice of either philosophical stance lies in the nature and objective of the research. While research quality issues for positivists are anchored around generalizability, precision, objectivity, reliability, and validity (Robinson & Tolley, 2004), those of interpretivism are anchored on trustworthiness and credibility. Such concerns open up to the inherent foundations of positivist and interpretivist thinking and their convergence as a valuable tool for enhancing business research where applicable.

Figure 4.2 presents the philosophical structure and different paradigms per Saunders et al. (2019). Looking into the works of Creswell (2014), Antwi and Hamza (2015), and Saunders et al. (2019), the majority of business research holds either positivist or interpretivist views. However, with inherent weaknesses in each view, Creswell (2014) argues that embracing both views becomes essential. It is also important to note that while a convergent outlook of positivism and interpretivism seems ideal, researchers should be cognizant of deriving the actual value of the research following philosophical stances that apply to the research questions under investigation. In addition, with recent developments and critics of positivist philosophy, positivism and interpretivism, which some scholars call post-positivism, emerged as modern and vital philosophies to tend to the shortcomings of either positivism or interpretivism. However, researchers should always note that it may be impractical to solve all the shortcomings of one philosophical stance using another. With such understanding, sections 4.3.2 and 4.3.3 provide a brief account of positivism and interpretivism as foundational paradigms in business research and for this study by extension.

4.3.2 Positivism

According to Antwi and Hamza (2015), the positivist research paradigm has foundations in the thinking of a French philosopher, August Comte, who argues that human behavior comprehension is pegged on observations and experiments. This means that such observations and experiments need to be objective. Antwi and Hamza (2015) further theorize that positivists typically generate a quantifiable system of generating knowledge from units of analysis. In the arguments of Wilsham (1995), positivism is anchored on facts, which means such a paradigm is deeply rooted in the determination of measurements for objectivity (Antwi & Hamza, 2015).

4.3.3 Interpretivism

The works of Wilsham (1993) hypothesizes that the interpretivism paradigm looks at the worldview of things from a subjective notion where there are no wrong or right theories. According to Antwi and Hamza (2015), interpretivism is more into drawing meaning for subjects under investigation rather than measurements. This means that interpretivists look into drawing meaning subjectively from the research subject.

4.4 Research Approach

According to Saunders et al. (2019), research approaches are commonly classified into deductive, inductive, and abductive, as per the second part of the research onion (figure 4.1).

Based on the research orientation of most business research studies, this study aligns itself with only deductive research reasoning based on positivist thinking. As such, Malhotra (2017) argues that deductive reasoning is based on the perspective of drawing facts from research. This resonates with the positivist thinking style of drawing meaning using a scale of measurements with objectivity in mind. Inductive reasoning seeks to draw subjective judgments from research (Malhotra, 2017), which resonates with interpretivism, as shown in Figure 4.2. That said, deductive reasoning was considered for this study based on the nature of the study, which sought to draw meaning using a quantifiable measurement scale.

Ontology (nature of reality or being)	Epistemology (what constitutes acceptable knowledge)	Axiology (role of values)	Typical methods
Positivism			
Real, external, independent One true reality (universalism) Granular (things) Ordered	Scientific method Observable and measurable facts Law-like generalisations Numbers Causal explanation and prediction as contribution	Value-free research Researcher is detached, neutral and independent of what is researched Researcher maintains objective stance	Typically deductive, highly structured, large samples, measurement, typically quantitative methods of analysis, but a range of data can be analysed
Critical realism			
Stratified/layered (the empirical, the actual and the real) External, independent Intransient Objective structures Causal mechanisms	Epistemological relativism Knowledge historically situated and transient Facts are social constructions Historical causal explanation as contribution	Value-laden research Researcher acknowledges bias by world views, cultural experience and upbringing Researcher tries to minimise bias and errors Researcher is as objective as possible	Retroductive, in-depth historically situated analysis of pre-existing structures and emerging agency. Range of methods and data types to fit subject matter
Interpretivism			
Complex, rich Socially constructed through culture and language Multiple meanings, interpretations, realities Flux of processes, experiences, practices	Theories and concepts too simplistic Focus on narratives, stories, perceptions and interpretations New understandings and worldviews as contribution	Value-bound research Researchers are part of what is researched, subjective Researcher interpretations key to contribution Researcher reflexive	Typically inductive. Small samples, in-depth investigations, qualitative methods of analysis, but a range of data can be interpreted

Figure 4.2: Philosophical Structure (Saunders et al., 2019)

4.5 The Philosophical Stance for this Study and the Strategy of Inquiry

This study implemented a quantitative research methodology as a strategy of inquiry. The works of Tashakkori and Teddlie (1998) and Creswell (2014) argue that pragmatism research methodology entails an integration of multiple research methodologies underpinning the combination of qualitative and quantitative research, which seems ideal for most research, but caution should be applied.

With such discussions, it is essential to understand that all research methodologies have biases (Sieber, 1973) which unfold their inherent weaknesses. As such, combining methodologies

works towards bringing together the strength of individual approaches, and while this is important, the nature and objective of research determines the best strategy of inquiry where researchers should determine the direction the research relies heavily on, whether quantitative or qualitative. According to Kothari (2004; Kumar, 2011), a research design is a conceptual strategy depicting the research structure. It also plans on how to get maximal information for the research questions.

That said, quantitative research design fundamentally follows a deductive approach. As previously discussed in section 4.4 and as per the arguments of Mitchell (2018), the deductive reasoning approach to research entails the view from a generalized perspective to a narrow perspective, while the inductive reasoning approach entails the view from a narrow perspective to a generalized perspective. For this study, a deductive approach was applied pragmatically through quantitative data interpretation, which seemed ideal for comprehending the influence of green and closed-loop supply chain management on the resilience and sustainability of SCs, underpinning an explanatory research design.

Methodologically, this study adopted an explanatory research design that seeks to follow a quantitative structure (Creswell, 2014). The structure begins with the collection of quantitative data, analysis and interpretation of the data, and then the use of the quantitative interpretations to discuss the findings against prior scholars' findings. This study settled on explanatory research design because the area of green and closed-loop supply chain management for achieving resilient sustainability is fragmented. This makes this research design ideal for getting general views and drawing facts from the unit of analysis to make inferences. For this study, green and closed-loop supply chains, resilient sustainability, and the effect of green closed-loop supply chains on resilient sustainability were first explored through a questionnaire for in-depth investigations around this phenomenon.

4.6 Target Population, Sample Size and Sampling Procedure

A research population is an entire unit of analysis under consideration (Kothari, 2004; Saunders et al., 2016), which provides information for answering questions on a given phenomenon. Besides, Kothari (2004) argues that the research population offers grounds for generalizing findings. This study initially focused on 329 manufacturing businesses in a Sub-Saharan African context, depicting a specific bias toward Kenya. The 329 manufacturing businesses were derived from the Kenya Association of Manufacturers (2019/2020/2021).

The study within the Kenyan Nairobi setting under the Sub-Saharan African context focused on the Nairobi industrial zone. The Nairobi industrial zone was of interest due to its more significant share in manufacturing compared to other industrial zones. Besides, the Nairobi industrial zone has advanced manufacturing systems. Under the Kenya Association of Manufacturers, Nairobi has four industrial zones. The zones are Machakos, Thika, Ruaraka, and the Nairobi industrial zone. The study looked into six sectors (food/beverage, building/mining/construction, chemicals/allied, energy/electrical/electronics, cosmetics and pharmaceuticals). The sectors were chosen due to their high greenhouse emission intensity. For instance, according to our world data, energy has a higher greenhouse gas effect, at 73.2% globally (Ritchie & Roser, 2020). The energy GHG emitter percentage includes energy used to process activities in other sectors.

For instance, energy use in various sectors sits at chemical (3.6%), building (17.5%), transport (16.2%), metal (7.2%) and food (1%). Energy use in chemical processing sits at 3.6%, and direct industrial processes for chemicals include manufacturing pharmaceuticals and cosmetics. Also, emissions from energy production sit at (5.8%) and cement at (3%). This highlights the urgent need to hotspot such sectors for implementing GCLSCM toward resilient, sustainable economies. Besides, the pandemic world denotes that food, chemicals, cosmetics, pharmaceuticals, energy, building/construction/mining, and metal are vital sectors toward the support of humanity in a COVID-19 world. This is evidenced by the mandatory use of sanitizers, disinfectants, facial masks, tissue papers, and other toiletries, treatment for COVID-19 and the massive use of energy for their production, and, of course, the consumption of food that always remains a default for man's existence. Mining, building, and construction materials are essential to expanding healthcare facilities, particularly during outstretched emergencies like COVID-19—finally, the use of metal through the need for medical equipment.

Out of the 329 manufacturing businesses, 66 (35 in Food and 31 in Chemicals) were in distribution (46 (22 in food and 24 in chemicals) and mixing (20). However, the researcher noticed that the 20 mixing companies (13 in food and 7 in chemicals) also had production processing in place, and thus, they were included in the study. As such, the study excluded 46 firms purely in the distribution space without a production aspect. This reduced the target population to a sample size 283 (329-46). Ordinarily, the final sample size for this study should sit at 283, as indicated earlier. However, 34 companies (within food (15), chemicals (13), pharmaceuticals (1), cosmetics (1), energy sectors (0), and building/construction/mining (4) indicated that their company policy did not allow research of whichever type to be conducted in their premises.

In this context, the researcher called the managing directors of these companies for a deeper understanding of the company research policy. The conversations yielded positive results in which, out of 34 companies, 28 (15 in food and 13 in chemicals) agreed to participate in the study, which they found was not limited to their company research policy. Their company research policy was against individual firms spying on competitors in the form of research. They agreed to participate since they realized the study was on academic terms. On the contrary, the companies (6) within pharmaceutical (1), cosmetic (1), and building (4) maintained the position of their company research policy, not participating in research of whichever kind. With such comprehension, the study considered their claims based on the ethics around research that allows participants to participate in a willful nature. This again brought the sample size down to 277 (283-6). Further, companies with an orientation to other industrial zones were eliminated.

Some listings denoted contact in the Nairobi industrial zone; however, when calling, the researcher realized the companies were no longer in that zone and thus eliminated them. In total, 39 companies (20 in food, 2 in building, 10 in chemicals, 5 in energy, 0 in cosmetics, and 2 in pharmaceuticals) were excluded from the study since they were not based in the Nairobi industrial zone. This brought the sample size down to 238 (277-39). Also, in the data collection process, especially in the years 2020/2021, most companies had to close down due to the COVID-19 pandemic. In total, 20 companies (13 in food and 7 in chemicals) had closed down their production, and the majority only had the guards and one point of contact still at the company premises. The companies that had sister branches in the other industrial area zones still existed with the belief that their sister companies would bail them out.

Omitting the 20 closed-down companies out of the research, the sample size was reduced from 238 to 218 (238-20). Fifty-nine companies under the list were nonexistent. The researcher noted a peculiar trend for companies enlisted within Enterprise Road A. The researcher personally did a round trip to assess the actual location of these companies to no avail. An example was a company that enlisted a long enterprise road A that did not exist. The researcher took a further step and engaged the motorcycle operators of different regions of the 59 non-existing companies to help locate the firms. The motorcycle operators were engaged because they knew the area's jurisdiction sufficiently. The companies did not exist. With such findings, the researcher noticed the need for data streamlining and updates from the policymaker for research activities such as this to be valuable. Also, their numbers in the directory were not going through, and for some that went through, the researcher noticed that they were owned by individuals who were surprised that their numbers were enlisted as companies.

With that, the 59 companies were eliminated, bringing the final sample size to 159 (218-59) manufacturing businesses in a Sub-Saharan African economy depicting the Kenyan Nairobi industrial zone setting. This study provides additional inclusion/exclusion criteria and justifications for the above sampling procedures to enhance further the target population's credibility and the sample size's credibility and trustworthiness. First, the study looked into manufacturing businesses in pure production and mixing. This analogy is supported by Cooper et al. (1997) description of a typical supply chain. The pure production orientation further demonstrates the centrality of manufacturing within supply chains, showing an orientation of branching upstream for the sourcing of materials and downstream for the distribution of end items. Second, the study excluded manufacturing businesses with a strict research policy not allowing research on their premises. This particular criterion had an exception where the researcher took a further step to understand the clauses of the manufacturing businesses. It was noted that most such businesses feared competitor firms spying on them in the name of research.

For a substantial percentage of firms that the researcher engaged with a company policy prohibiting research; out of 34, 28 accepted to engage in research and thus included. Third, this study only considered manufacturing businesses that existed during the study period. The businesses that had closed down were not considered. This study considered manufacturing businesses that must have existed for more than one year for stability and have gone through their financial period denoting stability. Further, the study looked into manufacturing businesses that must have some degree of sustainability practice. This was supplemented by exploring their websites and preliminary assessments before data collection. All 159 manufacturing businesses met this criterion. Finally, manufacturing businesses interlinked with other industrial zones were excluded since they did not depict the Nairobi industrial zone. Given the nature of the study, no further sampling procedures were conducted. This is supported by the study's orientation towards the law of large numbers and statistical regularity. Both laws allude to large samples being better than small samples. Under the above observations, it is then authentically right to argue that this study utilized a multi-stage and judgmental sampling approach.

4.7 Data Collection Methods and Procedures

4.7.1 Ethical Clearance

Regarding data collection, the institution of research permitted the execution of this study through field research, of which the study first sought ethical clearance from the institution of study. Further, to collect data in Kenya, the national research statutory requirement under the Science and Technology Act (chapter 250 of the Kenyan law) emphasizes that one needs to get a clearance permit from the National Commission for Science, Technology, and Innovation. The purpose of this institution is to offer guidance on matters about research, among other aspects. Obtaining this research permit entailed filling in an application form with payment of Kenyan shillings 2,000 with the attachment of required documents (University research permit, copy of the research protocol, curriculum vitae, a letter of admission as a Ph.D. candidate, copy of Identification Number and a passport size photograph).

The process was done twice (2019-2020/2020-2021), given the nature of the study in which companies were unwilling to participate, thus taking longer. Each of the applications took about 1-2 weeks. After receipt of the clearance permit, a call was made to the county commissioner of education, county director, and county governor office of Nairobi County to inform them of the research exercise stipulated under condition three as guided by science, technology, and innovation regulations of 2014.

4.7.2 Pilot and Feasibility Analysis

The study started with a pilot investigation of 30 manufacturing businesses in a Sub-Saharan African context (Nairobi industrial zone in Kenya). The 30 companies were distributed across food, chemical, pharmaceutical, building/construction/mining, electrical/electronic/energy, cosmetics, and mining. The results of the pilot study pointed out the need to expand the survey questions in a manner that can be understood and measurable by the research respondents. Also, the pilot study results communicated the need to simplify concepts for easier comprehension. Finally, the pilot study results reported a need to incorporate research respondents from the occupational health and safety, quality assurance, and environmental functions, as the majority dealt directly with the study's pertinent issues.

4.7.3 Data Collection

The study employed primary collection data methodology. Primary data collection was conducted through the use of questionnaires and website explorations. The study used both structured and unstructured questionnaires.

However, only the structured part of the questionnaires was utilized for analysis since respondents notified the researcher of the longevity of the questionnaire, and open-ended questions were eliminated. Even though the demographic section was maintained. The questionnaires were self-administered physically and through Google Forms. The website explorations were done by reviewing the 159 company's websites. Upon reaching the study participants, the researcher developed a list of the sample size, defined the sampling frame for this study, and tabulated it with the target respondents' contact list (managing directors and front office phone contacts and email addresses). This was mined from the target population's source, the Kenya Association of Manufacturers Members Directory (2019/2020/2021). With this, the researcher had first to call the managing director or front office personnel using the phone numbers in the association directory.

Most of the time, the contacts for the managing directors and researcher would be connected through the front office line. From the front office line, the researcher would be connected directly to the concerned respondents (procurement, supply chain, logistics, inventory, finance, accounts, human resource, managing directors, chief executive officers and marketing, occupational health, production, environmental, and quality assurance experts) and in some instances through the human resources function for permission to partake the study within the company premises. On getting hold of the relevant respondent, the researcher would request authorization and consent for participation, of which some agreed to fill out a Google form, and some asked for physical copies. On average, getting feedback would take between two weeks and three months. In addition, data on business size was mined from the respective manufacturing businesses' websites to control for resilient sustainability.

4.7.4 The Research Instrument Preliminaries

This study was biased toward the general supply chain and other networks regarding quality, environment, and occupational health. In essence, the target respondents cut across supply chain specialists, procurement specialists, logistics specialists, production specialists, marketing specialists, accounting/finance specialists, and managing directors who conducted the procurement processes themselves.

This explains the triadic orientation of the study of being fully cognizant of manufacturing as the focal point of SCs connecting to other networks. As previously indicated, the researcher used both physical questionnaires and Google Forms. The structure of the questionnaire had a demographic section and closed-ended Likert items.

The study utilized a six-point Likert scale where one strongly disagrees, two disagree, three slightly disagree, four slightly agree, five agree, and six strongly agree. This particular Likert scale was employed to eliminate the error of central tendency. Green and Rao (1970) state that a six-point and 7-point Likert scale increases information retrieval. In addition, Preston and Colman (2000) argue that a 9-point Likert scale shows high levels of validity. Also, Preston and Colman (2000) further argue that similar validity is achieved at the Likert scales of 5 and above. Preston and Colman also conclude that a Likert scale informs higher convergent validity with more (6 or more) responses. To that effect, this study utilized a six-point Likert scale.

4.7.5 Questionnaire Development and Measurement

This study utilized 83 measurement items: 17 for resilient sustainability, 63 for green and closed-loop supply chains, and three for internal environmental management derived through an extensive review of the extant literature. The measurement items were newly developed through mining of their indicators from previous works, as shown in table 4.1. Different contexts reveal different results and therefore it is important to be careful on the measurement items. Besides, given the dual combination on both the dependent (resilience and sustainability) and independent (green and closed-loop supply chain considering circular economy) variables, it was important to carefully select indicators and develop a survey suitable for the phenomena under study. The 17 factors relate to resilient sustainability, resilience with nine factors, environmental sustainability with three factors, economic sustainability with two factors, and social sustainability with three factors. The 63 factors relate to CLSCM, green design (9), green procurement (7), green manufacturing (17), green logistics (22), and reverse logistics (8), and the three factors relating to IEM. Table 4.1 shows the details of the measurement items.

Table 4.1: Survey Instrument Items

Measure	Indicator	Author and Year
Green Design/ Design for the Environment (9)	<ol style="list-style-type: none"> 1. Dematerialization 2. Design for disassembly 3. Design for recyclability 4. Design for recoverability 5. Design for regulatory compliance 6. Design for no or less hazardous ingredients in materials 7. Design for easier 8. ISO Certified 9. Substitutability 	<p>Kumar & Kumar, 2013 Saeed et al. 2018 Khan et al., 2022 Qalati et al., 2022</p>
Green Procurement (7)	<ol style="list-style-type: none"> 1. Procuring materials with greater energy and water efficiency 2. Procuring materials that utilize clean energy and technology 3. Procuring materials with controlled use or an absence of toxic substances 4. Procuring materials improves recycling ability 5. Procuring materials with minimal packaging needs 6. Procuring materials with extended durability 7. Supplier audits 	<p>Govindan et al., 2014 Khan et al., 2022 Qalati et al., 2022</p>
Green Manufacturing (11)	<ol style="list-style-type: none"> 1. Reduction of water/energy use 2. Use of recyclable and biodegradable materials 3. Use of less toxic materials 4. Just-in-time manufacturing 5. Employee/stakeholder safety measures 6. Employment of work schedules of shifts 7. Provision of protective gear for safety 8. Recycling/reuse of water 9. Working towards zero defects 10. Cleaning Equipment 	<p>Chin et al. 2015 Mohamed et al. 2018 Khan et al. 2022 Qalati et al. 2022 Jaca et al. 2015 (5S) Chen et al. 2019 (TPM)</p>

	11. Servicing Equipment	
Green Manufacturing (6)	<ul style="list-style-type: none"> 12. The existence of a maintenance department 13. Sorting 14. Setting in order 15. Shine 16. Standardize 17. Sustain 	<p>Chin et al. 2015 Mohamed et al. 2018 Khan et al. 2022 Qalati et al. 2022 Jaca et al. 2015 (5S) Chen et al. 2019 (TPM)</p>
Green Logistics (22)	<p>Green Transportation (6)</p> <ul style="list-style-type: none"> 1. Direct deliveries 2. Well-planned vehicle routes 3. Energy efficient vehicles 4. Grouping orders for the same destination together 5. Well-temperature-controlled systems 6. Keen on good disposal of vehicles 	<p>Govindan et al. 2014 Saeed et al. 2016; 2018 Qalati et al., 2022</p>
	<p>Green Warehousing (7)</p> <ul style="list-style-type: none"> 7. Reusing older facilities 8. Efficient space usage 9. Energy/water saving and Improved indoor air quality 10. Usage of sensor bulbs and doors 11. Well-coordinated labelling of inventory 12. Training of workforce 13. Warehouse waste management 	<p>Bartolini et al. 2019</p>
	<p>Eco-Packaging and Labelling (9)</p> <ul style="list-style-type: none"> 1. Downsizing packaging 2. Recycling/reuse of packaging 3. Standardized packaging 4. Materials with natural texture for its packaging 5. Packaging that is easier to open and store and use less space 6. Keen on good labeling 	<p>Chin et al. 2015</p>

	<ol style="list-style-type: none"> 7. Use of natural colors for packaging 8. Use packaging that is free of excess layers 9. Second life packaging 	
Reverse Logistics (8)	<ol style="list-style-type: none"> 1. Reusing 2. Reduction 3. Recycling 4. Refurbishing 	
	<ol style="list-style-type: none"> 5. Remanufacturing 6. Product return collection centres 7. Product return awareness platform for customers 8. Supportive to customers for product return 	Souza, 2013 Govindan et al. 2014;2015 Qalati et al., 2022
Adaptability (3)	<ol style="list-style-type: none"> 1. Your supply chain plans for uncertainties by developing a risk register 2. Your supply chain reacts to risk disruptions through environmental supply chains 3. Your supply chain adapts quickly to a disruption 	Wieland & Wallenburg, 2012
Robustness(1)	<ol style="list-style-type: none"> 1. Your supply chain is careful in the selection of environmental supply chains for managing risk disruptions 	Christopher & Peck, 2004 Tukamuhabwa et al. 2005 Wieland & Wallenburg, 2012
Agility: (2)	<ol style="list-style-type: none"> 1. Your supply chain responds very quickly to disruptions 2. Your supply chain understands the status of its supply chain environment and assets 	Christopher & Peck, 2004 Tukamuhabwa et al., 2015 Fiksel, 2013 Juttner & Maklan, 2011 Erol et al. 2010 Wieland & Wallenburg, 2012
Risk Management Culture (3)	<ol style="list-style-type: none"> 1. Your supply chain identifies areas of risk exposure 2. Your supply chain prepares on how to cope with foreseeable uncertainties 3. Has a formal risk management plan 	Gunasekaran et al. 2015 Erol et al. 2010

Economic Sustainability (2)	<ol style="list-style-type: none"> 1. Keen on achieving the lowest total cost of ownership across the supply chain (reduction in costs) 2. Keen on efficient resource utilization 	Kates Et al.2006 Emas, 2015
Environmental Sustainability (3)	<ol style="list-style-type: none"> 1. Keen on achieving near zero carbon emissions (reduction of carbon emissions) 2. Keen on achieving near zero waste (reduction of waste) 3. Keen on Climate Resilience 	Kates et al. 2006 Emas, 2015
Social Sustainability (3)	<ol style="list-style-type: none"> 1. Keen on the safety of its employees 2. Keen on the health of its employees and customers 3. Keen on fair selection of employees 	Kates et al. 2006 Emas, 2015
Internal Environmental Management (3)	<ol style="list-style-type: none"> 1. Building Trust 2. Information Sharing 3. Transparency 	Beamon, 2005 Mafini & Loury-Okoumba, 2018

4.7.6 Research Questionnaire Design Reflections

The design of the research questionnaire unfolded many issues:

1. *Gender, position, and department of work:* Most participants had mixed reactions to providing information about their gender, position, and department. Some respondents argued that there would be no need to request such data if the research were promising anonymity. The researcher offered clarity that every supply chain or organization has such specialists within their structures. It would be easier to identify the respondent if someone knows the company's name.
Most respondents welcomed the researcher's response positively, except for a few who requested not to provide such information.
2. *Asking for green and closed-loop supply chain information:* Most respondents hesitated to give information on this aspect. The researcher had to call several times and do follow-ups. The respondents feared that the researcher would be an agency for the government under the environmental arm spying in the form of research. The researcher provided clarity and used official emails to build the respondent's confidence and trust. This was also supported by the University's ethical permit and the National Commission of Science and Technology research permit.
3. *Design of the Research Questionnaire:* Some respondents noted that they did not like the design of the research questionnaire in terms of longevity. However, each of the sections had a purpose reflecting the research objectives.

4.8 Data Analysis

The nature of the study demanded a dichotomy branching of research analysis into descriptive and structural equation modeling. Statistically, the study conducted a holistic descriptive sense-making of all research objectives. This led to partial least Squares-structural equation modeling analysis for relational objectives. The PLS-SEM analysis presents both the measurement and structural model analysis. Both descriptive and PLS-SEM statistical analysis have been conducted through the SMART- PLS software version 4.0, further emphasizing descriptive comparative analysis on the STATA software, version 17.

4.8.1 Statistical Data Analysis

Statistically, the study employed descriptive analysis (percentages, mean, standard deviation, kurtosis, and skewness) and partial least squares structural equation modeling (PLS algorithm, PLS bootstrapping, and PLS predictive relevance).

4.8.2 The Analytic Tool, Structural Equation Modelling

With complexities in handling multiple indicator data, multivariate analysis techniques have proved efficient for the practical sense-making of data. According to Mengual-Macennle et al. (2014), multi-variate analysis techniques are a family of statistical methods for data analysis in case of multiple variables to draw meaning out of complex datasets and various variables. Multi-variate analysis techniques come in two generations (first generation and second generation). The first-generation multi-variate analysis techniques, such as regression analysis, have been argued to face difficulties in running analyses of many multiple research variables (Elangovan & Rajendran, 2015). First-generation multi-variate analysis techniques have to run models several times with different combinations in case of multiple variables to reach a satisfactory conclusion, which is cumbersome. In addition, hair et al. (2021) argue about the shortcomings of first-generation multivariate analysis, such as the simple model structure theory, considering all variables as observable and the presumption that variables are measured without error.

To overcome these limitations, Cole and Preacher (2014) postulate that second-generation multivariate analysis (Structural Equation Modeling) can model complex structures with multiple dependent and independent variables, consider unobserved variables, and consider the measurement error in observed variables. Such observations show how the advancements in research and data analytics point out the need to examine the interaction of multiple variables with sophisticated and robust statistical techniques. Structural equation modeling (SEM) has been argued to be an excellent second-generation multi-variate analysis technique (Elangovan & Rajendran, 2015), which can handle complex models in a systematic and logical sequence and thus address the first-generation statistical technique inadequacies.

In four approaches, SEM presents itself: covariance-based (CB-SEM), partial least squares (PLS-SEM), component-based, non-linear universal structural, and relational modeling (Wong, 2019). CBSEM is utilized to confirm or reject hypotheses when the sample size is large and the data is normally distributed (Hair et al., 2011). Accurate data is rarely normally distributed and industry-specific in developing economies, constituting smaller sample sizes.

In such instances, partial least squares structural equation modeling becomes important to complement (Barroso et al., 2010) the statistical capability of CBSEM. Besides, Peng and Lai (2012) argue that using PLS-SEM when using CBSEM will likely lead to estimation challenges. PLS-SEM has been chosen for this study since it can assess multi-level analysis, such as moderation effects, without inadmissible solutions. Peng and Lai (2012) posit that assessing multi-level analysis in CBSEM leads to increased parameter estimates, creating model identification and convergence challenges. PLS-SEM utilizes an iterative solution algorithm to solve different blocks of the measurement model individually for structural path coefficient estimates (Peng & Lai, 2012). This enables PLS-SEM to estimate highly complex models better than CBSEM so long as adequate sample size is utilized to estimate the most complex structural relationships in the model.

4.8.3 Partial Least Squares Structural Equation Modelling (PLS-SEM)

According to Vinzi et al. (2010), PLS-SEM aims to estimate relationships among research constructs. PLS-SEM is a second-generation multivariate analysis technique that handles relationships among constructs without data distribution assumption. Wong (2019) argues that PLS-SEM is an efficient statistical relationship technique that can be used when the sample sizes are small when data is not normally distributed, and when the research seeks to assess the predictive capability of research variables. PLS-SEM literature argues for a minimum sample size based on the number of arrows pointing to a latent variable and thus calls for proper estimation to achieve significant statistical power.

4.8.4 Sample size determination for PLS-SEM

Sample size estimation is essential in achieving the statistical power of research. This study used G* power 3.1.9.4 to determine the sample size given four primary and five total predictors for the research model. The sample size estimation was calculated with a basis to Cohen (1988) and Hair et al. (2014) based on the effect size, statistical power, minimum coefficient determination (R^2) used in the model, and the maximum number of arrows pointing to a latent variable. Cohen (1988) and Hair et al. (2014) argue that a good statistical power sits at 0.8 under the effect size of 0.15, an error of probability of 1-0.05, and a beta value (alpha less) of 0.95. For four predictors (4) and five total predictors (5), the sample size was estimated through an F-test under multiple linear regressions (of which PLS-SEM imitates) of fixed model R^2 increase. This was done through a three-level G-power test to determine the most appropriate sample size for the study.

First, a G-power test was conducted under a statistical power of 0.95, the highest possible statistical power, which reflected an appropriate sample size of 129 observations. Second, a G-power test was conducted under the threshold statistical power of 0.8, yielding a sample size of 85 observations. For the robustness check, a mid-level G-power test was conducted under a statistical power of 0.87 $(0.95+0.80/2)$, yielding a sample size of 100 observations.

Looking at the three tests, this study utilized the mid-level statistical power of 0.87, which yielded a sample size of 100 observations, proving ideal for conducting structural equation modeling. Figure 4.3 shows the G-power test results. According to Cohen's (1988) table, five total predictors (resonating to the number of arrows pointing to a latent variable) show a sample size of 70 to achieve a reasonable statistical power of 0.8 and above. Besides estimating the sample size at 0.8 statistical power using G^* 3.1.9.4, this study found a sample of 85 observations. This means that the estimated sample size of 85, giving a statistical power of 0.8, is sufficient. Statistically arguing then and based on Cohen (1988), using 100 observations as a sample size in this study gives a higher statistical power above the estimated sample size of 85 and the suggested sample size as per Cohen's (1988) table. Besides, Hoyle (1995) argues that reasonable sample estimations should range between 100 and 200 for statistical significance.

4.8.5 Use of PLS-SEM Justification in this Study

For a long time, covariance-based SEM has been a method of choice in data analysis using second-generation multi-variate analysis (Hair et al., 2021). However, PLS-SEM has also gained popularity in various disciplines, such as marketing and management information systems and, more significantly, business management (Hair et al., 2014). PLS-SEM looks into the prediction of research variables by constructing measurement and structural models and can handle complex models (Hair et al., 2014). Compared to covariance-based SEM, PLS-SEM has the advantage of conducting predictive capability better than covariance-based SEM (Hair et al., 2014). Besides, PLS-SEM handles non-normal data better than covariance-based SEM.

From a softer modeling perspective, PLS-SEM has also been argued to manage smaller sample sizes better with better predictive power than covariance-based SEM. For those reasons, this study utilizes PLS-SEM based on *Data records=100 data points** predicting the effect of green and closed-loop supply chains on resilient sustainability*. In addition, PLS-SEM has a higher capability for testing the magnitude of moderation effects and effects between multi-group comparisons (Qureshi & Campeau, 2009).

F tests - Linear multiple regression: Fixed model, R² increase

Analysis: A priori: Compute required sample size

Input: Effect size f^2 = 0.15
 α err prob = 0.05
Power (1- β err prob) = 0.87
Number of tested predictors = 4
Total number of predictors = 5

Output: Noncentrality parameter λ = 15.15000000
Critical F = 2.4685330
Numerator df = 4
Denominator df = 94
Total sample size = 100
Actual power = 0.8733055

The screenshot shows the G*Power software interface. The main window displays the following information:

- Central and noncentral distributions** | Protocol of power analyses
- F tests - Linear multiple regression: Fixed model, R² increase**
- Analysis:** A priori: Compute required sample size
- Input:**
 - Effect size f^2 = 0.15
 - α err prob = 0.05
 - Power (1- β err prob) = 0.95
 - Number of tested predictors = 4
 - Total number of predictors = 4
- Output:**
 - Noncentrality parameter λ = 19.3500000
 - Critical F = 2.4447662
 - Numerator df = 4
 - Denominator df = 124
 - Total sample size = 129
 - Actual power = 0.9505747

Below the main window, there are several dropdown menus and input fields:

- Test family:** F tests
- Statistical test:** Linear multiple regression: Fixed model, R² increase
- Type of power analysis:** A priori: Compute required sample size - given α , power, and effect size
- Input Parameters:**
 - Determine =>
 - Effect size f^2 : 0.15
 - α err prob: 0.05
 - Power (1- β err prob): 0.87
 - Number of tested predictors: 4
 - Total number of predictors: 5
- Output Parameters:**
 - Noncentrality parameter λ : 15.0000000
 - Critical F: 2.4685330
 - Numerator df: 4
 - Denominator df: 94
 - Total sample size: 100
 - Actual power: 0.8733055

Figure 4.3: G Power Estimates

Based on the thorough justification of the choice of PLS-SEM (4.8.5) coupled with the sample size estimation for PLS-SEM (4.8.4), it is then statistically authentic to conduct a PLS-SEM analysis. Before the PLS-SEM analysis report, it is right to present the comparison model taxonomy to interpret PLS-SEM results first. According to Hair et al. (2014; Ringle et al., 2015), PLS-SEM analysis and reporting are threefold: model specifications, measurement model (outer), and structural model (inner) analysis and reporting.

On an outer (measurement) model thereof, of most importance (Hair et al., 2014) is the assessment of;

- *Nature of the model (reflective or formative or a combination) = Model specification *
- *Indicator reliability*
- *Internal consistency reliability*
- *Convergent validity*
- *Discriminant validity*

The model's nature (reflective or formative or a combination) is argued to inform the direction of analysis. A reflective measurement scale denotes a scenario where indicators are highly correlated and interchangeable (Hair et al., 2014) without change of meaning. In addition, Wong (2019) argues that in a reflective model, each tetrad should be zero; if any of the tetrads deviate from zero, the model is formative. CTA-PLS looks into testing hypothesis (Wong, 2019) of the nature:

$$H_0: t = 0 \text{ (Reflective)}$$

$$H_a: t \neq 0 \text{ (Formative)}$$

A confirmatory tetrad analysis needs to be conducted to assess the nature of the model.

4.8.6 Confirmatory Tetrad Analysis (CTA-PLS)

Most researchers face difficulties in assessing the nature of the model to be either reflective, formative, or a combination (Wong, 2019). It is essential to determine the nature of the model for results to be valuable. Wong (2019) presents a confirmatory tetrad analysis as an impactful tool to evaluate the nature of the model. Wong goes ahead to document that in software such as SMART PLS, CAT-PLS is inbuilt, whereby reflective models are presented with latent variable arrows pointing to the indicators and formative models with indicator arrows pointing to latent variables. Figure 4.4 shows a diagrammatic representation of the same.



Figure 4.4: Formative and Reflective Models (Adapted from Peng & Lai, 2012)

Softwares such as SMART PLS always present the models as reflective, and as such, it is upon the researcher to change the direction of arrows for formative models.

Looking into CTA-PLS, the confidence interval adjustments (low and up adjustments) reflect the nature of the model being reflective if all tetrads fall within the range of zero.

	CI Low adj.	CI Up adj.		Measurement Model is
If all values are...	-	-	then	formative
If all values are...	+	+	then	formative
If one or more of the values are	-	+	then	reflective

Figure 4.5: Confirmatory Tetrad Analysis Interpretation (Wong, 2019)

If the low adjusted is negative and the up adjusted is positive, then the model is reflective; otherwise, it is formative. After confirmatory tetrad analysis, reliability and validity assessments need to be conducted. Table 4.2 presents the PLS-SEM measurement model interpretation as per Hair et al. (2021).

Table 4.2: PLS-SEM Measurement Model Meaning and Interpretation

Reflective measurement model components	Meaning	Interpretation (acceptable range)
Indicator reliability	Analysis of the degree to which an indicator's variance is explained by its construct.	Indicator loadings => 0.0708 are preferred as the threshold shows the capability of the construct to explain more than 50% of its indicator variance.
Internal consistency reliability	Analysis of the degree to which indicators measuring the same construct are related.	Measured through; Composite reliability (Maximum is 0.95) Cronbach alpha (0.7 or 0.6 in ER) Reliability coefficient rho (0.8-0.9)
Convergent Validity	The degree to which a construct converges to explain an indicator variance.	Measured through; Average variance extracted (> 0.5)
Discriminant Validity	The degree to which a construct is empirically distinct from other constructs in the structural model.	Measured through heterotrait-monotrait (HTMT) ratio (< 0.9)

Reliability analysis checks the reliability from an indicator -indicator reliability and a construct internal consistency reliability (Hair et al., 2021). Validity measures convergent validity using the average variance extracted (Hair et al., 2021). Besides, on a higher level, the heterotrait-monotrait (HTMT) ratio measures the discriminant validity of a construct in comparison to other constructs measures in the same model (Hair et al., 2021). Hair et al. (2021) argue that the next step after this is to evaluate the structural model.

This starts with the assessment of collinearity issues, an evaluation of the significance and relevance of the structural model relationships, and an evaluation of the model's explanatory power and the model's predictive power. Figure 4.6 shows the structural model parameters.

Criterion	Metrics and thresholds
Collinearity	Critical collinearity issues likely occur if $VIF \geq 5$. Collinearity issues are usually uncritical if $VIF = 3-5$. Collinearity is not a problematic issue if $VIF < 3$
Significance and relevance of the path coefficients	Apply bootstrapping to assess the significance of the path coefficient on the ground of t -values or confidence intervals Assess the magnitude of path coefficients Assess the f^2 values for each path and check that they follow the same rank order as the path coefficient magnitude.
R^2 value	R^2 values of 0.75, 0.50, and 0.25 are considered substantial, moderate, and weak. However R^2 values have to be interpreted in the context of the model and its complexity. Excessive R^2 values indicate that the model overfits the data
$PLS_{predict}$	Focus on one fundamental target construct in the analysis. Set $k = 10$, assuming each subgroup meets the minimum required sample size. Use ten repetitions. Compare the RMSE (or the MAE) values produced by PLS-SEM with those produced by the LM for each indicator. Check if the PLS-SEM analysis (compared to the LM) yields lower prediction errors in terms of RMSE (or MAE) for all (high predictive power), the majority of the same number (medium predictive power), the minority (low predictive power), or none of the indicators (no predictive power) Use the DA approach to generate predictions in mediation models.
Model comparison	Select the model that minimizes the value in BIC or GM compared to other models in the set. Compute Akaike weights for additional evidence for a model's relative likelihood.

Figure 4.6: Interpretation of the PLS-SEM structural model (Hair et al., 2022)

Beyond the PLS-SEM model parameter meaning and interpretation, choosing the right software for its analysis is essential. Kumar and Puran (2017) posit that appropriate selection of PLS-SEM analysis software can improve the analysis results.

The works of Hair et al. (2011) emphasize that it is essential to report the software details for an impactful analysis. Temme et al. (2006) present a myriad of softwares for PLS-SEM analysis, such as SMART PLS, Visual PLS, and warp PLS, among many others. Wong (2013; 2021) argues that SMART PLS is a prominent software for running partial least squares structural equation modeling. The SMART PLS software has a friendly user interface and sophisticated reporting features (Wong, 2013) and is thus a good choice for running PLS-SEM. As previously indicated, PLS-SEM has two models (inner and outer). Figure 4.7 shows the structural model representation.

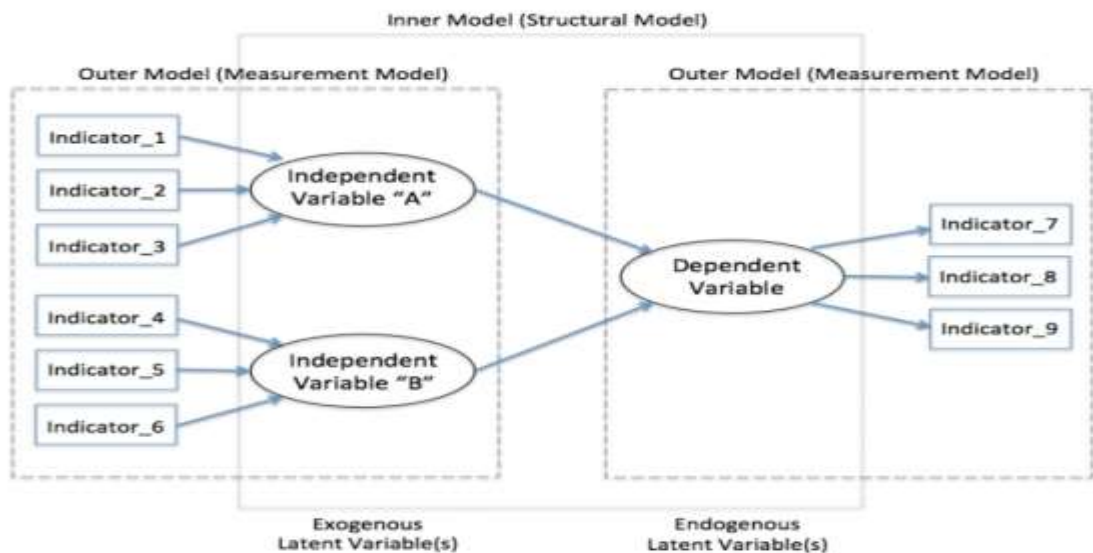


Figure 4.7: PLS-SEM Model Depiction

4.9 Research Quality: Tests for Reliability and Validity

In the arguments of Zohrabi (2013), research quality rests on two central tenets: validity and reliability. Validity entails that the research study evaluates what it promises to assess and is categorized into internal and external validity. According to Kothari (2004), internal validity looks at how the results and findings of the study touch on the target population selection, data recording, and data analysis, while external validity looks at the generalizability of study results to an entire population. This study achieved validity and reliability by employing the triangulation approach (surveys and website exploration). Kothari (2004) argues that reliability aims to ensure the consistency of research instruments in different settings and can be tested using test-re-test, multiple forms, and Cronbach's alpha test.

This study subjected the research instrument to different sectors of the manufacturing industry in Kenya for consistency. Besides, this study conducted the Cronbach alpha, composite reliability, and average extracted variance. The results, as indicated in Chapter Five through the use of the PLS-SEM analytic tool, show that the study achieved reliability and validity. In addition, this study also conducted further robust checks about PLS-SEM that are anchored on testing for non-linearity, endogeneity, and unobserved heterogeneity, as discussed in Chapter Five.

4.10 Ethical Considerations

Ethics is a must-check in academia, practice, and even contemporary society. This study sought not to compromise on ethical principles as documented in moral and humanity literature and ethical principles on logic, reason, and emotion. The study presents findings on their values without any alterations to suit the researcher's interest or hypothesis. Similarly, the study promised confidentiality to research respondents and their companies on the study's findings that may affect their public image. The research participants were informed about the author's intentions to conduct research through a letter of consent, and no participant was forced to provide information; instead, the exercise was based on a willful nature.

4.11 Chapter Summary

This chapter grounds the research strategy of quantitative research methodology with a focus on the explanatory research design using primary data from 159 manufacturing businesses selected using multi-stage and judgmental sampling. A structural equation model is utilized to make sense of the data.

Chapter Five: Presentation of Research Findings

5.1 Introduction

This study sought to investigate building a resilient, sustainable economy through green and closed-loop supply chain management in the context of the circular economic model for manufacturing businesses in a Sub-Saharan African economy. Since chapter four has already laid a concrete methodological foundation for the study, this chapter presents the findings through data analysis results and their interpretation. This chapter presents its core areas into six sections in light of this context. Section 5.1 introduces the chapter. Section 5.2 presents the response rate analysis. Section 5.3 discusses data preparation, and section 5.4 presents the demographic profile taxonomy of the study respondents. Section 5.5 offers the presentation of findings, and section 5.6 presents the chapter summary.

5.2 Response Rate Analysis

One hundred fifty-nine questionnaires were issued to the identified manufacturing businesses that met the inclusion/exclusion criteria. Out of 159 questionnaires, 100 valuable responses were received. An additional 30 responses were received but realized not to be helpful for the study due to a more significant percentage of missing values and thus eliminated. The 100 helpful responses translated to a response rate of 62.8930%, which proved useful for the generalizability of the study to larger manufacturing businesses in a Sub-Saharan African context. For the 30 questionnaires with missing values, it was noted that some experts within the supply chain line did not answer their sections.

In addition, looking into the response rate, a triadic supply chain approach was taken where a minimum of three respondents filled out the questionnaire depicting the typical structural orientation of the supply chain (procurement-production-distribution). To that effect, on average, the participant response rate was 300 (100*3). Such a triadic approach (Jraisat et al., 2021) has been proven to be a better transformation than the dyadic approach. Besides, the supply chain triadic approach assists in dealing with central tendency errors.

5.3 Preparation of Data

As previously discussed, data was collected using a survey and website exploration. The survey data collection was twofold: an online survey (Google form) and a physical survey. Besides, data on business size was mined from the respective manufacturing businesses' websites.

After data collection, the Google forms were downloaded as an Excel file, and the data was streamlined to suit the objectives under study. In addition, the physical survey data was equally keyed into the downloaded online Excel file. The website explored data was equally arranged in line with the respective manufacturing businesses and the survey data (in its column). This then led to the coding of all 100 data records collected.

*Green closed-loop supply chains (Green Procurement & Design for the Environment- GPDF AND GP, cleaner production- CP, green logistics- GL, and reverse logistics- RL) *.

* Resilient Sustainability (Resilience-RES, economic sustainability-EconSus, environmental sustainability-EnvSus and, social sustainability-SocSus) *.

Internal Environmental Management (IEM).

Statistically, assessing the data collected for any missing values, outliers, and normality issues about statistical data distribution before data analysis is right. This study had minimal missing values of less than 5%. According to Scafer (1999), missing values of less than 5% are insignificant toward influencing a particular outcome for a study. Bennet (2001) argues that statistical analysis bias is likely for missing values above 10%. For this study, the missing values then were inconsequential. The few missing values were handled through the imputation method through the forward fill, assuming that respondents could have entered a value similar to their previous value.

On statistical normal distribution, the study assessed the normalcy of the data through measures of symmetry (kurtosis and skewness). This was evaluated under the SMART PLS software version 4. According to Mishra et al. (2019), most analysis techniques assume all data is standard. In addition, the central limit theorem acknowledges that violation of normalcy is never an issue where the sample size is 100 and above (Mishra et al., 2019). Testing for normalcy in its simple sense entails assessing the symmetrical distribution of data through skewness and kurtosis, among other tests. Skewness is a lack of symmetry, and kurtosis is the peakedness of a distribution (Mishra et al., 2019). Statistically, a symmetrical distribution is one in which the mean=mode=median=0, where kurtosis and skewness are zero. However, when there is a departure from symmetry, the distribution experiences excess kurtosis and skewness regarding direction (skewness) and shape (kurtosis).

Table 5.1: Excess Kurtosis and Skewness Values

No.	Indicator	Excess Kurtosis	Skewness	No.	Indicator	Excess Kurtosis	Skewness
1	IEM 1	3.524	-1.344	21	CP2	1.187	-1.153
2	IEM 2	8.864	-2.105	22	CP3	1.967	-1.493
3	IEM 3	8.806	-2.492	23	CP4	4.296	-2.012
4	DF1	3.338	1.804	24	CP5	3.449	-1.583
5	DF2	1.749	-1.085	25	CP6	-0.430	0.167
6	DF3	1.692	-1.489	26	CP7	2.662	-1.599
7	DF4	5.426	-1.243	27	CP8	1.144	-0.952
8	DF5	8.461	-2.663	28	CP9	3.146	-1.256
9	DF6	7.771	-2.500	29	TPM1	4.285	-1.575
10	DF7	4.284	-1.756	30	TPM2	4.184	-1.859
11	DF8	5.620	-1.646	31	TPM3	0.705	-0.908
12	DF9	8.843	-2.299	32	TPM4	1.291	-0.962
13	GP1	3.080	-1.651	33	S1	7.775	-1.760
14	GP2	-0.240	-0.713	34	S2	6.019	-2.165
15	FGP3	0.065	-8.60	35	S3	0.320	-0.996
16	GP4	0.085	-0.781	36	S4	1.806	-1.579
17	GP5	-1.443	-0.201	37	S5	-0.521	-0.499
18	GP6	4.363	-1.959	38	LP1	2.161	-1.179
19	GP7	4.204	-1.735	39	LP2	5.110	-1.768
20	CP1	0.705	-1.153	40	LP3	0.739	-1.022
41	LP4	3.648	-1.685	61	RL1	2.523	-1.662
42	LP5	1.324	-1.118	62	RL2	2.748	-1.489
43	LP6	4.346	-1.856	63	RL3	1.961	-1.334
44	LP7	0.726	-1.006	64	RL4	0.864	-1.043
45	LP8	4.963	-2.085	65	RL5	0.510	-1.118
46	LP9	6.642	-2.140	66	RL6	0.792	-1.205
47	LW1	5.565	-2.060	67	RL7	1.977	-1.478
48	LW2	-1.418	-0.145	68	RL8	-0.573	-0.408
49	LW3	-1.189	-0.220	69	ADAP 1	2.751	-1.505
50	LW4	-1.357	-0.192	70	ADAP 2	0.768	-0.806
51	LW5	4.561	-1.956	71	ADAP 3	1.984	-1.365
52	LW6	1.576	-1.191	72	ROBUSTNESS	1.771	-1.174
53	LW7	2.066	-1.539	73	AGIL 1	1.241	-1.200
54	LW8	0.588	-1.023	74	AGIL 2	1.172	-1.327
55	LL1	5.935	-2.025	75	RISK 1	1.130	-1.228
56	LL2	4.138	-1.410	76	RISK 2	1.348	-1.151
57	LL3	1.487	-1.274	77	RISK 3	0.105	-0.429
58	LL4	1.292	-1.147	78	ECON 1	4.736	-1.904
59	LL5	3.394	-1.826	79	ECON 2	1.219	-1.384
60	LL6	4.358	-1.855	80	ENV 1	3.338	-1.804
81	ENV 2	1.237	0.672	83	SOC 1	4.412	-1.797
82	ENV 3	2.981	-1.540	84	SOC 2	1.189	-1.337
				85	SOC 3	2.119	-1.566

Also, Mishra et al. (2019) argue that normal distribution should have skewness and kurtosis values between -1 and +1. Table 5.1 shows excess kurtosis and skewness values, reflecting that the data is not normal. Against this background, it has been argued that PLS-SEM can handle non-normal data. To detect outliers, this study first scanned through the mean and low and high values of the data sets as a first step to detect outliers before using more sophisticated statistical and graphical methods such as plotting box graphs. It was noted that the data points were within normalcy, and no extreme data points were realized. As a result, no post-evaluation of outlier detection was conducted.

Table 5.2: Detection of Outliers Using the Mean and Low and High Values

No.	Indicator	Low	High	Mean
1	IEM 1	2	6	5.310
2	IEM 2	1	6	5.280
3	IEM 3	1	6	5.450
4	DF1	1	6	4.970
5	DF2	3	6	5.400
6	DF3	1	6	4.870
7	DF4	2	6	5.040
8	DF5	1	6	5.380
9	DF6	1	6	5.400
10	DF7	2	6	5.400
11	DF8	2	6	5.450
12	DF9	1	6	5.320
13	GP1	1	6	5.180
14	GP2	2	6	4.980
15	GP3	2	6	5.040
16	GP4	3	6	5.100
17	GP5	1	6	3.77
18	GP6	1	6	5.17
19	GP7	1	6	5.140
20	CP1	1	6	4.960
21	CP2	1	6	4.910
22	CP3	1	6	5.160
23	CP4	1	6	5.090
24	CP5	1	6	5.010
25	CP6	3	6	4.620
26	CP7	1	6	5.080
27	CP8	2	6	5.120
28	CP9	2	6	5.150
29	TPM 1	1	6	4.890
30	TPM 2	1	6	5.290
31	TPM 3	1	6	4.940
32	TPM 4	1	6	4.900

33	S1	1	6	5.140
34	S2	1	6	5.270
35	S3	1	6	4.840
36	S4	1	6	5.070
37	S5	2	6	4.060
38	LP1	2	6	5.150
39	LP2	1	6	5.240
40	LP3	1	6	4.730
41	LP4	1	6	5.170
42	LP5	1	6	4.880
43	LP6	1	6	5.140
44	LP7	1	6	4.900
45	LP8	1	6	5.400
46	LP9	1	6	5.160
47	LW1	1	6	5.140
48	LW2	1	6	3.750
49	LW3	1	6	3.810
50	LW4	1	6	3.780
51	LW5	1	6	5.270
52	LW6	1	6	4.860
53	LW7	2	6	4.960
54	LW8	1	6	4.970
55	LL1	1	6	5.150
56	LL2	1	6	5.040
57	LL3	1	6	5.040
58	LL4	1	6	4.730
59	LL5	1	6	4.50
60	LL6	1	6	5.130
61	RL1	1	6	5.200
62	RL2	1	6	4.920
63	RL3	1	6	4.920
64	RL4	1	6	4.640
65	RL5	1	6	4.800
66	RL6	1	6	4.750
67	RL7	1	6	4.830
68	RL8	1	6	4.140
69	ADAP 1	2	6	5.150
70	ADAP 2	3	6	5.080
71	ADAP 3	1	6	4.730
72	ROBUSTNESS	2	6	5.150
73	AGILE 1	2	6	5.040
74	AGILE 2	2	6	5.240
75	RISK 1	2	6	4.930
76	RISK 2	2	6	5.120
77	RISK 3	3	6	4.980
78	ECON 1	1	6	5.200
79	ECON 2	1	6	5.050

80	ENV 1	1	6	4.970
81	ENV 2	2	6	4.680
82	SOC 1	1	6	5.170
83	SOC 2	1	6	4.950
84	SOC 3	1	6	5.050

5.4 Demographic Profile Taxonomy of Study Respondents

To understand the demography of manufacturing businesses in a Sub-Saharan African context, this study collected demographic data based on the industry type, position, department, years of experience, and gender orientation of respondents. The demographic taxonomic characteristics were subjected to descriptive analysis using frequencies and percentages. Table 5.3 shows the taxonomy of respondents' demographic profiles. Analysis of industry type showed that most respondents were from the food and beverage manufacturing industry (38%) followed by the chemical and allied manufacturing industry with the same response rate (17%) as the pharmaceutical manufacturing industry.

Building, mining and construction took the third position (10%); and the energy, electrical and electronic manufacturing industry took the fourth position (9%). Further, the cosmetics manufacturing industry showed 8% of respondents taking the fifth position. The analysis of industry types showed respondents who did not indicate their industry type (1%) sitting at position six. It is not surprising that most respondents are from the food and beverage sector since this sector houses most manufacturing businesses within the larger manufacturing category. This also applies to the chemical and allied sector, which has a larger share of businesses, as reported by the Kenya Association of Manufacturers (2019, 2020, and 2021). An exciting trend is revealed across the pharmaceutical manufacturing sector. The responses from this sector indicate a 95% pharmaceutical response rate when rated against the number of pharmaceutical manufacturing businesses in this context.

This shows the openness of the pharmaceutical sector toward manufacturing sustainability. The low response rate of the building and energy sector indicated sectors that are not fully established in the manufacturing arena from the lens of pure production. Also, the cosmetics response rate shows a 100 percent response rate when rated across the number of businesses in this sector, which denotes openness to research toward manufacturing cosmetic sustainability. Analysis of gender orientation revealed that males were the main respondents, with a percentage of 67, and females, with a percentage of 32. The gender analysis also showed that 1% of respondents preferred not to reveal their gender identity. On affiliate department analysis, most respondents were from the procurement and logistics department (45%).

This is followed closely by the production and quality assurance department (20%). The general SC followed closely with 16% of respondents. The analysis further revealed interesting findings of respondents in the general operations category (managing directors/owners/chief executive officer), who sat at 9%.

The analysis of the affiliate department also showed some respondents coming from the accounts/finance/administration department (8%) and finally, 1% of respondents who did not reveal their affiliate department. The affiliate position analysis shows the SC as an area still fragmented with scope confusion about what SCs are. Ordinarily, one could expect the various sub-sections of the SC, such as procurement and logistics, to fall into the more extensive SC department. However, the affiliate department analysis indicates organizations with both the SC and the procurement/logistics departments.

This shows that manufacturing businesses in a Sub-Saharan African context (Kenya) are still operating under the traditional departmental model of procurement and logistics. Besides, the findings of this study noticed that some supply chain functionalities were still conducted under the accounts/finance/administration department with heads of departments with expertise in accounts, finance, human resources, and marketing. This demonstrates the earlier connotation of supplies in the Kenyan context, which is pegged in the Public Financial Management Act of 2012 and the Public Procurement and Asset Disposal Act of 2015.

The analysis still shows a peculiar model of the industry's segmentation of departments where all departments sometimes are under the administration umbrella. While it could make good economic sense for businesses, it is essential for a valid supply chain departmental model that can streamline the functionalities of the different subsections of the supply chain toward manufacturing sustainability. The analysis of affiliate positions is closely tied to the affiliate department. The results showed that the majority of positions were at the managerial level. This reflects managers, heads, and directors. The procurement and logistics department still had the majority of respondents under the affiliate position, sitting at 45%. Years of experience revealed that most respondents were in their early career days (1%). However, most of these respondents had worked in the same organization in a different SC department. Also, the results indicated the category of 5-10 taking the second position at 20%, 10-15 years of experience at 12%, 15-20 years at 5%, and those that had worked for more than 20 years at 7%. The results also showed that respondents who did not reveal their years of experience accounted for 5%. Table 5.3 shows the demographic taxonomy.

Table 5.3: Demographic Taxonomy

<i>Demographic Data A: Industry Type</i>	<i>Frequency</i>	<i>Percentage</i>
Food & Beverage	38	38
Chemical & Allied	17	17
Pharmaceuticals	17	17
Building, Mining, and Construction	10	10
Energy, Electricals & Electronics	9	9
Cosmetics	8	8
Unresponsive	1	1
<i>Demographic Data B: Gender Orientation</i>	<i>Frequency</i>	<i>Percentage</i>
Male	67	67
Female	32	32
Prefer not to say	1	1
<i>Demographic Data C: Affiliate Department</i>	<i>Frequency</i>	<i>Percentage</i>
Procurement, Imports, Purchasing, Planning & Logistics	45	45
Production & Quality Assurance	20	20
General Supply Chain	16	16
General Operations like Managing the Directors' Office	9	9
Accounts, Finance & Administration	8	8
Unresponsive	2	2
<i>Demographic Data D: Affiliate Position</i>	<i>Frequency</i>	<i>Percentage</i>
Procurement (Senior Manager, Head, In charge, Officer & Analyst), Logistics (Assistant and officer), Stores Manager, Export Dispatch Manager, Marketing Manager, Purchasing Manager, and Managing Director (Finance and Administration)	45	45
Supply Chain (Head, Manager (Tenders & Contracts), Group Manager, Manager (Logistics & Supply Chain), Procurement and supplies Expert, Assistant Store and stock Controller, Procurement Officer, Project Manager & Procurer	20	20
Production Manager, Quality Officer, Compliance Officer, safety and environment manager, and Assistant Lab Manager	16	16
Managing Director, Chief Executive Officer & General Manager	9	9
Accountant, Administrator & Human Resource Officer	8	8
Unresponsive	2	2
<i>Demographic Data E: Years of Experience</i>	<i>Frequency</i>	<i>Percentage</i>
0-5	51	51
5-10	20	20
10-15	12	12

>20	7	7
15-20	5	5
Unresponsive	5	5

5.5 Descriptive Data Analysis and Interpretation

5.5.1 Resilient Sustainability Dimensions

5.5.1.1 Resilient Sustainability Adoption Level

The adoption level of resilient sustainability dimensions was analyzed using descriptive statistics (mean and standard deviation) under STATA version 17. The results are reflected in Table 5.4. In evaluating resilient sustainability adoption level within manufacturing businesses in a Sub-Saharan African context, this study utilized a six-point Likert scale where 1 strongly disagreed, 2 disagree, three slightly disagree, four slightly agree, five agree, and six strongly agree. In addition, this objective sought to establish the adoption level for resilience and sustainability as among the first empirical investigations towards recommendations on the convergence of resilience and sustainability. Based on Table 5.4, it is evident that businesses are uptaking both sustainability and resilience practices from a supply chain perspective.

This shows that even though the convergence of resilience and sustainability has started gaining momentum, the practice space is already implementing such practices, which need further investigation into the best optimal practices for each sector. Table 5.4 shows that the adoption level for economic and social sustainability sits at agree while that of environmental sustainability is slightly agreed. In addition, under the resilience construct, it is notable that the adoption level of robustness, adaptability, and agility on average sits at agree, and that of a risk management culture sits at slightly agree.

This shows some harmony in how resilient sustainability dimensions are measured from a theoretical perspective and from a practitioner's lens, which reflects the right trajectory toward building resilient sustainability. From an average cumulative perspective, economic sustainability has the highest adoption level (Mean= 5.12). This is followed by social, resilience, and environmental sustainability with (Mean = 5.05, 5.04, and 4.79), respectively.

Table 5.4: Resilient Sustainability Dimensions Adoption Level

Variable	Obs	Mean	Std. dev.	Min	Max	Adoption Level
Social Sustainability						
Soc3	100	5.05	1.149220	1	6	Agree
Soc2	100	4.95	1.209182	1	6	S.A
Soc1	100	5.17	0.964575	1	6	Agree
Average		5.05				
Environmental Sustainability						
CarbonRedu~n	100	4.72	0.985552	1	6	S.A
WasteRed	100	4.68	0.863163	2	6	S.A
ClimResi	100	4.97	1.175980	1	6	S.A
Average		4.79				
Economic Sustainability						
Econ2Resou~e	100	5.05	1.200799	1	6	Agree
Econ1Cost	100	5.20	0.984732	1	6	Agree
Average		5.12				
Sustainability Average		4.98				
Resilience						
Risk3	100	4.98	0.738275	3	6	S.A
Risk2	100	5.12	0.935063	2	6	Agree
Risk1	100	4.93	1.094107	2	6	S.A
Average		5.01				
Agil2	100	5.24	0.965255	2	6	Agree
Agil1	100	5.04	1.033969	2	6	Agree
Average		5.14				
Robustness	100	5.15	0.891883	2	6	Agree
Average		5.15				
Adap3	100	4.73	1.221483	1	6	S.A
Adap2	100	5.08	0.774336	3	6	Agree
Adap1	100	5.15	0.957427	2	6	Agree
Average		4.98				
Resilience Average		5.07				

Notes**Soc3= fairness, Soc2=health, Soc1=safety, CarbonRedu~n= carbon reduction, WasteRed=waste reduction, ClimResi=climate resilience, Econ2Resou~e=resource utilization, Econ1Cost (cost reduction, total cost of ownership), Risk3,= has a formal risk management plan, Risk2,= prepares on how to cope with foreseeable uncertainties, Risk1=identifying areas of risk exposure, Agil2 =understands the status of its supply chain environment and assets, Agil1= responds very quickly to risk disruptions, Robustness= careful on selection of environmental supply chains for managing risk disruptions, Adap3 = ability to adapt quickly from a disruption, Adap2= reacts to risk disruptions through environmental supply chain,Adap1= plans for uncertainties by developing a supply chain risk register.**

5.5.2 Green Closed-Loop Supply Chains based Circular Economy Adoption Level

Assessing green and closed-loop supply chain practices based on the circular economic model was evaluated through a six-point Likert scale where 1 was strongly disagree, 2 was disagree, 3 was slightly disagree, 4 was slightly agree, 5 was agree and 6 was strongly agree. Based on table 5.5, it is notable that majority of the GCLSCM practices uptake is at the agree level except for green logistics and reverse logistics that is on the slightly agree level. This shows the importance of hot spotting the GCLSCM practices to find out the capability of businesses pertaining to their supply chains on which practices they can be able to uptake. Also, this results shows the importance of awareness creation and further development of established framework on measurement of GCLSCM. Even though, since all of the practices sit at the agree uptake level (agree and slightly agree), it is authentic to argue that the progress of up taking GCLSCM is on the right path towards resilient sustainability of SCs.

Table 5.5: Green and Closed-Loop Supply Chains Adoption Level

Variable	Obs	Mean	Std Dev	Min	Max	Adoption Level
GP & DF						
DF1	100	4.97	1.17598	1	6	S.A
DF3	100	4.87	1.330717	1	6	S.A
DF5	100	5.38	0.992701	1	6	Agree
DF6	100	5.4	0.984732	1	6	Agree
DF7	100	5.4	0.778499	2	6	Agree
DF8	100	5.45	0.672325	2	6	Agree
DF9	100	5.32	0.827312	1	6	Agree
DF2	100	5.4	0.666667	3	6	Agree
DF4	100	5.04	0.634369	2	6	Agree
GP2	100	4.98	0.994734	2	6	S.A
GP3	100	5.04	0.983911	2	6	Agree
GP4	100	5.1	0.858705	3	6	Agree
GP5	100	3.77	1.824939	1	6	S.D
GP6	100	5.17	1.092259	1	6	Agree
GP7	100	5.14	0.964208	1	6	Agree
GP1	100	5.18	1.104445	1	6	Agree
Average		5.100				
CP/GM						
CP1N	100	4.96	1.162721	1	6	S.A
CP2Y	100	4.91	1.198442	1	6	S.A
CP3N	100	5.16	1.125642	1	6	Agree

CP4Y	100	5.09	1.189983	1	6	Agree
CP5N	100	5.01	1.058825	1	6	Agree
Variable	Obs	Mean	Std Dev	Min	Max	Adoption Level
CP/GM						
CP7	100	5.08	1.088786	1	6	Agree
CP8	100	5.12	0.844232	2	6	Agree
CP6	100	4.62	0.749141	3	6	S.A
CP9	100	5.15	0.757121	2	6	Agree
TPM1	100	4.89	0.897753	1	6	S.A
TPM2	100	5.29	0.997927	1	6	Agree
TPM3	100	4.94	1.080778	1	6	S.A
TPM4	100	4.9	1.020002	1	6	S.A
S1	100	5.14	0.765678	1	6	Agree
S2	100	5.27	0.962478	1	6	Agree
S3	100	4.84	1.308249	1	6	S.A
S4	100	5.07	1.216511	1	6	Agree
S5	100	4.66	1.156623	2	6	S.A
Average		4.998				
GL						
LP1Y	100	5.15	0.857233	2	6	Agree
LP2N	100	5.24	0.900281	1	6	Agree
LP3N	100	4.73	1.213185	1	6	S.A
LP4Y	100	5.17	0.97499	1	6	Agree
LP5N	100	4.88	1.157147	1	6	S.A
LP6Y	100	5.14	0.99514	1	6	Agree
LP9N	100	5.16	0.96106	1	6	Agree
LP7N	100	4.9	1.141504	1	6	S.A
LP8N	100	5.4	0.97442	1	6	Agree
LW1Y	100	5.14	1.015237	1	6	Agree
LW2N	100	3.75	1.771691	1	6	S.D
LW3N	100	3.81	1.673893	1	6	S.D
LW4N	100	3.78	1.772859	1	6	S.D
LW5Y	100	5.27	0.993464	1	6	Agree
LW6Y	100	4.86	1.137248	1	6	S.A
LW7N	100	4.96	1.362707	1	6	S.A
LW8N	100	4.77	1.309291	1	6	S.A
LL1N	100	5.15	0.9783	1	6	Agree
LL2N	100	5.04	0.886715	1	6	Agree
LL3N	100	5.04	1.11844	1	6	Agree
LL4Y	100	4.73	1.162156	1	6	S.A
LL5Y	100	4.95	1.209182	1	6	S.A
LL6Y	100	5.13	1.041124	1	6	Agree
Average		4.876				
RL						

RL1	100	5.20	1.073087	2	6	Agree
RL2	100	4.92	1.051022	1	6	S.A
RL3	100	4.92	1.098024	1	6	S.A
RL4	100	4.64	1.15924	1	6	S.A
Variable	Obs	Mean	Std Dev	Min	Max	Adoption Level
RL						
RL5	100	4.8	1.3633	1	6	S.A
RL6	100	4.75	1.380784	1	6	S.A
RL7	100	4.83	1.27172	1	6	S.A
RL8	100	4.14	1.356019	1	6	S.A
Average		4.77				
IEM						
IEM1	100	5.31	0.7343657	2	6	Agree
IEM2	100	5.28	0.7795363	1	6	Agree
IEM3	100	5.45	0.857233	1	6	Agree
Average		5.34				

IEM1= building trust, IEM2 = information sharing, IEM3= transparency, DF1,=dematerialization, DF2= disassembly, DF3 = recyclability, DTF4= recoverability, DF5= regulatory compliance, DF6= less hazardous ingredients, DF7=easy disposal, DF8= ISO certified, DF9= substitutability, GP1= greater energy and water efficiency, GP2=clean energy and technology, GP3= absence of toxic substances, GP4=improved recycling ability, GP5=minimal packaging needs, GP6=extended durability, GP7=supplier audit, CP1N= water and energy reduction, CP2Y=use of recyclable and biodegradable materials, CP3N= use of less toxic materials, CP4N= just in time manufacturing, CP5N=safety measures, CP6Y= work schedule, CP7Y= protective gear, CP8N= water recycling, CP9N= zero defective products, TPM1= cleaning, TPM2 = servicing, TPM3= not placing weights on machineries, TPM4= a maintenance department, S1=sorting, S2= setting in order, S3=shine, S4=standardize, S5=sustain, LP1Y= downsizing packaging, LP2N= recycling and reusing packaging, LP3N= standardized packaging, LP4Y= materials with natural texture for its packaging, LP5N= packaging that is easier to open, store and use less space, LP6Y= keen on well labelling, LP7N= use of natural colours for packaging, LP8N= use of packaging that is free of excess layers, LP9Y=second life packaging, LW1Y= reuse of older facilities, LW2N=efficient space usage, LW3N= energy/water saving and indoor air quality, LW4N=usage of sensor bulbs and doors, LW6Y=well-coordinated labelling of inventory, LW7N= training of workforce, LW8N= warehousing waste management, LL1N= direct deliveries, LL2N=well planned vehicle routes, LL3N= energy efficient vehicles, LL4Y= grouping orders for same destination together, LL5Y= well temperature controlled system, LL6Y= keen on good disposal of its vehicles, RL1=reusing, RL2= reduction, RL3=recycling, RL4=refurbishing, RL5= remanufacturing, RL6=product return collection centre, RL7= product return awareness platform for customers, RL8= supportive to customers for product returns .**

5.6 Structural Equation Modelling Analysis and Interpretation

5.6.1 PLS-SEM Overview

In the building of a resilient sustainable economy through green closed-loop supply chains based on the circular economic model for manufacturing businesses in a Sub-Saharan African context, this study came up with five main hypotheses and 18 sub-hypotheses as discussed in chapter five (hypothesis and conceptual development) and as depicted in the research model 1 (graphical output with moderator). The PLS-SEM analysis starts with the presentation of the graphical output and then an in-depth presentation of data analysis results for both the measurement model and structural model. In addition, this section presents results on the interaction effects and robust check results.

5.6.2 PLS-SEM Graphical Output with Moderator

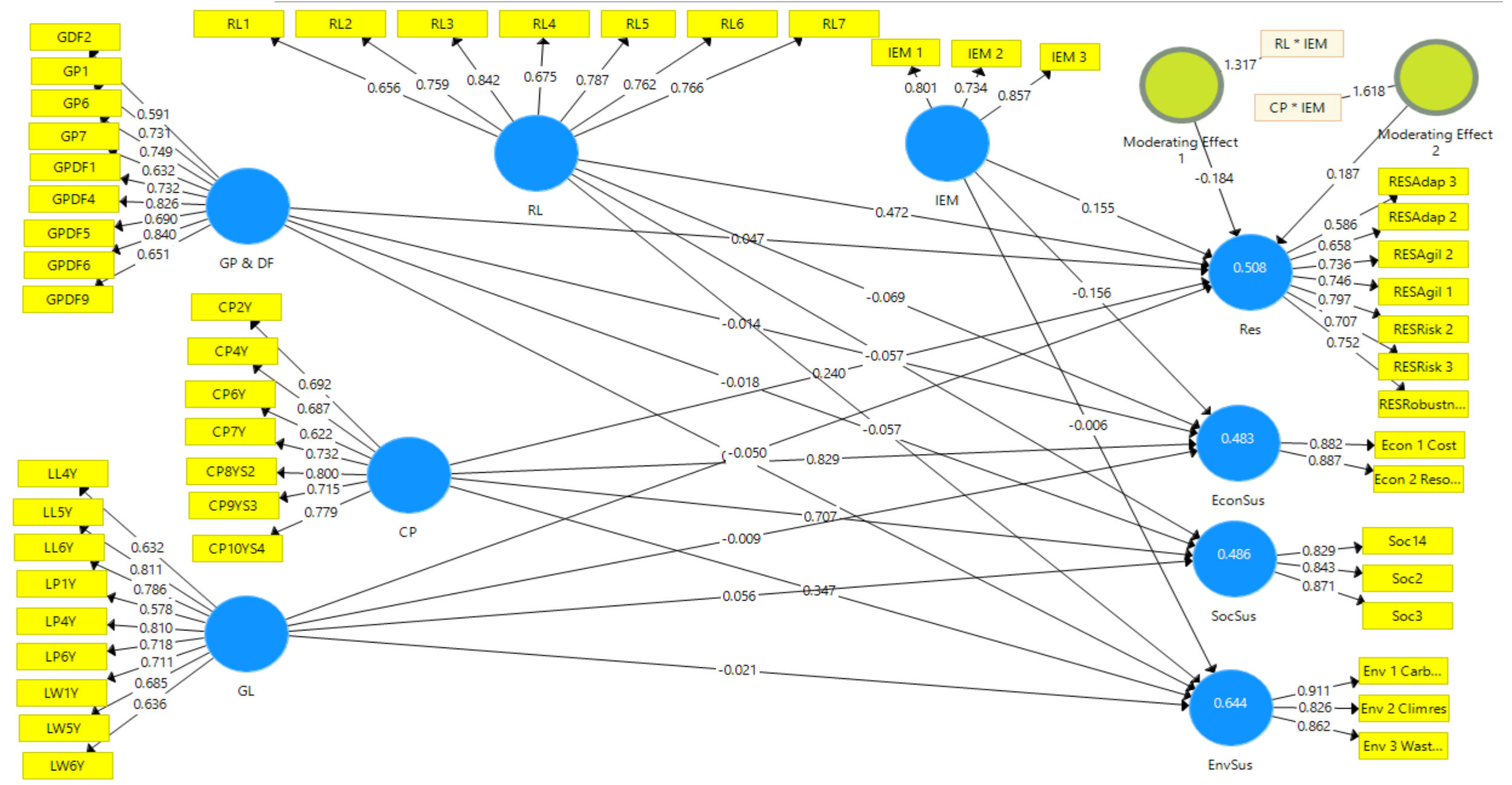


Figure 5.1: Research Model- PLS-SEM Graphical Output (With Moderator)

Based on Figure 5.1 and Table 5.6, most constructs attained the threshold indicator reliability. For instance, resilience in six out of eight indicators attained outer loading values of 0.708 and above, with two indicators achieving between 0.5 and 0.6. All sustainability-oriented variables achieved indicator loadings of 0.708 and above. For the GCLSCM, Green procurement and design for environment, cleaner production, green logistics, and reverse logistics attained 5, 4, 5, and 5 indicators with outer loadings of 0.708 and above with 4, 3, 4, and 2 indicators achieving a threshold of outer loading below 0.708 but not under 0.5 respectively.

While indicators less than 0.708 should be eliminated, indicator loadings of 0.4 and above may not be eliminated on certain circumstances (Hair et al., 2021). For instance, Hair et al. (2021) argue that, instead of eliminating such indicator loadings automatically, it is essential to first check the effects of such indicator loadings on the reliability and validity measures. Hair et al. (2021) further argue that indicator loadings between 0.4 and 0.708 should only be eliminated if deleting them increases the value's internal consistent reliability or convergent validity above the threshold levels. To reiterate, Hair et al. (2021) posit that indicators with lower loadings than 0.4 should be eliminated from the model. Also, Hair et al. (2014) argue that indicator loadings of 0.4 and above should not be eliminated from the model to avoid misrepresentation. For this study, it can be argued that all indicators achieved internal reliability. It is, however, worth noting that a few of the indicators had loadings between 0.5 and 0.708 but still argued to be included to avoid model misrepresentation. All indicators below 0.4 and those that lowered the average extracted variance were eliminated to avoid model misrepresentation.

5.6.3 PLS-SEM Measurement Model

Interpreting the measurement model calls for assessing; Loadings, Cronbach alpha, Composite Reliability, PA, AVE, and HTMT (Hair et al., 2019). Also, to check for robustness, Hair et al. (2019) point out the need to conduct a CTA-PLS.

5.6.3.1 PLS-SEM Measurement Model, Indicator Reliability (Indicator Loadings)

The first step in assessing the measurement model involves evaluating indicator loadings (Hair et al., 2019), which should not be less than 0.708, denoting that the indicator can explain more than 50% of the indicator variance. This proves an acceptable reliability level (Hair et al., 2019). However, Hair et al. (2021) argue again that this should be decided upon carefully since indicator loadings between 0.4 and 0.708 can be retained if deleting them affects the internal reliability and convergent validity. Table 5.6 presents the indicator loadings.

Table 5.6 PLS-SEM Measurement Model, Indicator Loadings

No.	Indicators	Outer Loadings								
		Resilience	Economic Sustainability	Environmental Sustainability	Social Sustainability	Green Proc & DFE	Cleaner Production	Green Logistics	Reverse Logistics	Internal Environment Management
1	Adap 1	0.723**								
2	Adap 2	0.659								
3	Adap 3	0.587								
4	Agil 1	0.746								
5	Agil 2	0.736								
6	Risk 2	0.797								
7	Risk 3	0.707								
8	Robustness	0.752								
9	Econ 1 Cost		0.881							
10	Econ 2 Resource		0.887							
11	Env 1 Carbon			0.912						
12	Env 2 Climres			0.826						
13	Env 3 Waste			0.863						
14	Soc 1				0.931					
15	Soc 2				0.76					
16	Soc 3				0.934					
17	GP1					0.734				
18	GP6					0.747				
19	GP7					0.636				
20	GPDF1					0.733				
21	GPDF2					0.585				

22	GPDF4					0.825				
23	GPDF5					0.693				
24	GPDF6					0.842				
25	GPDF9					0.645				
26	CP2						0.693			
27	CP4						0.689			
28	CP6						0.62			
29	CP7						0.727			
30	CP8S2						0.798			
31	CP9S3						0.721			
32	CP10S4						0.78			
33	LL4							0.636		
34	LL5							0.814		
35	LL6							0.789		
36	LP1							0.573		
37	LP4							0.81		
38	LP6							0.716		
38	LW1							0.707		
40	LW5							0.684		
41	LW6							0.633		
42	RL1								0.66	
43	RL2								0.761	
44	RL3								0.842	
45	RL4								0.669	
46	RL5								0.789	
47	RL6								0.764	
48	RL7								0.764	

49	IEM 1									0.801
50	IEM 2									0.734
51	IEM 3									0.857

The ** depicts constructs removed after running quadratic effects.

5.6.3.2 PLS-SEM Measurement Model, Internal Consistency Reliability (Cronbach Alpha, rho-a & rho-c)

According to Ringle and Sarstedt (2011), composite reliability should be between 0.7 and 0.9. However, for exploratory research, values of 0.6 are acceptable as a minimum (Hair et al., 2019). Also, Hair et al. (2019) argue that values above 0.90 may cause redundancy issues. However, for single-indicator constructs, values above 0.90 are acceptable since PLS-SEM has been found not to have problems with one single-item variable. However, researchers should be careful when using single-construct to avoid reliability issues. Table 5.7 shows the internal consistency reliability for this study. In the arguments of Hair et al. (2014) and Hair et al. (2021), Cronbach's alpha is ineffective in assessing internal consistency reliability. The model achieved internal consistency reliability by looking at the rho-A and composite. All values are within range for composite reliability and have not gone pasbpast5. For rho-A, all values are within the range of 0.8 and 0.9.

Table 5.7 PLS-SEM Measurement Model-Internal Consistency Reliability

	Cronbach's Alpha	Composite Reliability (rho-a)	Composite Reliability (rho-c)	Validity
RES	0.848	0.854	0.879	Supported
Econ Sus	0.721	0.721	0.878	Supported
Env Sus	0.835	0.838	0.901	Supported
Soc Sus	0.851	0.891	0.910	Supported
GP & DFE	0.882	0.893	0.905	Supported
CP	0.844	0.848	0.883	Supported
GL	0.877	0.892	0.901	Supported
RL	0.872	0.881	0.901	Supported
IEM _m	0.723	0.746	0.841	Supported

Notes IEM_m is the moderating variable*

5.6.3.3 PLS-SEM Measurement Model: Convergent Validity (AVE)

According to Hair et al. (2019), convergent validity is measured by average extracted variance (AVE), which should equal or greater than 0.5. Table 5.8 shows the AVE. All AVE values are supported with values above 0.5.

Table 5.8 PLS-SEM Measurement Model-Convergent Validity, AVE

Variable	Average Variance Extracted	Validity
RES	0.511	Supported
Econ Sus	0.782	Supported
Env Sus	0.752	Supported
Soc Sus	0.772	Supported
GP & DFE	0.519	Supported
CP	0.519	Supported
GL	0.506	Supported
RL	0.566	Supported
IEM	0.638	Supported

5.6.3.4 PLS-SEM Measurement Model, Discriminant Validity

Discriminant validity is typically assessed through fornell-larcker, cross-loadings, and heterotrait-monotrait (HTMT) ratio. The fornell-larcker is assessed through the square root of the average extracted variance greater than other correlation values among latent variables (Mohammadi & Mahmoodi, 2019). In cases where the average extracted variance is not greater, minimal deviations are acceptable. Table 5.10 shows values for the fornell-larcker. According to Radomir and Moisescu (2019), the Fornell-larger criterion is not a reliable measure of discriminant validity due to its inability to detect discriminant validity when indicator loads only have a slight difference (0.65-0.85). As such, the HTMT has been proposed as the best measure for testing discriminant validity (Henseler et al., 2015). In addition, Hair et al. (2019) posit that discriminant validity is best assessed through the HTMT values, which should be less than 0.90 for conceptually similar constructs and less than 0.85 for conceptually different constructs. In addition, HTMT values have been argued to range from 0 to 1, and while values close to zero are suspect, HTMT values should not be greater than 1. Table 5.9 shows the HTMT values where all HTMT values are supported.

Table 5.9: PLS-SEM Measurement Model, Discriminant Validity, HTMT

Variables	CP	Econ Sus	Env Sus	GL	GP & DFE	Moderator = IEM	RL	RES	Soc Sus	Validity
CP										
Econ Sus	0.841									Supported
Env Sus	0.874	0.474								Supported
GL	0.656	0.391	0.582							Supported
GP & DFE	0.878	0.578	0.873	0.785						Supported
Moderator = IEM	0.825	0.437	0.685	0.745	0.816					Supported
RL	0.575	0.303	0.450	0.636	0.603	0.586				Supported
RES	0.519	0.583	0.429	0.443	0.494	0.477	0.641			Supported
Soc Sus	0.845	0.820	0.519	0.494	0.609	0.485	0.401	0.305		Supported

Table 5.10: PLS-SEM Measurement Model, Fornell-Larcker Values

Indicators	CP	EconSus	EnvSus	GL	GP&DFE	IEM	Moderation `1	Moderation 2	RL	RES	SocSus
CP	0.720										
EconSus	0.678	0.884									
EnvSus	0.725	0.372	0.867								
GL	0.558	0.311	0.522	0.712							
GP&DFE	0.756	0.405	0.770	0.692	0.720						
IEM	0.648	0.333	0.544	0.589	0.655	0.799					
Moderation 2	- 0.519	-0.314	-0.498	- 0.433	-0.519	- 0.398	1				
Moderation 2	- 0.639	-0.384	-0.519	- 0.350	-0.583	- 0.560	0.693	1			
RL	0.498	0.253	0.415	0.595	0.563	0.492	-0.443	-0.422	0.752		
RES	0.514	0.459	0.436	0.487	0.509	0.470	-0.430	-0.314	0.643	0.715	
SocSus	0.695	0.674	0.405	0.403	0.522	0.372	-0.407	-0.149	0.317	0.312	0.848

5.6.4 PLS-SEM Structural Model

The structural model assesses the collinearity, R^2 , F^2 , Path Coefficients, Q^2 , and PLS prediction (Hair et al., 2019).

5.6.4.1 PLS-SEM Structural Model-Collinearity Assessment

According to Hair et al. (2011), collinearity assessment is measured using VIF values that should not exceed 5. Values greater than 5 indicate potential issues of collinearity. Table 5.11 shows the outer VIF, and Table 5.12 shows the inner VIF.

Table 5.11: PLS-SEM Structural Model, Collinearity Assessment using Outer VIF

No.	Indicator	Outer VIF	Validity
1	CP*IEM	1.000	Supported
2	CP2	2.100	Supported
3	CP4	1.940	Supported
4	CP6	1.395	Supported
5	CP7	1.828	Supported
6	CP8S2	2.831	Supported
7	CP9S3	1.766	Supported
8	CP10S4	2.174	Supported
9	GPDF1	1.871	Supported
10	GPDF5	3.213	Supported
11	GPDF6	3.657	Supported
12	GPDF9	4.242	Supported
13	GP1	2.018	Supported
14	GP6	2.067	Supported
15	GP7	1.783	Supported
16	GPDF4	2.813	Supported
17	Econ 1	1.466	Supported
18	Econ 2	1.466	Supported
19	Env 1	2.908	Supported
20	Env 2	1.582	Supported
21	Env 3	2.495	Supported
22	LL4	1.490	Supported
23	LL5	2.467	Supported
24	LL6	2.751	Supported
25	LP1	1.586	Supported
26	LP4	2.355	Supported
27	LP6	1.958	Supported
28	LW1	1.994	Supported

No.	Indicator	Outer VIF	Validity
29	LL4	1.490	Supported
30	LL5	2.467	Supported
31	LL6	2.751	Supported
32	LP1	1.586	Supported
33	LP4	2.355	Supported
34	LP6	1.958	Supported
35	LW1	1.994	Supported
36	LW5	2.117	Supported
37	LW6	1.732	Supported
38	RL1	1.726	Supported
39	RL2	1.816	Supported
40	RL3	2.496	Supported
41	RL4	1.541	Supported
42	RL5	2.364	Supported
43	RL6	2.231	Supported
44	RL7	2.252	Supported
45	Adap 2	1.282	Supported
46	Adap 3	1.223	Supported
47	Adap 1	3.177**	Supported
48	Agile 1	2.427	Supported
49	Agile 2	2.810	Supported
50	Risk 3	2.391	Supported
51	Risk 2	3.106	Supported
52	IEM1	1.278	Supported
53	IEM2	1.644	Supported
54	IEM3	1.905	Supported
55	Soc 1	3.561	Supported
56	Soc 2	1.525	Supported
57	Soc 3	3.547	Supported
58	Robustness	1.933	Supported

Table 5.12: PLS-SEM Structural Model, Collinearity Assessment Using Inner VIF

Indicators	CP	Econ Sus	Env Sus	GL	GP & DFE	SC*CP	RES	RL	SC	Soc Sus	Validity
CP		2.604	2.604				2.887			2.380	Supported
Econ Sus											Supported
Env Sus											Supported
GL		2.269	2.269				2.481			2.182	Supported
GP & DFE		3.249	3.249				3.357			3.153	Supported
IEM		2.067	2.067				2.243				Supported
RES											Supported
RL		1.701	1.701				1.753			1.686	Supported
Soc Sus											

5.6.4.2 PLS-SEM Structural Model-R Square

Hair et al. (2014) argue that the threshold values of R-square are 0.25,0.50 and 0.75 as weak, moderate, and substantial, respectively. For this study, an R-square value falls between the ranges of moderate and substantial. All the p values for the R squares in Table 5.13 are supported.

Table 5.13: PLS-SEM Structural Model, R Square, and Adjusted R Square Values

R Square				
Indicator	Original Sample (O)	T Statistic (O/STADEV)	P Values	Validity
Res	0.507	8.292	0.000	Supported
EconSus	0.477	4.660	0.000	Supported
EnvSus	0.645	8.703	0.000	Supported
SocSus	0.542	5.774	0.000	Supported
Adjusted R				
Indicator	Original Sample (O)	T Statistic (O/STADEV)	P Values	Validity
Res	0.470	7.136	0.000	Supported
EconSus	0.449	4.167	0.000	Supported

EnvSus	0.626	8.022	0.000	Supported
SocSus	0.523	5.343	0.000	Supported

5.6.4.3 PLS-SEM Structural Model-F Square

Hair et al. (2019) state that f-square values should be 0.02, 0.15, and 0.35 (considered weak, moderate, and significant, respectively). Table 5.14 shows values for the F square.

Table 5.14: PLS-SEM Structural Model, F Square Values

	F Square Values	T Statistics (O/STADEV)	P Values	Validity
CP -> Econ Sus	0.496	1.858	0.032	Supported
CP -> Env Sus	0.130	1.095	0.137	Unsupported
CP -> RES	0.039	0.737	0.231	Unsupported
CP -> Soc Sus	0.547	2.014	0.022	Supported
GL -> Econ Sus	0.000	0.009	0.497	Unsupported
GL -> Env Sus	0.000	0.016	0.493	Unsupported
GL -> RES	0.002	0.080	0.468	Unsupported
GL -> Soc Sus	0.007	0.359	0.360	Unsupported
GP &DF -> Econ Sus	0.000	0.003	0.499	Unsupported
GP &DF -> Env Sus	0.272	1.777	0.038	Supported
GP &DF -> RES	0.002	0.060	0.476	Unsupported
GP &DF -> Soc Sus	0.008	0.362	0.359	Unsupported
IEM -> Econ Sus	0.022	0.530	0.298	Unsupported
IEM -> Env Sus	0.000	0.002	0.499	Unsupported
IEM -> RES	0.022	0.597	0.275	Unsupported
Moderating 1-> RES	0.055	1.162	0.123	Unsupported
Moderating 2-> RES	0.067	0.976	0.165	Unsupported
RL-> Econ Sus	0.005	0.304	0.380	Unsupported
RL-> Env Sus	0.006	0.151	0.440	Unsupported
RL-> RES	0.257	1.880	0.030	Supported
RL-> Soc Sus	0.000	0.005	0.498	Unsupported

5.6.4.4 PLS-SEM Structural Model-Path Coefficients (Bootstrap, 10,000 samples)

Estimating path coefficients is essential for hypothesis testing for empirical investigations (Kock & Hadaya, 2018). Path coefficient estimation is the basis for hypothesis testing in PLS-SEM (Kock & Hadaya, 2018). Path coefficient estimations look into two approaches (use of p-values and confidence intervals). The P-value threshold is 0.05, where any value less than 0.05 is supported toward rejecting a null hypothesis. On the other hand, confidence interval values are interpreted because if zero does not fall within the intervals, the hypothesis is supported (Kock & Hadaya, 2018).

Both P-values and confidence interval results show similar results, and either can be used. For this study, a bootstrap of 10,000 samples was run, and the t-statistics show the significance of GCLSCM on resilient sustainability. Table 5.15 shows supported path coefficients through their t-statistics and p-values, which have been highlighted.

Table 5.15: PLS-SEM Structural Model, Path Coefficient Values

Indicators	Original Sample (O)	T statistics (O/STDEV)	P values	Validity
CP -> Econ Sus	0.822	6.238	0.000	Supported
CP -> Env Sus	0.346	2.476	0.007	Supported
CP -> RES	0.236	1.679	0.047	Unsupported
CP -> SocSus	0.772	6.033	0.000	Supported
GL -> Econ Sus	-0.013	0.105	0.458	Unsupported
GL -> Env Sus	-0.018	0.147	0.442	Unsupported
GL -> RES	-0.050	0.331	0.370	Unsupported
GL -> SocSus	0.085	0.904	0.183	Unsupported
GP &DF -> Econ Sus	-0.010	0.063	0.475	Unsupported
GP &DF -> Env Sus	0.560	3.798	0.000	Supported
GP &DF -> RES	0.050	0.293	0.385	Unsupported
GP &DF -> Soc Sus	-0.109	0.822	0.206	Unsupported
IEM-> Econ Sus	-0.153	1.267	0.103	Unsupported
IEM -> Env Sus	-0.006	0.047	0.481	Unsupported
IEM-> RES	0.156	1.256	0.229	Unsupported
RL -> Econ Sus	-0.068	0.743	0.260	Unsupported
RL -> Env Sus	-0.062	0.644	0.258	Unsupported
RL -> RES	0.471	4.532	0.000	Supported
RL -> SocSus	-0.007	0.085	0.466	Unsupported

5.6.4.5 PLS-SEM Structural Model-Q Square

According to Hair et al. (2019), the Q square shows the model's capability to predict. This is usually assessed by running a blindfold or conducting a PLS-predict, and values below zero indicate that the model's predictive power is weak. In recent literature, blindfolding has been argued not to provide out-of-sample predictive power, and as such, an alternative to PLS-predictive has been suggested (Hair et al., 2021). Tables 5.16 and 5.17 show Q square values through blindfolding and PLS-predict, respectively. When the Q square value exceeds zero, the model has higher predictive power, even for out-of-sample assessments (PLS-predict).

Table 5.16: PLS-SEM Structural Model, Q Square (Blindfolding, Omission distance=7): Construct Cross Validated Communality

Indicators	SSO	SSE	Q ² (1-SSE/SSO)	Validity
CP	700.000	482.789	0.310	Supported
Econ Sus	200.000	137.033	0.315	Supported
Env Sus	300.000	154.222	0.486	Supported
GL	900.000	563.720	0.374	Supported
GP	900.000	549.797	0.389	Supported
IEM	300.000	218.141	0.273	Supported
RES	700.000	469.329	0.330	Supported
RL	700.000	409.656	0.415	Supported
Soc Sus	300.000	140.405	0.532	Supported

Table 5.17: PLS-SEM Structural Model, Q Square (PLS-Predict, ten folds, ten repetitions): LV Prediction Summary

	RMSE	MAE	Q2_Predict	Validity
Econ Sus	0.800	0.593	0.405	Supported
Env Sus	0.686	0.517	0.572	Supported
RES	0.797	0.625	0.391	Supported
Soc Sus	0.730	0.560	0.498	Supported

5.6.5 Assessing Interaction Effects (Moderation Analysis)

5.6.5.1 Change in R Square, F Square, and Path Coefficients

According to Tehseen et al. (2017), researchers should carefully assess interaction effects. Ramaya et al. (2017) further argue that researchers should consider changing the R square after adding a moderating variable. This is equally supported by Memon et al. (2019), who argue the importance of assessing the significance of the moderation and effect size. In addition, researchers need to check the reliability of moderator variables to avoid measurement errors that might lead to misleading results. Tables 5.18, 5.19, and 5.20 show the moderation analysis's R square, F square, and path coefficients change.

Table 5.18: Assessing Interaction Effects (Change in R Square)

Endogenous Variable	Original Sample (O) Main Model	Original Sample (O) Interaction Model	Change in R Square
Econ Sus	0.477	0.477	0.000
Env Sus	0.645	0.645	0.000
Res	0.469	0.507	0.038
Soc Sus	0.542	0.542	0.000

**Its notable that the changes are negligible. *

Table 5.19: Assessing Interaction Effects (F Square)

Moderating Effect	Original Sample (O)	Mean Sample (M)	Standard Deviation (StaDev)	T Statistics	P Values	Validity
Moderating Effect 1-> Res (RL)	0.055	0.055	0.047	1.162	0.123	Not Supported
Moderating Effect 2-> Res (CP)	0.067	0.080	0.068	0.976	0.165	Not Supported

Table 5.20: Assessing Interaction Effects (Path Coefficients)

Moderating Effect	Original Sample (O)	T Statistics	P Values	Validity
Moderating Effect 1-> Res (RL)	-0.184	1.650	0.049	Supported
Moderating Effect 2-> Res (CP)	0.188	1.990	0.023	Supported

5.6.5.2 Interaction Effects through Simple Plots

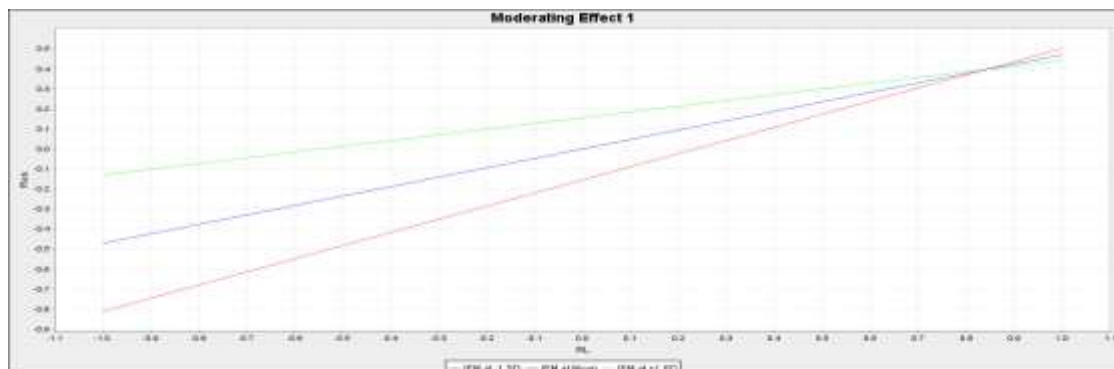


Figure 5.2: Simple Plot Moderating Effect 1

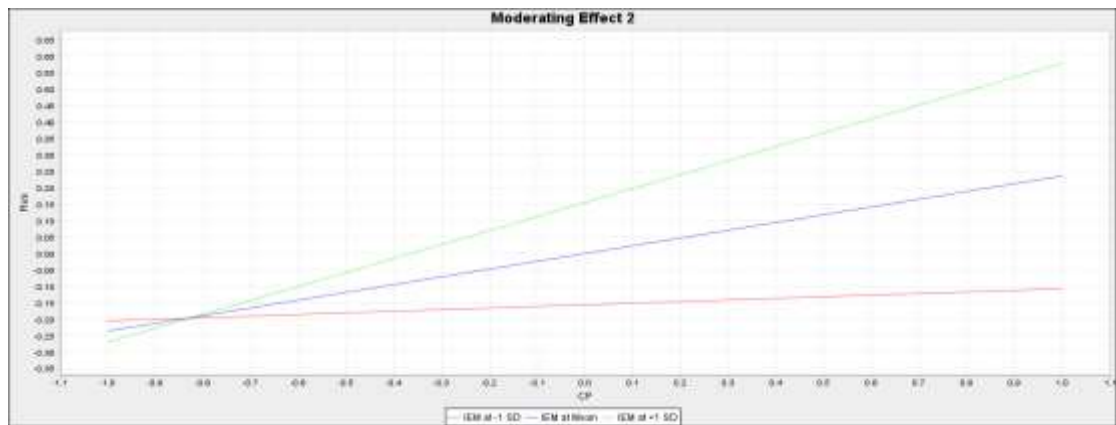


Figure 5.3: Simple Plot Moderating Effect 2

5.6.6 Robust Checks: Measurement Model, Confirmatory Tetrad Analysis

Wong (2019) notes that confirmatory tetrad analysis (CTA-PLS) is essential to ensure model specification. For SMART PLS 3, Wong (2019) argues that the software can reflect a reflective model and calls for the researcher to change arrows in case of a formative model. In addition, CTA-PLS can be used to specify the nature of the model, as comprehensively discussed in chapter six. Also, Wong (2019) posits that researchers should be careful since the CTA-PLS can only accurately specify the model when variables have more than 3 or 4 indicators. On the other hand, Bollen and Ting (2000) argue that CTA-PLS can also be used in more or less than four indicators.

In instances where the indicators are less than 3, Wong (2019) recommends using theoretical reasoning for model specificity, while Bollen and Ting (2000) posit that there is no error in the model specificity with less than four or three indicators. According to Wong (2013), model specifications are based on the nature of the relationship among indicators feeding a variable. This means that if the indicators are highly related and interchangeable, then it is a reflective and formative model (Wong, 2019). For this study, both theoretical reasoning and CTA-PLS have been used, and the results are shown in Figure 5.4. CTA-PLS has been run through 19,000 bootstrap samples and all values reflect a reflective model since the low-adjusted and up-adjusted values fall between the ranges 0 as tetrads. Chapter six also provides a comprehensive discussion on the same.

5.6.7 Robust Checks: Structural Model, Non-Linear Effects

According to Sarstedt et al. (2020), researchers typically assume a linear effect when testing the relationship among variables in PLS-SEM. The nature of the relationship is not always linear. PLS-SEM researchers have rarely looked into nonlinear effects (Sarstedt et al., 2020).

Since relationships are not always linear, checking for non-linearity is essential to avoid reporting misleading results. Sarstedt et al. (2020) argue that PLS-SEM's non-linear effects can be tested through RAMSEYS 1969 regression equation specification error test (RESET). According to Sarstedt et al. (2020), the RAMSEY RESET test in PLS-SEM is conducted by first running the PLS-SEM model and using its construct model scores to run the RAMSEYS RESET test in standard software packages such as STATA and SPSS. The results of a RAMSEY RESET test indicate non-linearity if the specification of non-linearity is significant. On the other hand, researchers could test for quadratic effects where if the quadratic impact is substantial, then non-linearity is detected; otherwise, the nature of the relationship among constructs is linear in nature (Sarstedt et al., 2020; Ringle et al., 2019).

This means that researchers could check the significance of the effect size. If it is significant, then non-linearity is detected; otherwise, the robustness of linearity has been achieved. In addition, Wong (2019) argues that researchers should check for significance and effect size to determine any presence of non-linearity in the model. For this study thereof using SMART-PLS version 3.3.7, non-linearity has been tested, and tables 5.21 and 5.22 show the results under the hypothesis:

H_A: Green Closed-loop supply chains and resilient sustainability have a significant non-linear, quadratic effect

H₀: Green closed-loop supply chains and resilient sustainability have an insignificant non-linear, quadratic effect

Table 5.21 (PLS-SEM path coefficients) and Table 5.22 (F Square through Bootstrapping) show non-linear results through quadratic effects conducted in SMART-PLS version 3.3.7. Notably, all the F square and path coefficient results for quadratic effects are non-significant, as shown in table 5.22 and table 5.21, respectively, where all p values and T statistics for path coefficients are non-significant. All the results then were non-significant for both the path coefficients and f square, reflecting the robustness of the model as a linear model without any non-linear effects. The Quadratic effect was run through endogenous variables against the independent variables through 10,000 bootstrap samples. This leads to rejecting the null hypothesis that green closed-loop supply chains and resilient sustainability have a significant non-linear, quadratic effect.

Table 5.21: Non-Linear Effects, Quadratic Effects (PLS-SEM, path coefficients)

It is notable that all path coefficients, their T statistics, and p values are not significant and, thus, a linear model.

PLS-SEM Non-Linearity Test through Path Coefficients (Quadratic Effect)					
Construct with added quadratic term	Original Sample (O)	Mean Sample (M)	Standard Deviation (StaDev)	T Statistics	P Values
GP-> Econ Sus _q	-0.015	-0.007	0.113	0.133	0.447
GP-> Env Sus _q	0.010	-0.007	0.091	0.105	0.458
GP-> RES _q	-0.057	-0.049	0.121	0.476	0.317
GP-> Soc Sus _q	0.030	0.024	0.073	0.415	0.339
GL-> Econ Sus _q	0.090	0.079	0.119	0.756	0.225
GL-> Env Sus _q	-0.023	0.005	0.108	0.213	0.416
GL-> RES _q	0.037	-0.065	0.135	0.273	0.392
GL-> Soc Sus _q	0.125	0.140	0.092	1.368	0.086
CP-> Res _q	0.125	0.129	0.129	0.971	0.166
CP-> Econ Sus _q	-0.058	-0.091	0.101	0.576	0.282
CP-> Env Sus _q	0.021	0.039	0.083	0.253	0.400
CP-> Soc Sus _q	-0.085	-0.091	0.069	1.232	0.109
RL-> Econ Sus _q	-0.004	0.004	0.077	0.50	0.480
RL-> Env Sus _q	-0.114	-0.102	0.086	1.334	0.091
RL-> Soc Sus _q	-0.070	-0.067	0.056	1.261	0.104
RL-> Res _q	0.019	0.054	0.095	0.196	0.422
IEM -> Econ Sus _q	0.031	0.084	0.098	0.317	0.376
IEM -> Env Sus _q	0.007	-0.034	0.084	0.081	0.468
IEM -> Res _q	0.051	0.110	0.126	0.404	0.343

Table 5.22: Non-Linear Effects, Quadratic Effects (PLS-SEM, F Square)

Notably, all path f square values, their T statistics, and p values are insignificant and thus a linear model.

PLS-SEM Non-Linearity Test through F Square (Quadratic Effect)					
Construct with added quadratic term	Original Sample (O)	Mean Sample (M)	Standard Deviation (StaDev)	T Statistic	P Values
GP-> Econ Sus _q	0.001	0.023	0.036	0.019	0.493
GP-> Env Sus _q	0.000	0.026	0.039	0.011	0.496
GP-> RES _q	0.009	0.031	0.039	0.228	0.410
GP-> Soc Sus _q	0.003	0.014	0.020	0.170	0.433
GL-> Econ Sus _q	0.016	0.026	0.033	0.487	0.313
GL-> Env Sus _q	0.002	0.025	0.036	0.045	0.482
GL-> RES _q	0.002	0.027	0.039	0.058	0.477
GL->Soc Sus _q	0.038	0.043	0.039	0.975	0.165
CP-> Res _q	0.020	0.038	0.046	0.444	0.328
CP-> Econ Sus _q	0.012	0.061	0.068	0.175	0.431
CP-> Env Sus _q	0.002	0.039	0.049	0.049	0.480
CP-> Soc Sus _q	0.031	0.052	0.056	0.565	0.286
RL-> Econ Sus _q	0.000	0.013	0.019	0.002	0.499
RL-> Env Sus _q	0.064	0.076	0.081	0.784	0.217
RL-> Soc Sus _q	0.021	0.025	0.028	0.742	0.229
RL-> Res _q	0.001	0.016	0.025	0.029	0.488
IEM -> Econ Sus _q	0.006	0.039	0.061	0.105	0.458
IEM -> Env Sus _q	0.000	0.031	0.051	0.009	0.496
IEM -> Res _q	0.006	0.030	0.036	0.161	0.436

5.6.8 Robust Checks: Structural Model, Endogeneity

According to Bascle (2008), endogeneity results from a predictor construct that correlates with the error term of the dependent variable that it relates. Failure to test and control for endogeneity may lead to the reporting of misleading results. In the contentions of Woodridge (2003), endogeneity is caused by omitted variables, simultaneity, and sample selection bias. Simultaneity or reverse causality happens when the predictor variable influences the response variable, and simultaneously, the response variable affects the predictor variable (Jean et al., 2016). Sample selection bias results from not grouping samples randomly (Jean et al., 2016). Sample selection bias can be equated to the absence of essential variables as predictors, leading to non-random sampling error. Omitted variables ought to have been included as explanatory

variables but were not included (Woodridge, 2010). Against the backdrop, Jean et al. (2016) argue that it is essential for researchers to consider comprehensive literature reviews to pick up on all explanatory variables and always consider using control variables for valuable results. Also, Hair et al. (2019) argue about three steps to test for endogeneity and address it. First, Hair et al. (2019) postulate that researchers should check if it is necessary to test for endogeneity by assessing the purpose of their model (explanatory or predictive). Hair et al. (2019) contend that there is no need to test for endogeneity for predictive models.

However, it is vital to address endogeneity in explanatory modeling to make valuable inferences of the hypotheses. In addition, if researchers seek to test for theory and derive practical implications, it is essential to consider testing and addressing any endogeneity. Second, Hair et al. (2019) argue that researchers should check the possibility of adding control variables to address endogeneity and, thirdly, perform the Gaussian copula test for endogeneity, which, if significant, researchers should proceed to treat endogeneity by first assessing the root cause of the endogeneity. For this study, the researcher first assessed the nature of the model, which is both explanatory and predictive oriented, and, as such, needs to test and address endogeneity. Second, the researcher thoroughly investigated the literature to understand commonly considered control variables in this area, such as industry type for mixed studies, business size, and gender, to control for any hidden endogeneity.

Thirdly, the researcher performed the Gaussian Copula test using Smart PLS 4, and the results are shown in Table 5.23 (F Square) and 5.24 (Path Coefficients). The Gaussian Copula results indicate no endogeneity issues from the path coefficients or F Square. Notably, endogeneity was detected in cleaner production and resilience, of which one of the resilience indicators (adap 1) was dropped as a first line to treat endogeneity. After dropping adap 1, all results showed no observable endogeneity, as shown in Tables 5.23 and 5.24.

Table 5.23: PLS-SEM Endogeneity Test (Gaussian Copula, F Square)

PLS-SEM Endogeneity Test Through F Square (Gaussian Copula)					
Construct with added quadratic term	Original Sample (O)	Mean Sample (M)	Standard Deviation (StaDev)	T Statistic	P Values
GP-> Econ Sus _{gc}	0.003	0.015	0.024	0.126	0.450
GP-> Env Sus _{gc}	0.000	0.020	0.031	0.005	0.498
GP-> RES _{gc}	0.004	0.019	0.026	0.143	0.443
GP-> Soc Sus _{gc}	0.003	0.015	0.021	0.151	0.440
GL-> Econ Sus _{gc}	0.014	0.029	0.034	0.414	0.339
GL-> Env Sus _{gc}	0.002	0.019	0.028	0.062	0.475
GL-> RES _{gc}	0.010	0.025	0.033	0.304	0.381
GL->Soc Sus _{gc}	0.033	0.040	0.042	0.786	0.216
CP-> Econ Sus _{gc}	0.032	0.051	0.055	0.589	0.278
CP-> Env Sus _{gc}	0.006	0.032	0.042	0.146	0.442
CP-> Soc Sus _{gc}	0.048	0.064	0.064	0.739	0.230
RL-> Econ Sus _{gc}	0.001	0.011	0.017	0.032	0.487
RL-> Env Sus _{gc}	0.017	0.038	0.049	0.352	0.363
RL-> Soc Sus _{gc}	0.004	0.012	0.019	0.219	0.413

Table 5.24: PLS-SEM Endogeneity Test (Gaussian Copula, Path Coefficients)

PLS-SEM Endogeneity Test Through Path Coefficients (Gaussian Copula)					
Construct with added quadratic term	Original Sample (O)	Mean Sample (M)	Standard Deviation (StaDev)	T Statistic	P Values
GP-> Econ Sus _{gc}	0.114	0.087	0.264	0.433	0.332
GP-> Env Sus _{gc}	0.021	0.068	0.268	0.125	0.450
GP-> RES _{gc}	0.130	0.270	0.223	1.434	0.076
GP-> Soc Sus _{gc}	0.113	-0.063	0.226	0.425	0.336
GL-> Econ Sus _{gc}	0.290	0.255	0.271	1.061	0.144
GL-> Env Sus _{gc}	-0.084	-0.076	0.254	0.415	0.339
GL-> RES _{gc}	-0.229	-0.256	0.264	1.051	0.147
GL->Soc Sus _{gc}	0.430	0.251	0.268	1.063	0.144
CP-> Econ Sus _{gc}	-0.409	-0.353	0.336	1.218	0.112
CP-> Env Sus _{gc}	0.147	0.129	0.313	0.470	0.319
CP-> Soc Sus _{gc}	-0.480	-0.427	0.316	1.522	0.064
RL-> Econ Sus _{gc}	-0.044	-0.028	0.217	0.201	0.420
RL-> Env Sus _{gc}	-0.206	-0.163	0.267	0.774	0.220
RL-> Soc Sus _{gc}	-0.118	-0.091	0.203	0.578	0.282

5.6.9 Robust Checks: Structural Model, Unobserved Heterogeneity

According to Sarstedt et al. (2020), unobserved heterogeneity results from different data groups, which yield different model estimates. In such circumstances, estimating the entire group without considering unobserved heterogeneity may lead to misleading results. In testing and controlling for unobserved heterogeneity, Sarstedt et al. (2020) argue that researchers need to run finite mixture-PLS to test for unobserved heterogeneity. FIMIX-PLS typically shows the absence of unobserved heterogeneity if results point to a one-segment solution or divergent results (Sarstedt et al., 2020). On the other hand, if results show significant heterogeneity, then researchers are advised to control it by running PLS prediction-oriented segmentation. As a first step, this study ran the FIMIX-PLS under the following steps (Hair et., 2015):

Assess the minimum sample size through G-Power= 85
Determine the study's actual sample size=100
Divide the study's actual sample size by the minimum sample size to obtain several segments= $100/85=1.1764$

Once the number of segments has been attained, which in this case could range between one and two, one runs the FIMIX-PLS several times depending on the segments and then analyzes the results through the fit indices. If the fit indices do not have a significant difference, it can be argued that there is no evidence of unobserved heterogeneity; otherwise, PLS-Prediction segmentation has to be conducted. The results for the FIMIX-PLS are shown in Table 5.25. Hair et al. (2015) argue that researchers can look into the differences in fit indices and compare them as per the segments used. If there are no significant differences, then it can be argued that there is no significant unobserved heterogeneity. For this study, and as shown in Table 5.25, the fit indices' values have no significant deviations, and thus, the results indicate no major unobserved heterogeneity. As such, no post-evaluations were conducted.

Table 5.25: Robust Checks, Unobserved Heterogeneity, FIMIX-PLS

FIMIX-PLS Fit Indices for Two Segments		
Model Criterion	Segment 1	Segment 2
AIC	764.731	702.176
AIC3	789.731	753.176
AIC4	814.731	804.176
BIC	829.861	835.040
CAIC	854.861	886.040
HQ	791.090	755.949
MDLS	1290.378	1774.495
LNL	-357.366	-300.088
EN		0.984
NFI		0.990
NEC		1.630

AIC= Akaike Information Criterion, AIC3= Modified Akaike Information Criterion with Factor 3, AIC4= Modified Akaike Information Criterion with Factor 4, BIC= Bayesian Information Criterion, CAIC= Consistent Akaike Information Criterion, HQ= Hannan-Quinn Criterion, MDLS= Minimum Description Length with Factor 5, LNL =, EN= Entropy Statistics, NFI= Non-Fuzzy Index and NEC = Normalized Entropy Criterion

5.6.10 Robust Checks with Control Variables

This study examined three control variables (gender, industry type, and business size (number of employees and sales revenue)). These control variables were chosen based on the nature of the study and the contextual structure of manufacturing businesses in a Sub-Saharan African economy. Gender was picked as it was realized that above 60% of respondents were male. This is equally supported by the historical orientation of supply chains being a preserve for males.

On the same note, the industry type was chosen based on the scope of the study that traversed more extensive manufacturing, which falls into different clusters. In addition, business size was chosen due to the different sizes of manufacturing businesses so that the study results can accurately depict manufacturing businesses in a Sub-Saharan African context. Ideally, analysis of control variables calls for a multi-group analysis or normal analysis of pointing control variables to dependent variables and then running both the PLS algorithm and the bootstrap to check for strength of relationship and significance. The latter approach was selected for this study since clustering the data set through the multi-group analysis seemed impractical due to a smaller sample size.

An example is the clustering of industry type into seven clusters (food (38), pharmaceutical (17), chemical (17), building (10), cosmetics (8), energy (9), and non-responsive (1), where analysis of fewer than ten observations seemed impractical and even with the combining of near similar sectors showed clusters with a sample size of less than 50 which still seemed impractical. For those reasons, the researcher used a theoretical lens to follow the control variable connected to the dependent variable approach. Notably, one indicator for business size (sales revenue) was dropped due to reliability issues. While PLS-SEM literature advocates for single-item constructs, more so in the control variable class, it is unclear how literature has addressed control variables with currency values.

In addition, while there are many controversies around handling control variables in PLS-SEM, most scholars agree to interpret the R square of the model after their addition and run a bootstrap to check for significance and effect size. This has been demonstrated in Table 5.26 (R square change), table 5.27 (F Square), and Table 5.28 (path coefficients).

Table 5.26: R Square change with Control Variables

Endogenous Variable	Original Sample (O) Main Model	Original Sample (O) Control Variables	Change in R Square
Econ Sus	0.477	0.484	0.007
Env Sus	0.645	0.663	-0.018
Res	0.507	0.524	0.017
Soc Sus	0.542	0.553	0.011

Notably, the R square change for environmental sustainability has gone down. Relating this change to theory, it could be a result of gender where, in this study, most respondents were male (67 in number). As such, speaking to literature, women are more relational and better at environmental management. At the same time, men are good at enhancing profitability.

Table 5.27: Assessing Control Variable Effects (F Square)

Control Variables F	Original Sample (O)	Mean Sample (M)	Standard Deviation (StaDev)	T Statistics	P Values	Validity
Industry Type-> Econ Sus	0.004	0.012	0.038	0.543	0.293	Unsupported
Industry Type-> Env Sus	0.020	0.030	0.018	0.202	0.420	Unsupported
Industry Type-> Res	0.008	0.024	0.036	0.559	0.288	Unsupported
Industry Type-> Soc Sus	0.026	0.032	0.031	0.273	0.392	Unsupported
Gender-> Econ Sus	0.004	0.018	0.023	0.188	0.425	Unsupported
Gender-> Env Sus	0.007	0.015	0.021	0.313	0.377	Unsupported
Gender-> Res	0.021	0.030	0.038	0.548	0.921	Unsupported
Gender-> Soc Sus	0.001	0.015	0.021	0.037	0.485	Unsupported
Business Size -> Econ Sus	0.004	0.033	0.060	0.066	0.474	Unsupported
Business Size -> Env Sus	0.020	0.033	0.037	0.555	0.290	Unsupported
Business Size-> Res	0.07	0.013	0.015	0.465	0.321	Unsupported
Business Size -> Soc Sus	0.000	0.023	0.038	0.000	0.500	Unsupported

Table 5.28: Assessing Control Variable Effects (Path Coefficients)

Control Variables P	Original Sample (O)	Mean Sample (M)	Standard Deviation (StaDev)	T Statistics	P Values	Validity
Industry Type-> Econ Sus	-0.044	-0.030	0.074	1.179	0.119	Unsupported
Industry Type-> Env Sus	0.085	0.073	0.066	0.593	0.277	Unsupported
Industry Type-> Res	0.066	0.071	0.082	1.274	0.101	Unsupported
Industry Type-> Soc Sus	-0.111	-0.101	0.067	0.796	0.213	Unsupported
Gender-> Econ Sus	0.049	0.061	0.077	0.636	0.262	Unsupported
Gender-> Env Sus	0.049	0.038	0.060	0.812	0.208	Unsupported
Gender-> Res	-0.112	-0.106	0.082	1.362	0.087	Unsupported
Gender-> Soc Sus	-0.019	-0.017	0.081	0.239	0.406	Unsupported
Business Size-> Econ Sus	-0.047	-0.075	0.108	0.437	0.331	Unsupported
Business Size-> Env Sus	0.087	0.090	0.063	1.365	0.086	Unsupported
Business Size-> Res	0.070	0.065	0.062	1.129	0.129	Unsupported
Business Size-> Soc Sus	0.002	-0.031	0.097	0.025	0.490	Unsupported

5.7 Chapter Summary

This chapter presents the main research findings for the study using descriptive analysis, PLS-SEM, and content analysis. Descriptively, most practices are at an agreed level except for reverse logistics, which is, on average, at a slightly agreed level. The resilient sustainability adoption level is at an agreed level with substantial findings on slightly agree. For green closed-loop supply chains on resilient sustainability, cleaner production, green procurement, design for the environment, and reverse logistics seem the most promising in enhancing resilient sustainability.

Chapter Six: Discussion

6.1 Introduction

This study sought to investigate building a resilient, sustainable economy through green and closed-loop supply chain management in the context of the circular economic model for manufacturing businesses in a Sub-Saharan African economy. This chapter summarizes the research findings from the data analysis results shown in chapter five, in which the hypothesized relationships have been statistically investigated. In addition, this chapter presents the discussion of such results as a valuable way for scholars, practitioners, regulators, and policymakers to contribute to the literature. In light of this context, this chapter is organized into four sections. Section 6.1 introduces the chapter; Section 6.2 summarizes Chapter Five's research findings; Section 6.3 presents the discussion; and Section 6.4 provides the chapter summary.

6.2 Summary of Research Findings

This chapter summarizes the research findings, taking the structure of research objectives. Looking at the research findings, while not all hypotheses for the study have been supported, it is notable that the research model holds reasonably well by the structural equation model parameters (PLS-SEM) both for the measurement and structural model. Against this backdrop, the research model is believed to represent the theoretical reasoning of the phenomenon under study. Besides, the empirical results of this study denote a strong relationship between green closed-loop supply chains and resilient sustainability. This is depicted through the five and four hypotheses supported by the path coefficients and F test, respectively.

Out of five hypotheses, three showed significances in relating to resilient sustainability. For instance, cleaner production had a strong relationship with resilient sustainability on all sustainability dimensions, and green procurement and design for the environment showed a significant relationship with economic sustainability on the effect size and on environmental sustainability on the path coefficient. In addition, reverse logistics showed a significant relationship with resilience. The three hypotheses out of five depict a robust model that sits at 60%. Also, given that the area of sustainability and resilience is still in the infancy in supply chains and especially in the most fragile and undeveloped regions like economies in Sub-Saharan Africa, it is notable that green closed-loop supply chains can aid build resilient-sustainable economies.

Also, it is notable that, while extant literature advocates for building resilient sustainability through sustainable supply chains, there is a dearth of studies directly linking green closed-loop supply chains with resilience, which this study contributes to and shows evidence through the significant results of reverse logistics on resilience. It is also realized that the effect of green closed-loop supply chains on environmental sustainability is not clear-cut, as none of the hypotheses shows significant results on environmental sustainability, except for combined green procurement and design for the environment on the path coefficients. On the contrary, cleaner production, green procurement, and design for the environment show a harmonized significance resulting in economic sustainability. This tells a story that, in the short term, the benefits of green closed-loop supply chains are more economical. However, in the long run, they will contribute to enhancing environmental sustainability. It was also realized that cleaner production affects social sustainability, an aspect that is ignored in practice and scholarly discourse.

In addition, this study realized results contrary to the hypotheses under study. For instance, internal environmental management was not significant in the relationship between green closed-loop supply chains and resilient sustainability. Also, reverse logistics, which has long been argued as a good practice for environmental performance, was found not to influence sustainability. On the same note, green procurement and design for the environment do not influence social sustainability, environmental sustainability, and resilience. With that being said, of importance is the evidence that the green closed-loop supply chains could influence resilient sustainability in its different facets. Besides, the results contrary to the hypothesis are evident of the new trajectories in the area of resilience and sustainable supply chains that inform further research towards the development of a theoretical framework to build resilient, sustainable supply chains and systems by extension.

6.3 Discussion

6.3.1 Resilient Sustainability Dimensions

6.3.1.1 Resilient Sustainability Dimensions

The empirical findings of resilient sustainability dimensions' adoption level show that manufacturing businesses in a Sub-Saharan African context uphold both resilient and sustainability dimensions through various practices such as waste reduction, climate resilience, carbon emission reductions, the safety of employees, the health of employees, fairness for employees, reduction of the total cost of ownership, resource utilization, adaptability, agility, robustness, and a risk management culture.

Most dimensions exhibit an adoption level of agreement, meaning that resilient sustainability from a dimension perspective is a common practice. While the majority of the dimension adoption level sits at agree, it is notable that none of the dimensions has an adoption level of strongly agree, meaning that there is more that needs to be done from a scholarly and policy perspective to encourage manufacturing businesses and their supply chains to build resilience and sustainability. Building upon this foundation, we argue using the systems thinking theory to adopt practices that can build both resilience and sustainability of supply chains, supply chains need to collaborate and invest in capabilities such as green and closed-loop practices. In essence, the systems thinking theory argues that it is important to look at systems from a broader perspective defining their totality rather than as individual parts. Building resilience and sustainability through the adoption levels of the different dimensions meaning viewing supply chains as a part of the world system and developing capabilities from a win-win situation to support supply chains but also support other world ecosystems.

Drawing inspiration from these arguments, this becomes important as economies walk toward recovery after COVID-19 and at a time when supply chains globally are struggling to keep abreast of their global expansion. It is interesting to note that building resilient, sustainable supply chains is at the forefront of many discussions among regulators, policymakers, researchers, and practitioners, yet very little progress is seen. Even though it is practically right to argue that as much as the convergence of resilience and sustainability is still a paradox and in infancy, there is evidence of some level of both practices within manufacturing businesses in a Sub-Saharan African context. Notably, some dimensional practices of resilient sustainability slightly agree. From systems thinking theory, it is essential then that all stakeholders of the world ecosystem join hands and build manufacturing resilience and sustainability as first-line milestones towards sustainable and resilient supply chains and, by extension, communities, and economies.

Also, the results of this investigation point out the need for more research to establish a well-grounded measurement framework defining resilient sustainability dimensions and their indicators. The study of Aigbogun et al. (2018) that looked into supply chain resilience from turbulence, external pressures, sensitivity, connectivity, flexibility, visibility, collaboration, adaptability, capacity, and supplier dispersion shows resilient dimensions above average from a measurement and adoption level. The results of Aigbogun et al. (2018) agree with this study on resilient dimensions. The agree level between this present study and Aigbogun et al., (2018) is based on the common shared dimensions such as adaptability and flexibility (that essentially informs agility). The study of Aigbogun et al. (2018) did not look into sustainability dimensions.

According to Negri et al. (2022), firms are beginning to appreciate the practice of resilience and sustainability together. In their study, sustainability dimensions seemed to have a higher adoption level than resilience. Such findings unfold a new trajectory of using resilience as an enabler of sustainability. In this present study, in this present study, all dimensions for both resilience and sustainability seemed to be on the same level except for environmental sustainability, which had an adoption level of slightly agreeable. Cumulatively, as much as both dimensions seemed to be on the same level, there was a minor discrepancy of 0.09 between resilience (5.07) and sustainability (4.98) dimensions adoption levels. From this perspective, it can then be argued that the findings of this present study reveal an inverse perspective to the findings of Negri et al. (2022).

It can be argued that economic sustainability, resilience, and social sustainability are at the forefront of adoption by manufacturing businesses in a Sub-Saharan context, even though it is essential and urgent to develop new measurement frameworks on how to combine resilience and sustainability for an in-depth investigation of their convergence from a dimension perspective. It is also worth noting that while extant literature, such as Zhu and Wu (2022), continue to propound on the convergence of resilience and sustainability from a supply chain perspective, very few scholars have addressed the combination from a dimension perspective. Resilience and sustainability dimensions are the first lines in developing a convergent theory integrating adaptation and transformation.

Historically, many studies, such as Olsson et al. (2014), have equally argued about building resilient and sustainable cities, where most scholars argue that future resilient systems will be smart systems. However, there are still minimal developments in building resilient and sustainable systems from a dimensional perspective, a gap that this present study fills. In addition, extant literature is also seen to have a bias to distinct dimensions of the concepts where scholars are either looking into SC resilience or supply chain sustainability dimensions. Such findings highlight a need for more investigations into the dimensions of resilience and sustainability, opening up many indicators beyond the triple bottom line for sustainability and adaptation for resilience. The UN-SDG also supports this towards building a more inclusive, resilient, and sustainable society. This study then forms a basis for future research to look into a combined dimensional perspective for resilient sustainability.

6.3.2 Green Closed-Loop Supply Chain Adoption Level

Investigating the green closed-loop supply chain adoption level reveals exciting findings. It is realized that the adoption level sits at agree and slightly agree, with a small percentage sitting at slightly disagree (some green logistics practices on warehousing).

Assessing all the green closed-loop supply chain practices, out of 16 practices on combined green procurement and design for the environment, 12 sit at agree, and four at slightly agree. This indicates the higher adoption level of designing for the environment and environmentally conscious procurement. Out of 19 cleaner production practices, 11 sit at the agree level while eight sit at the slightly agree level. It is worth noting that cleaner production in this study has extensions to total productive maintenance and the Japanese 5S methodology, which are consistent in findings at an agree and slightly agree level. Of The 23 green logistics practices, 12 sit at agree, eight at slightly agree, and three at slightly disagree. The 12 agree, and eight slightly agree on cutting across the different aspects of green logistics (transportation, warehousing, and packaging), while slightly disagree is only evidenced by some warehousing practices. This shows that warehousing is still viewed from a mechanical perspective and not as an essential facet of supply chain sustainability and resilience. Alternatively, given the historical perception of warehousing as stores and material handling work, it may be a forgotten link in driving the resilient sustainability agenda for the supply chain.

This exciting discovery points out the importance of balanced mapping and hot spotting of SCs for resilient sustainability. According to Negri et al. (2022), design for the environment seems to be the practice with the highest adoption levels. Also, Negri et al. (2022) report that green logistics is highly practiced within organizations. For the present study, internal environmental management seems to have a higher adoption level (Mean=5.34), followed by combined green procurement with design for the environment (5.100), cleaner production (4.998), green logistics (4.876), and finally reverse logistics (Mean= 4.77) respectively. The findings of Negri et al. (2021) on green logistics being the most adopted practice differ from this study's findings, where green logistics is seen as the second and last most adopted practice. It is also surprising that manufacturing businesses in the Sub-Saharan context do not welcome reverse logistics. This can be supported by the fact that reverse logistics seems impractical in some sectors, such as pharmaceutical, which is very sensitive and has stringent regulations.

This highlights a need for the government to offer support by upstarting circular economy ideation with bias to manufacturing. For instance, government support on material recovery facilities and return and refill centres would help support these businesses in upholding reverse logistics. It is also interesting to note that the findings of this study demonstrate that, manufacturing businesses in this context view reverse logistics as an expensive investment. Such discussions then highlight the need for environmental awareness to the consumers and the public in general. It is important to let every stakeholder of planet earth know the intention of greening our economies, not only for businesses to make more money but for collective effort towards keeping planet earth safe.

On the other hand, it is also important to let businesses know of the repercussions of pollution through serious laws on the polluter-pay principle. This means that the containers that are highly contaminated, for instance, belong to the businesses; what belongs to the consumers is the content inside the containers. What that means then is for proper design for sustainability for businesses to have accommodating containers for customers, which can encourage reverse logistics. Perotti et al. (2012) suggest that green logistics practices seem highly adopted, while investment recovery and customer cooperation are not in use. Perotti et al. (2012) disagree with the findings of this study, especially on investment recovery, green logistics, and customer cooperation. At the same time, the findings of Perotti et al. agree with the findings of Negri et al. (2022). For this study, reverse logistics is the least adopted practice, but sits at the slightly agree, meaning, there is some form of appreciation which need to be cultivated.

Such discussions highlight the possibility of a lack of fully established frameworks to successfully implement reverse logistics. On the other hand, 2012, when the study of Perotti et al. was conducted, is such a long time, and a lot has happened encouraging progress in this area. For instance, the results of Perotti et al. (2012) disagree with this study. While this study found internal environmental management to be highly adopted, Perotti et al. (2012) found that its central element of customer cooperation is not in use. In the study of Laosirihongthong et al. (2013), reverse logistics seems to have the lowest adoption level. These findings agree with the findings of this study where reverse logistics has been argued not to make sense at all. However, in comparing the two studies, there is remarkable progress in the adoption rates of reverse logistics as per the findings of this present study compared to the study of Laosirihongthong et al. (2013).

Once more, it has been argued that the concept of reverse logistics could be impractical in the Thai manufacturing industry, the same case as the business manufacturing industry in a Sub-Saharan African context where we see the same insights of reverse logistics not being practical. The other green supply chain practices were adopted well, as per Laosirihongthong et al. (2013), which once more agrees with the results of this study. Looking at the low adoption levels of reverse logistics, there needs to be more sensitization on how it should be carried out in an emerging economy like Sub-Saharan Africa and, more importantly, laws that can promote its uptake towards a greener and more resilient Sub-Saharan Africa.

Besides, it is surprising to see reverse logistics well facilitated in a different Sub-Saharan African manufacturing context (Uganda) in the study of Namagembe and Sridharan (2018). Their study provided a comparative argument with a study that considered Chinese manufacturing firms (Zhu & Sarkis, 2007), in which the authors argued about the differences in laws and markets between China and Uganda.

However, coming closer home, it is interesting that the findings of Kenya and Uganda are different, given that both contexts sit in the Sub-Saharan. Even though Namagembe and Sridharan (2018) argue that Uganda is more welcoming of reverse logistics due to its restricted domestic and regional customer base. It could also be argued that different contexts in the Sub-Saharan have different structures of supply chains. Being that Kenya is ahead of Uganda in terms of gross domestic product and manufacturing added value, it is possible to have such discrepancies. What is surprising, however, is the impracticality of respondent's sentiments in the Kenyan context, which calls for more investigation and even comparative analysis among different contexts in the Sub-Saharan. Also, multiple pairwise cases looking into developing and developed economies would provide foundations for building resilient and sustainable economies across the world ecosystem.

In the findings of Jayarathna (2016), green supply chain practices are well adopted in the Sri Lanka manufacturing sector. This is in harmony with the findings of this present study, though there are some differences in the level of adoption. The adoption levels could also be influenced by the industry type, gender, and business size, considered control variables in this study. For instance, some sectors not involved in heavy machinery that utilize human labor in their processing may be at the early stages of such adoption. Also, this study noticed that males (67%) were the primary respondents, and females took the lowest percentage, 32%. Once more, this provides a starting ground for discussions on the role of eco-masculinities and eco-feminists on the uptake of green and closed-loop supply chains. This means that there needs to be the development of a theoretical base carrying from the eco-feminist philosophy, which argues that women are better at environmental management, while men are better at profit making highlight a need for synergies where men could be working to enhance economic performance and women to be working towards enhancing social-environmental performance.

Metaphorically, we could have male eco-feminists, meaning men passionate about environmental and societal safety. On business size, it is expected that the different clusters could have different adoption levels depending on their size from a sales revenue perspective or the number of employees. Future research could consider a more in-depth study to see the role of firm size and industry type as moderators on the relationship between green closed-loop supply chains and resilient sustainability. Notably, there are still inconsistencies in the findings of green closed-loop supply chains across different economies. While some findings report high-level adoption, some results report low-level adoption, and some report no adoption. From the experience of this study, it is realized that research in this area is sensitive in the collection of data where the respondents are not willing to provide informed responses. This means that manufacturing businesses are afraid and shy away from such research.

This is because, it is assumed that the government through ministries of environment, could be spying on the manufacturing businesses. Such an experience could be one of the reasons for inconsistent findings. For instance, there could be cases where manufacturing businesses are not authentic in their data dissemination concerning their adoption level. This again points out the need to develop and polish existing research and innovation policies that encourage authentic data dissemination and openness of studies such as this. Moreover, this calls for industry-university partnerships on research execution where the industry sees a clear cut line on how the research will benefit their operations and performance directly. Building upon this basis, this study provides theoretical arguments based on the ecological modernization theory which argues about sustainable innovations towards developing our economies and communities. The different practices under the umbrella of GCLSCM are cotemporary innovations that are designed to arrest the ecological crisis in responding to the defining challenge of our time, climate change. In this regard, this study argues about the need for theoretical arguments to be based on the ecological modernization theory in enhancing sustainable urbanization and industrialization.

6.3.3 Green Closed-Loop Supply Chains on Resilient Sustainability

Assessing the effect of green closed-loop supply chains on resilience sustainability, the R square results that seek to measure the predictive accuracy of a model are evaluated through the thresholds of 0.75, 0.50, and 0.25 as substantial, moderate, and weak, respectively (Hair et al., 2014). For this study, the R squares of the four endogenous variables depicting dimensions of resilient sustainability sit between moderate and substantial (resilience, R square=0.507; economic sustainability, R square=0.477; environmental sustainability, R square=0.645, and social sustainability, R square=0.542). Environmental sustainability exhibits a higher predictive power, followed by social, resilience, and economic sustainability. In general, the model shows predictive accuracy with precision averaging at moderate.

Hair et al. (2019) posit that to understand the predictive relevance of the model, researchers need to conduct blindfolding and PLS prediction. In smart PLS version 3, researchers have provisions to conduct blindfolding. However, blindfolding lacks the capability to assess out-of-sample predictive relevance (Hair et al., 2019). For this reason, PLS-predict was added onto smart PLS 4 to evaluate both predictive relevance in and out of the sample. For both techniques, it argued that a good model with better precision in predictive relevance has Q^2 values greater than zero. For this study, all endogenous constructs exhibited a higher predictive relevance through PLS-predict (economic sustainability, $Q^2=0.405$; environmental sustainability, $Q^2=0.572$; resilience, $Q^2=0.391$; and social sustainability, $Q^2=0.498$).

Also, the blindfolding test depicts higher predictive relevance since all constructs exhibited Q^2 values greater than zero. Negri et al. (2021) argue that the convergence of resilience and sustainability is still in its infancy, and the interactions are poorly addressed. Such reasoning opened up the investigation of the relationship between green closed-loop supply chains and resilient sustainability. By hypothesizing green closed-loop supply chains and resilient sustainability into four hypotheses and 16 sub-hypotheses, it is notable that the four hypotheses are significant on path coefficients, and four hypotheses are significant on the effect size. Cleaner production proves to be the strongest green closed-loop supply chain, showing significance on economic ($F=0.496$, $T=1.858$, $P=0.032$) and social sustainability ($F=0.547$, $T=2.014$, $P=0.022$) on effect size and social ($\beta=0.772$, $T=6.033$, $P=0.000$), economic ($\beta=0.822$, $T=6.238$, $P=0.000$) and environmental ($\beta=0.346$, $T=2.476$, $P=0.000$) sustainability on path coefficients. Reverse logistics ($F=0.257$, $T=1.880$, $P=0.030$) and combined green procurement and design for the environment ($F=0.272$, $T=1.777$, $P=0.038$) show significance on resilience and economic sustainability, respectively. Interestingly, none of the green Closed-loop supply chains showed significant results on environmental sustainability, except for combined green procurement and design for the environment on the path coefficients. This means that more needs to be done towards environmental sustainability.

Even though such results could be explained by the long-term effect of green closed-loop supply chains that might influence environmental sustainability, it is encouraging that the supply chain focal point is the strongest practice, showing higher chances of supply chains enhancing their sustainability and resilience. According to the study of Cankaya and Sezen (2019), green supply chain management showed significant effects on environmental sustainability with not-so-positive results on social and economic sustainability, which contradicts the findings of this study where green closed-loop supply chains showed significance on social sustainability, economic sustainability, and resilience with no significance effect on environmental sustainability. Notably, debates on GCLSCM and resilient sustainability based on the findings of this study and those of prior scholars provide a link to theoretical underpinnings on ecological modernization theory that calls for sustainable solutions to revive an ecological crisis, the systems theory, and the dynamic capabilities theory.

6.3.3.1 Combined Green Procurement and Design for the Environment on Resilient Sustainability

The findings of this study show that combined green procurement and design for the environment only affect economic sustainability with no relationship to social sustainability, environmental sustainability, and resilience.

The works of Cankaya and Sezen (2019) report similar findings where they found green purchasing to have an effect on corporate sustainability. Cankaya and Sezen (2019) argue that such results could be influenced by the fact that green purchasing is an external practice and that no one stakeholder has full control of its practice. Even though manufacturing businesses, through collaboration and stringent policies, can engage effectively with suppliers toward low-carbon procurement. In the study of Jermisittiparsert et al. (2019), green procurement had a positive effect on sustainable performance. These findings agree with this study, where combined green procurement and design for the environment affected economic sustainability. However, they disagree on whether green procurement and design for the environment did not influence environmental and social sustainability. Negri et al. (2021) report that green purchasing improved environmental and social performance with reduced risk disruptions. This is contrary to the findings of this study, where green procurement combined with design for the environment only influenced economic sustainability without a trace of its effect on social and resilience dimensions.

From a different perspective, the study of Negri et al. (2021) noted that green procurement, particularly on local sourcing, improved economic performance by reducing costs, which agrees with this study's findings. In disagreement, Green et al., (2012) found no relationship between local sourcing as a measure of green procurement and sustainability. This points out contrasts in the literature on the accurate measure of green procurement and resilient sustainability. Also, the study of Negri et al. (2021) posits that design for the environment enhances sustainability from the triple bottom line. This was realized in some firms and not in others. Design for the environment, combined with green procurement, proved beneficial for economic sustainability in this present study from the perspective of reducing costs and utilizing resources. In agreement, Zhu and Sarkis (2004) also found eco-design to be an excellent contributor to economic sustainability. In addition, Namagembe and Sridharan's (2018) study found that green procurement positively affected economic sustainability. Design for the environment was equally a good enabler for risk disruptions in the study of Negri et al. (2022).

Drawing motivation from these arguments, while many manufacturing businesses quote GCLSCM as a costly investment, the commercial benefits are equally practical, amid social, environmental and resilience benefits. Against this backdrop, this study draws from the underlying principles of both the dynamic capability theory and the ecological modernization theory on the importance of developing sustainable solutions and dynamic capabilities to build both resilience and sustainability of supply chains. To augment this claim, SCs are inherently unpredictable and such underlying principles becomes important in stabilizing these SCs.

6.3.3.2 Cleaner Production on Resilient Sustainability

In agreement with Cankaya and Sezen (2018), this study found cleaner production not to be affecting environmental sustainability but to be affecting social sustainability. Also, cleaner production through lean practices was found to influence the sustainability of SME manufacturing, as per the study by Dey et al. (2018). In this current study, cleaner production had elements of lean manufacturing that anchored total productive maintenance. Notably, the Japanese 5S approach enhanced social and economic sustainability for this current study. What this means, then, is a dire need to redefine cleaner production and inculcate aspects of lean manufacturing into cleaner production. Looking at the two, they are both pegged on waste reduction amid their other objectives. It is also worth noting that cleaner production sits at the forefront of supply chains. While it is encouraging to see cleaner production influence social and economic sustainability, there is reason to develop a cleaner production framework that comprehensively contributes to both resilience and sustainability.

It is also worth noting the need to develop cleaner production centers in the Sub-Sahara and other world regions to encourage and promote cleaner production as the centrality of sustainable supply chains. It would be interesting to see synergies between the government and private sector in promoting and fostering responsible production and consumption. Looking at the Sub-Saharan African context used in this study, it is encouraging to see the industrial clusters and parks as a path to enhancing manufacturing, even though it would be essential to align the industrial parks and clustering to different cleaner production centers to build cleaner manufacturing. It is essential to note the heavy dependence of manufacturing firms in this region on the natural resource endowments evidenced by sectors with an orientation to agriculture as the ones with a more significant share. What is surprising also is the heavy reliance on international sourcing, particularly from China and Asia, with no clear-cut laws towards forensics on the scope stretch of these regions on the responsibility to sustainability. That said, with the upstarting of laws like the Sustainable Waste Management Act, 2021 and the Extended Producer Responsibility Regulations, 2022 in Kenya, this study hopes for behavior change among the general public, producers and consumers in upholding sustainable consumption and production choices.

6.3.3.3 Green Logistics on Resilient Sustainability

The results of green logistics as a green closed-loop supply chain practice reveal that transportation and its management, packaging, and warehousing are essential to achieving resilience and sustainability of supply chains in four dimensions (economic, environmental, social, and resilience).

The results of this study indicate insignificant results on green logistics towards enhancing resilient sustainability in its four dimensions. Checking on the significance of the path coefficients, green logistics did not show any significance based on the path coefficients and their p-values (GL-economic sustainability, $F=\beta=-0.0013$, $T=0.105$, $P=0.458$, GL-environmental sustainability, $\beta=-0.018$, $T=0.147$, $P=0.442$, GL-resilience, $\beta=-0.050$, $T=0.331$, $P=0.370$ and GL-social sustainability, $\beta=0.085$, $T=0.904$, $P=0.183$). In addition, green logistics exhibited a too-small effect size (its meaningful relationship with the endogenous variables through the F test; GL-economic sustainability, $F=0.000$, $T=0.009$, $P=0.497$, GL-environmental sustainability, $F=0.000$, $T=0.016$, $P=0.493$, GL-resilience, $F=0.002$, $T=0.080$, $P=0.468$ and GL-social sustainability, $F=0.007$, $T=0.359$, $P=0.360$; against the threshold p-value of 0.05 at 95% confidence interval. From a predictive relevance perspective, green logistics exhibited a valid predictive relevance for the endogenous variables from a blindfolding and pls-predict perspective where the Q^2 was above zero, indicating higher predictive relevance.

The results of this study then, from a green logistics perspective, disagree with the results of Trivellas et al. (2020), which positively affected sustainability performance. Even it is realized that the study of Trivellas et al. (2020) did not have a resilient component and had a different measurement model for green logistics, including the collaboration aspect. It can be argued that collaboration could have influenced the results of green logistics to enhance its positive effect on sustainable performance. This discovery calls for comparative studies on green logistics and sustainable performance and green logistics and collaboration and sustainability performance. It is also notable that the findings of this study are different from those of Trivellas et al. (2020) due to the novel path of treating resilience as a pre-cursor of sustainability in this present study, which still calls for comparative studies to assess the efficacy of the models with and without resilience. Green logistics in this study entailed transportation and its management, green packaging and labeling, and green warehousing.

According to Trivellas et al. (2020), green packaging is a significant arm of logistics, making it a critical determinant for achieving sustainability. Besides, transportation has a huge role in overall performance and is a vital element in achieving logistical sustainability (Trivellas et al., 2020). Green warehousing is equally an essential element through intelligent decisions for its locational choice that can inform the transportation distance towards lowering emissions. Once more, the findings of this study disagree with those of Agyabeng-Mensah et al. (2020), who argue that green logistics calls for newer practices, such as logistics ecocentricity and supply chain traceability, to enhance sustainable performance.

This is because other prior studies have indicated negative and insignificant effects of green logistics and sustainability performance. Looking into this ideology, it is essential to note the role of green logistics in building supply chain resilience. With the new quest of practices, it is vital to have resilience and sustainability in mind. Surprisingly, the lack of established logistical systems for manufacturing businesses in a Sub-Saharan context hinders their full practice of green logistics towards resilient sustainability. It is also realized that the infrastructures in this context partially support enabling green logistics. In addition, Jermittiparsert et al. (2019) present positive results on green logistics and sustainable performance. In support, the study of Negri et al. (2022) realized a positive effect between green logistics and resilience and sustainability. It is evident then that prior literature has a contrasting effect with this study on the position of green logistics, which calls for more in-depth research to unfold areas of disparity.

6.3.3.4 Reverse Logistics on Resilient Sustainability

According to Cankaya and Sezen (2019), reverse logistics did not have an effect on economic sustainability. This is in agreement with the findings of this present study, where reverse logistics did not show any effect on sustainability dimensions. This concurs with the sentiments of Cankaya and Sezen (2019) that emerging economies are less interested in reverse logistics. In addition, it could also be argued that the top and bottom line for businesses in developing economies is economic performance, which could explain the lack of significance on reverse logistics and sustainability. Conversely, this study realized a positive result between reverse logistics and resilience, highlighting that reverse logistics could be an important dynamic capability in driving the resilience of supply chains.

6.3.4 IEM on Green Closed-Loop Supply Chains and Resilient Sustainability

Most prior scholars have treated internal environmental management as a green practice, while others treat it as an antecedent of GSC adoption. Even though, in this study, internal environmental management was treated as a moderator and was mainly defined by collaboration among SC partners. Notably, internal environmental management from past studies influenced the relationship between GSCM and sustainability. Such findings differ from the findings of this present study, where internal environmental management seems not to have a significant effect on the relationship between GCLSM and resilient sustainability. More investigation is needed to understand how best to treat internal environmental management as a moderator or mediator. The change in R square was only exhibited in resilience by 0.038, which is negligible, indicating that internal environmental management does not influence the relationship between GCLSCM and resilient sustainability.

Internal environmental management on reverse logistics and resilience ($F=0.055$, $T=1.162$, $P=0.123$) and internal environmental management on cleaner production and resilience ($F=0.067$, $T=0.976$, $P=0.165$) show no significant effect on the relationship between green closed-loop supply chains and resilient sustainability. However, the significance of path coefficients was supported by p values on reverse logistics and resilience ($P=0.049$) and cleaner production and resilience ($P=0.023$). This showed that internal environmental management can influence the relationship between green closed-loop supply chains and resilient sustainability. According to the findings of Arora et al. (2020), environmental collaboration that depicts internal environmental management influences sustainable purchasing and performance for small firms but negatively influences more prominent firms. These findings agree and disagree at the same time with the findings of this study. The contrast in such results still calls for more inquiry into IEM and its effect on the relationship between GCLSCM and resilient sustainability.

Accordingly, Chin et al. (2015) support the idea that environmental collaboration influences the relationship between green supply chains and sustainability performance. The discussions on internal environmental management and its effect on the relationship between green closed-loop supply chains and resilient sustainability provide a connection to theoretical reasoning based on network and stakeholder theory, where the interconnections among supply chain partners are informed by perfect

information sharing among these stakeholders leading to the building of strategic partnerships, confidence and trust on environmental uptake for the achievement of resilience and sustainability. Once more, this study builds theoretical arguments based on the dynamic capability theory postulating that dynamic capabilities such as the level of information sharing on green supply chain and closed loop practices should be deeply engraved in the management philosophies of supply chain to foster both resilience and sustainability in supply chains.

6.3.5 Control Variables on Resilient Sustainability

This study examined industry type, business size, and gender as control variables. All control variables were insignificant in influencing the resilient sustainability of the supply chains of manufacturing businesses in a Sub-Saharan African context. In agreement, the study of Habib et al. (2021) found the same results on industry type and business size except for industry type on positive environmental performance. On gender, it is notable that not all scholars look into gender in green supply chains and sustainability. However, gender is an essential factor to consider particularly in contexts with highly skewed gender numbers in their manufacturing businesses like in the context of businesses in a Sub-Saharan African economy.

6.4 Chapter Summary

This chapter points out exciting statistics. Its notable that there are some inconsistencies in literature about the findings of this study. For instance, reverse logistics seems to contribute to sustainability in some research and not in others. This means that context-based factors like legislation could be in place that encourage the uptake of such practices. It is also realized that resilient sustainability needs more investigations, especially framework measurement that should guide its adoption.

Chapter Seven: Conclusions and Recommendations

7.1 Introduction

This study sought to investigate building a resilient, sustainable economy through green and closed-loop supply chain management in the context of the circular economic model for manufacturing businesses in a Sub-Saharan African economy. This being the final chapter, the sections revisit the research objectives and formulated hypotheses by drawing out the study's main contributions with critical implications stemming from the research findings and discussions. Also, this chapter outlines the study's limitations, recommendations, and areas for further research. In summary, the chapter is organized into ten sections. Section 7.1 introduces the study; Section 7.2 revisits the research objectives; Section 7.3 revisits the research methods; Sections 7.4, 7.5, and 7.6 show the research conclusions, the relevance of a multi-theoretical perspective, and the research contribution, respectively. Sections 7.7, 7.8, 7.9, and 7.10 present the study's implications, recommendations, limitations, areas for further research, and the chapter summary, respectively.

7.2 Research Objectives

The study sought to investigate building a resilient, sustainable economy through green and closed-loop supply chain management in the context of the circular economic model for manufacturing businesses in a Sub-Saharan African manufacturing economy. The first objective sought to investigate the level of resilient sustainability adoption. The second objective sought to determine the level of green and closed-loop supply chain adoption. The third objective sought to investigate the influence of green and closed-loop supply chains on resilient sustainability in the circular economy context, and the fourth objective sought to investigate the moderating effect of internal environmental management on the relationship between green and closed-loop supply chains and resilient sustainability.

7.3 Research Methods

The study adopted an explanatory research design to achieve the objectives underpinning the positivist research philosophy. The explanatory research design targets 159 manufacturing businesses in a Sub-Saharan African manufacturing economy, where 100 valid responses were utilized. The study conducted descriptive and structural equation modeling analyses using Stata version 17 and Smart-PLS version 4.

7.4 Research Conclusions

This study underpins the investigation in a Sub-Saharan African manufacturing context depicting a fragile economy with a dwindling gross domestic product and manufacturing added value. The manufacturing businesses selected are for the Nairobi industrial zone, showing a zone with a larger share of manufacturing. The investigation into green closed-loop supply chains and resilient sustainability sits at the core of this research. It is found that green closed-loop supply chains strongly influence resilient sustainability, particularly in cleaner production, combined green procurement and design for the environment, and reverse logistics. Notably, only green closed-loop supply chains have influenced economic sustainability, social sustainability, and resilience. Green logistics was found not to affect resilient sustainability, and internal environmental management does not affect the relationship between green closed-loop supply chains and resilient sustainability. To achieve the objectives, a thorough review of extant literature was conducted, providing a frame for measurement scale for each research construct.

Both validity and reliability tests were done, and more importantly, on the primary research hypotheses depicting a reflective model under structural equation modeling of partial least squares. Under such observations, it is notable that the three most dominant theories anchoring systems thinking theory, dynamic capabilities, and ecological modernization underpin this study both from a literature and a findings perspective. While posited hypotheses claim an effect among the various invested constructs, it was realized that reverse logistics, which has long been argued to be practical for environmental sustainability, was reported as an impractical practice. This is evidenced through it being the least adopted GCLSCM practice. Against the backdrop, the conclusions are presented as per the structure of the research objectives: (7.4.1) resilient sustainability adoption levels, (7.4.2) the adoption levels of the green closed-loop supply chain, and (7.4.3) the effect of green closed-loop supply chains on resilient sustainability.

7.4.1 Resilience and Sustainability of Supply Chains

The objective sought to investigate the adoption levels for resilience and sustainability dimensions in supply chains for manufacturing firms in a Sub-Saharan African manufacturing context. Data was collected through a six-point Likert scale survey. Resilient sustainability was operationalized through seven dimensions, where resilience had four and sustainability three.

Resilience was measured through adaptability, agility, robustness, and a risk management culture. Sustainability was measured from the triple environmental, social, and economic bottom line. The findings of this present study reveal that while combining both resilience and sustainability from a literature perspective seems to be in infancy (Marchese et al., 2018; Negri et al., 2022), practitioners are already employing the two dimensions simultaneously. This present study found that the resilience average sat at 5.07 (agree level) and sustainability at 4.98 (a strong slightly agree level).

Robustness seemed to have a higher adoption level of all the resilient sustainability dimensions, followed by agility, economic sustainability, social sustainability, risk management culture, adaptability, and environmental sustainability, respectively. All dimensions sat at the agreed level (both agree and slightly agree), denoting that these firms already know which parameters need monitoring for achieving resilience sustainability. From a systems thinking theory perspective, combining the different components to form resilient sustainability proves instrumental in solving society's most pressing issues. Here, the different components of the supply chain integrated with green and closed-loop thinking influence the growth of SCs through their sustainability and resilience. This response to the ability to recognize the challenges and the capacity to respond to these challenges in modern supply chains anchored the ecological modernization theory. These findings still show the need for SCs to be cognizant of the double effect of resilience and sustainability dimensions as capabilities that can continuously elevate the performance of SCs.

7.4.2 Green and Closed-Loop Supply Chain Management

This second objective sought to determine the adoption level of GCLSCM for manufacturing businesses in Sub-Saharan Africa, which was achieved through data collected using a six-point Likert scale survey. GCLSCM was operationalized using five practices: combined green procurement and design for the environment, cleaner production/green manufacturing, green logistics, reverse logistics, and internal environmental management. The findings reveal adoption levels for each of the GCLSCM as IEM (5.34) combined green procurement and design for the environment (5.1), cleaner production/green manufacturing (4.998), green logistics (4.876), and reverse logistics (4.77) with higher adoption levels in that order. These results show that internal environmental management is the most adopted, and reverse logistics is the least adopted.

Specifically, transparency with customers seems to be the most adopted IEM practice. Under the category of combined green procurement and design for the environment, they are buying ISO-certified materials (5.45), designing for disassembly (5.4), buying materials with less or no hazardous ingredients (5.4), designing easy disposal (5.4) and designing for recoverability (5.04) as the most adopted practices. This shows the importance of circularity in the design and procurement components of the SC.

From a cleaner production/green manufacturing perspective, total productive maintenance based on continual servicing of equipment and machinery (5.29), the Japanese 5S methodology, particularly setting everything in order in the factory (5.27), use of less materials in production (5.16), producing towards zero defective products (5.15), water recycling (5.12) as the most adopted practices. Again, aspects deeply engraved in the circular economy seem the most adopted in these manufacturing firms towards waste reduction. This could be influenced by the advancement of circular economy awareness and adoption in Kenya, with the upstarting of the Sustainable Waste Management ACT of 2021 and the Extended Producer Responsibility of 2022.

From a green logistics perspective, packaging free of excess layers (5.4), sensor bulbs and doors (5.27), packaging for recycling and reusing (5.24), packaging using natural materials and texture (5.17), and downsized packaging are the most adopted practices. The works of Negri et al. (2022) argue that green logistics is the most practiced green supply chain practice, contrary to this study's findings, unfolding gaps for more research on these practices and in different contexts. From a reverse logistics perspective, reusing (5.20), reducing (4.92), recycling (4.92), customer product return awareness (4.83), and remanufacturing (4.8) are the most adopted practices. Even though reverse logistics is the least adopted practice, reuse seems to be the most prevalent in these manufacturing businesses. This could be explained by the lack of capacity and technology to support recycling and remanufacturing in the country. Besides, the higher costs for reverse logistics make these businesses not see the commercial sense of reverse logistics, necessitating the need for more support from the government for cleaner manufacturing.

7.4.3 Green and Closed-Loop Supply Chain Management and Resilient Sustainability

The third objective sought to investigate the influence of green and closed-loop supply chain management practices on resilient sustainability. The relationship was moderated by internal environmental management. Here, the findings reveal that environmental

sustainability (0.645), social sustainability (0.542), resilience (0.507), and economic sustainability (0.477) sit at moderate levels of the R square, denoting the percentage explained by the GCLSCM. From an effect perspective (five hypotheses are supported (four on F Square and five on path coefficients). Combined green procurement and design for the environment on environmental sustainability sit at ($F= 0.272$, $\beta=0.560$).

Combined green procurement and design for the environment show a medium effect size. Cleaner production on economic, social, and environmental sustainability sits at ($F=0.496$, $\beta= 0.822$; $F=0.547$, $\beta0.772$; $F=, 0.13$, $\beta=0.346$ respectively).

This shows a large effect size. Reverse logistics on resilience sits at ($F=0.257$, $\beta=0.471$). This shows a medium effect size. These findings reveal that the effect of cleaner production is vast for sustainability performance. This shows good progress for this region; amid the challenges of few factories and the burden of less advanced technologies, cleaner production practices can still build the sustainability of SCs. Besides, it is interesting to see the combined effect of green procurement and design for the environment, with a medium effect showing the effect of GCLSCM on sustainability. Procurement being the consumption pipe of SCs, it is essential to see that these businesses are reaping benefits from green design and procurement practices. From a reverse logistics perspective, it is notable that reverse logistics may be a context and sectoral-specific practice depending on the laws and regulations of the land, given its small effect size and adoption levels. In addition, sectors like pharmaceuticals and food that are highly regulated and deal with sensitive products could shy away from reverse logistics.

This brings out interesting findings on conflicting policies, where the pharmacy and poisons board could argue strongly about the need not to recycle, and environmental policies could recommend recycling and reuse, for instance, as ways of building circular economies. This research poses a question for policy: Can economies be furnished with integrated policies on controversial and conflicting practices toward a unified model of building resilient sustainability? This study acts as a reference point to provide grounds for such discussions.

Interaction effects should be assessed by changing the R square and the effect size (Tehseen et al., 2017). For this present study, the change in R square is negligible, where economic sustainability, social sustainability, environmental sustainability, and resilience show 0.000, 0.000, 0.000, and 0.038. This shows no interaction effects.

On the F square and path coefficients, reverse logistics ($F=0.055$, $\beta= -0.184$) and cleaner production ($F=0.067$, $\beta= 0.188$) on resilience are supported only from a path coefficient perspective. These findings reveal the need to further open the IEM building blocks to enhance their interaction effects as part of further research.

7.5 Relevance of a Multi-Theoretical Perspective

This research sought to determine if supply chain sustainability theories could be used to explain the influence of GCLSCM on resilience and sustainability utilizing the explanatory research design. The quantitative data analysis results, as presented in chapter five, show that GCLSCM and resilient sustainability are complex phenomena to be explained by a single theory, unfolding the need to consider a multi-theoretical perspective. The study determines that the influence of GCLSM on resilient sustainability is explained by ecological modernization, dynamic capability, and systems theories. The ecological modernization theory is confirmed strongly by the positive influence of GCLSCM on both resilience and sustainability, more so through combined green procurement and design for the environment, cleaner production, and reverse logistics. The systems thinking theory is equally confirmed by the different strengths of the dimensions of resilience and sustainability and again by the different components of GCLSCM dimensions as sub-parts that contribute to the resilience and sustainability of the more extensive supply chain network. Dynamic capabilities theory is confirmed by the positive interaction effect of IEM on the relationship between GCLSCM and resilient sustainability, evidenced by the supported p values of the path coefficients. It is also worth noting that these prominent theories traverse the entire study.

7.6 Research Contribution

This study presents several contributions to the SCM body of knowledge. First, it contributes to the advancements in the convergence of resilience and sustainability by investigating the adoption levels of both resilience and sustainability. Unlike prior studies that do not provide a broader convergence of resilience and sustainability (Michael-Villareal, 2021), this present study offers a starting line to an empirical convergent framework for resilience and sustainability. This study also contributes to this convergence in a Sub-Saharan African manufacturing economy, revealing the need for emerging economies to develop such frameworks and continuously test them for manufacturing and more significant SC sustainability.

Second, this study contributes by providing a joint investigation of both green and closed-loop supply chains based on the circular economy, unfolding the importance of such adoption in an emerging economy. This present study distinguishes itself from prior studies that only look into green supply chain management, such as Cankaya and Sezen (2019). Third, this study contributes by showing the link between the joint exploration of green and closed-loop supply chain management and both the resilience and sustainability of SCs. Most prior research, such as Nkrumah et al. (2020), have only looked into GSCM and sustainability. Other studies such as Ullah et al. (2021) have looked into GSCM and resilience.

This study brings forth the combinations of green and closed-loop supply chains and their effect on the combinations of both resilience and sustainability, providing room for more debates towards unfolding the tensions in extant literature. Fourth, this study contributes through an explanatory research design anchoring structural equation modeling. From a structural equation modeling perspective, this study contributes to the body of knowledge on sustainable and resilient supply chain management on a thorough need to conduct robust checks on endogeneity, unobserved heterogeneity, and non-linearity as proposed by Hair et al. (2021), which most scholars leave out. Fifth, this study also contributes by investigating the phenomena in a Sub-Saharan African economy.

7.7 Implications for the Study

7.7.1. Implications to Scholars

The works of Saidi et al. (2021) posit minimal studies on integrating resilience and sustainability. This points out the need to surpass conventional SD frameworks to capture resilience as a major pre-condition to sustainability. Besides, Saidi et al. (2021) present a framework combining resilience and sustainability by merging their building blocks. To that effect, borrowing from Colontanio (2009), SD has not grown fully in its conventional pillars of economic, social, and environmental sustainability. The European Parliament (2020) report posits that there has been so much bias to sustainability's environmental and economic aspects in the past. This has always brought about confusion on integrating social sustainability into both economic and environmental pillars of sustainability. This study serves as a guideline for comprehending adoption levels of resilient sustainability dimensions, adoption levels of GCLSCM, and the relationship of GCLSCM on resilient sustainability under the moderating effect of IEM in a Sub-Saharan African manufacturing context.

Previous studies have not been comprehensive, as they have primarily focused on sustainable supply chains or resilient supply chains. This study provides an integrated approach to converging supply chain resilience and sustainability. In addition, this study offers avenues that will attract scholars to take a deep dive into the theoretical foundations and newer trajectories for building resilient, sustainable economies. This study adds to scholarly discourse by providing novel suggestions for a more complex convergence of concepts (resilience and sustainability). First, the results reveal priority GCLSCM as cleaner production, combined green procurement, and design for the environment, and reverse logistics on SCRes and SCSus for manufacturing firms in a Sub-Saharan African context. Green logistics does not influence resilience sustainability, and green closed-loop supply chains do not affect environmental sustainability. These findings provide gaps for more probing, looking into several context-specific factors like the laws and regulations and culture of the country or region.

7.7.2. Implications to Practice (Managerial Implications)

Practitioners seem to be working towards resilience and sustainability. However, from the findings of this present study, resilience seems to be at a higher adoption level than sustainability. However, the difference sits at 0.009 which is negligible and could be explained by the fact that this study was conducted during COVID-19. It is evidenced from extant literature that few scholars look at resilience and sustainability more so from a dimensional perspective. The works of Marchese et al. (2018) and Espiner et al. (2017) argue about the need for research to concentrate on empirical investigations on both resilience and sustainability. This present study provides implications for managers to consider developing capabilities for both resilience and sustainability to boost their SC performance. A first line resilience capability that managers should consider working towards is robustness of their supply chains.

According to Stricker and Lancer (2014), firms must develop capabilities to enable them maintain stability amid disturbances. Managers are also provided with suggestions for building their agility, a risk management culture, and adaptability. From a sustainability perspective, managers are guided that as much as environmental sustainability seems to be the most considered pillar of sustainability, it would be important for these businesses to consider trade-offs at the beginning as they work towards a quadruple bottom line. Cumulatively, economic, social, resilience, and environmental sustainability in that order seem to be the most important.

This is towards the building of both resilience and sustainability of supply chains for these businesses. It is also essential for these businesses to consider green closed-loop supply chains to reverse their anthropogenic supply chain effect and work towards waste management beyond contracting companies to pick their wastes from the business premises.

The business must know how their waste is managed as it leaves the company premises. These debates encourage the practice community to prioritize green closed-loop supply chains such as cleaner production, combined green procurement, and design for the environment. Practitioners are also furnished with discussions to consider resilience alongside sustainability, and that the short-term rewards of environmental sustainability may not be practical, but in the long term, they might be applicable. Manufacturing businesses in a Sub-Saharan African context are also provided with a tested conceptual framework for building resilience and sustainability of their supply chains through green and closed-loop supply chain management in the context of the circular economic model.

The first line of green closed-loop supply chains on resilient sustainability is cleaner production. This finding is significant for these manufacturing businesses, insinuating the importance of the centrality of supply chains. It is interesting to note that the focus of the supply chain has more weight towards resilient sustainability. It is also worth noting for these businesses that green investments and adoption, such as green closed-loop supply chains, have commercial benefits. For instance, this study deduces that green procurement design for the environment and cleaner production influence economic sustainability. The businesses are still furnished with the findings of enhancing social sustainability and taking center stage on the well-being of their employees and customers.

7.7.3. Implications to Policy

A transition from the triple bottom line to a quadruple bottom line is one of the recent significant contributions for policymakers, given the effects of COVID-19 and a myriad of climate-related supply chain risk disruptions to enhance resilience and sustainability. Also, policymakers have been furnished with a conceptual framework pointing to the need for more stringent policies towards the resilience and sustainability of SCs. The findings of this study unfold loopholes in policy that show a need for laws and regulations to be more stringent. In the past, laws and policies in this region have not been stringent.

With the introduction of the Sustainable Waste Management ACT of 2021 and the Extended Producer Responsibility of 2022, the researcher believes that the findings of this study will upstart the stringency of the laws placed towards compliance, more particularly from a circular economy practice perspective. It is also worth noting the regulators in this area in a Sub-Saharan African manufacturing context. The Ministry of Environment and Forestry, with affiliate laws such as the Sustainable Waste Management Act, Climate Change Act, and Environmental Management Act, are provided with discussions that can inform policy. For instance, the findings of this present study elucidate the critical green and closed-loop supply chain practices considering circular economy such as cleaner production, combined green procurement and design for the environment and reverse logistics in building both resilience and sustainability of Scs.

These results can help policy makers map out critical green practices and hotspot manufacturing activities that need them the most due to the challenges of affordability. Besides, this study provides a starting line that can guide policy on measurement items to utilize in upstarting and revising existing policy frameworks towards manufacturing sustainability. Looking into some of the existing policies, while the building of resilience has been captured in the Climate Change ACT of Kenya, 2016 for instance, the policies do not provide clear guidelines on how to build resilience. Better still, this opens up the need for policymakers to consider careful sectoral mapping and assess priorities toward building resilient sustainability by first investigating the possibility of their convergence through adoption levels.

A first-line consideration would be the findings of this present study coupled with the guidelines under the Kenya National Climate Change Action Plan of 2018-2022, which provides a clear road map on priority climate change areas. Even though manufacturing regarding climate change adaptation and mitigation is seen as priority six in the Kenya National Climate Change Action Plan. While it makes good societal sense, the proposed action plan is disadvantaged by not comprehending the core role of manufacturing in nationalities. Looking into the agendas for national development such as the Big FOUR agenda put forth during President Kenyatta's tenure, enhancing manufacturing takes priority, and this is important to prevent the Kenyan context from leaping to pre-industrialization. Current statistics as denoted by the OECD, (2017; 2021), the recent gross domestic product performance insinuates Kenya is en route to pre-industrialization, where the service industry is contributing more to economic development compared to manufacturing.

Primarily, Kenya's economy is characterized as a consuming economy. Here, the findings of this study can help policy makers realize the importance of manufacturing, coupled with the negative externalities associated with its activities and thus calling for the embedment of GCLSCM considering circular economy to promote both resilience and sustainability for the sector. In addition, other associations like the Kenya Association of Manufacturers can benefit from this study towards sensitizing manufacturing to build resilience and sustainability through GCLSCM. Under such discussions, this study provides insights to the government of Kenya through its various ministries, such as the national treasury, environment and forestry, and trade and transportation, to consider the employment of green and closed-loop SCM through public-public and public-private partnerships toward comprehensive policies and frameworks.

It is also essential for all these stakeholders to dive deeply into existing laws and give provisions for clear-cut aspects of the circular economy and closing the supply chain loop. While some of these policies, such as the Sustainable Waste Management Act of 2021, have provided a percentage of such approaches as extended producer responsibility, 2022, it is essential to provide clear guidelines on their adoption and a broader scope that anchors different sectors of the economy. In addition, while there are provisions of adaptation and mitigation approaches to all sectors of the economy, more so from a climate change perspective, it is essential to understand sectoral and context-specific approaches toward building resilient sustainability. For instance, guidelines on manufacturing based near residential places are pretty different from those offered to manufacturing in industrial zones. Against this backdrop, it is also notable that concrete policies around this area call for multi-stakeholder collaborations and points of convergence for all affiliate ACTS of parliament, such as the Occupational Safety and Health ACT of 2007.

Besides, other well-meaning laws such as those under the pharmacy and poisons board, food and drug enactment; and chemical and plastic pollution among many become important towards their convergence for meaningful attaining of resilience and sustainability of SCs through the uptake of GCLSCM. It is interesting to note the dormancy of the ACTS in place. While the maturity of concepts in sustainability and resilience is gaining momentum, and the belief that contexts in the global south are not the main contributors to harm hindering SD, such policies and laws must be stringent and active in upstarting the joint uptake of both green and closed-loop SCs.

A significant reason with bias to environmental occurrences is that Kenya continues to face massive climate-related disturbances such as the melting of glaciers such as those of Mt Kenya; Lake Victoria is in a highly deteriorating state, leading to a shortage of fish and depletion of the Mau forest to name a few.

7.8 Recommendations

The following recommendations are made based on the findings and discussion of these studies. First, the need for hot spot analysis and mapping of priority green closed-loop supply chains and their affiliate resilient dimensions will enable these businesses to give priority areas effort and energy to avoid more resource wastage. Indeed, achieving points of balance seems unrealistic. However, economies can adopt trade-offs as they work towards points of balance. Second, converging resilience and sustainability from a dimension perspective is the first line in developing workable frameworks. Third, there is a need for a joint exploration of green and closed-loop supply chains to build both resilience and sustainability. Moreover, drawing inspiration from these recommendations, there is a need for sustainability-related ACTS to be aligned with the agendas of national development. For instance, the need to integrate climate issues into the Big Four agenda and provide clear-cut building blocks of climate action in the KENYA KWANZA manifesto, even with its mention of climate action, the manifesto is not entirely clear on a road map to achieving climate action.

This study provides insights to the regulators to consider the integrated framework as a guide to building resilient, sustainable economies. While some of the study's tenets have been borrowed from existing ACTS, a systematic process mapping and steps to their achievement would be necessary. What is also interesting is the lack of established measurement frameworks to act as boundary maps for implementing such practices. Notably, while there is a mention of a practice like circular economy in some of these ACTS and several conversations towards Kenya's green growth agenda, it is unclear what circular economy is in such policy guidelines. A need arises to partner with knowledge centers like Universities to offer concrete measurement models for practitioners and policymakers. Here Universities are expected to champion circular educational models in the context of higher learning SCs (Aming'a et al., 2023) to accelerate both resilience and sustainability of SCs. A worthwhile recommendation would also emphasize establishing cleaner production centers for manufacturing and SCSus. Such centers would be initiated by the public and through partnerships with the private sector and knowledge centers.

A clear line for such centers would be to take advantage of Kenya's model of special economic zones, more so the industrial park model. This means that every cluster of industrial parks should be organized under a cleaner production center.

The centers could also link to the existing national cleaner production center. As envisioned in Kenya's Climate Change Act of 2016 about integrating climate change into curricula, knowledge centers could be the second line after the special economic zones and the government to provide cleaner production centers that are research-based to offer advisory to those of the government and the private sector.

7.9 Limitations and Areas for Further Research

This study is not without limitations. First, the study is limited to a particular context in the Sub-Saharan (Kenya). Second, the study is limited to environmental collaboration as a defining factor for internal ecological management. Lastly, the study is limited to manufacturing businesses in a city setup involved in pure production and mixing. Future research could look into a broader scope involving a comparative case among the different regions of the Sub-Saharan to provide a holistic case for Sub-Saharan African manufacturing businesses. Second, consider more factors as moderators, such as the utilization of technology like the fourth industrial revolution. Third, extend the resilient sustainability framework beyond green closed-loop supply chains. Lastly, future research could look into divergences and convergences of existing policies on closing the supply chain loop for a more integrated policy outline to achieve resilient sustainability.

7.10 Chapter Summary

This chapter provides the conclusions and recommendations by outlining the research contribution and implications for research for scholars, practitioners, and policymakers.

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Appendices

Appendix A: Ethical Clearance Confirmation



15th March 2021

Ms Aming'a, Mary
maminga@strathmore.edu

Dear Ms Aming'a,

REF: Proposal: SU-IERC0892/20 "A Model toward a Resilient Sustainable Economy through Green Closed Loop Supply Chains"

We acknowledge receipt of your request regarding the referenced study, which was accompanied by the following:

1. A progress report dated 9th September 2020.
2. Interview guides for stakeholders, questionnaires, focus interview guides 9th September 2020.

The Strathmore University Institutional Ethics Review Committee has reviewed and approved the request for an extension for "*A Model toward a Resilient Sustainable Economy through Green Closed Loop Supply Chains*".

The approved extension is effective on **15th March 2021** and will automatically expire on **14th March 2022**.

If the study extends beyond the stated period, you are required to seek another extension approval from the Ethics Committee prior to its expiry. You are required to submit any proposed changes to this protocol to SU-IERC for review and approval prior to their implementation.

SU-IERC should be notified when your study is complete.

Sincerely,

A handwritten signature in black ink, appearing to read "Virginia Gichuru".

for: Dr Virginia Gichuru,
Secretary,

Strathmore University Institutional Ethics Review Committee.



Appendix B: NACOSTI Research Permit

Republic of Kenya
National Commission for Science, Technology and Innovation

Ref No: 667684

RESEARCH LICENSE



This is to Certify that Ms. Mary Aming'a of Strathmore University, has been licensed to conduct research in Nairobi on the topic: **A Model toward a Resilient Sustainable Economy through Green Closed-Loop Supply Chains for Business Manufacturing Organizations in Kenya for the period ending : 23/November/2021.**

License No: NACOSTI/P/20/7841

Date of Issue: 23/November/2020

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Appendix C: Thesis Similarity Report

Thesis 8th April 2024.docx

ORIGINALITY REPORT

6%

SIMILARITY INDEX

4%

INTERNET SOURCES

4%

PUBLICATIONS

6%

STUDENT PAPERS

PRIMARY SOURCES

1

Submitted to Strathmore University

Student Paper

3%

2

journal.sagpb.com

Internet Source

<1%

3

ideas.repec.org

Internet Source

<1%

4

jbc.bj.uj.edu.pl

Internet Source

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Student Paper

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Appendix D: The Survey Instrument

Survey

Dear Respondent,

This survey seeks to provide answers about the sustenance and resilience of supply chains through environmental supply chains based on the circular economy within manufacturing firms in Kenya. You have been selected as an expert within the supply chain (procurement, production/quality assurance, logistics, warehousing, packaging, sales, product returns, and environment supply chain) to help give responses to the best of your knowledge.

Please provide your responses true the questions and in a clear manner. In case you need clarity on any of the sections, please do not hesitate to inquire through 0727394669.

PART A: Demographics

Please tick and respond where appropriate.

- QA1.** What’s your gender? **Female** **Male** **Other**
- QA2.** What’s the name of your firm.....?
- QA3.** Is your firm a member of the Kenya Association of Manufacturers.....?
- QA4.**What’s your position..... Which department are you based at.....?
- QA5.**Which section of supply chain do you deal with.....?
- QA6.** For how long have you been working in your firm.....?
- 0-5 Years
 - 6-10 Years
 - Over 10 Years

QA7a. How many males and how many females are working in your department?

Males **Females**

QA7b. How many of those males and how many of those females hold positions of power (e.g., the head of the department)? **Males** **Females**

QA8a. How many males and how many females are working in the larger supply chain (Procurement/Production/logistics)? **Males** **Females**

QA8b. How many of those males and how many of those females hold positions of power (e.g., head of department)? **Males** **Females**

Part B: Supply Chain anthropogenic practices

This section of the survey examines practices within supply chains that can be improved to create better supply chains and be safe for the environment and society.

*This section uses a six-point Likert scale where 1 is Strongly disagree, 2 is disagree, 3 is slightly disagree, 4 is slightly agree, 5 is agree, and 6 is strongly agree.

To what extent do you agree with the following practices within your daily work life across your department as a daily practice?

	Supply Chain Anthropogenic Activities	1	2	3	4	5	6
1.	Your company has a proper garbage collection system.						
2.	Your company has chimneys in its production sites that help get out the smoke from the factories						
3.	Your supply chain discloses its carbon footprint to concerned bodies.						
4.	Your supply chain still uses vehicles that are not energy-efficient						

5.	Your supply chain function directs its industrial effluents to water bodies and the soil.						
6.	Your supply chain function directs its untreated sewer to the nearby rivers						
7.	Your supply chain function directs its garbage to the nearest landfill.						
8.	Your company, through the supply chain, normally experiences fires and explosions						
9.	Your supply chain function experiences chemical/radiation spills.						
10.	Availability of water for your supply chain operations is scarce.	.	.				
11.	Your supply chain function has its workers working for more than 8 hours a day.						
12.	Your supply chain function has its workers on machine monitoring, working more than 2 hours without a break.						
13.	Sometimes, tap water is left running unattended along supply chain activities in your firm.						
14.	There's no reserve for rainwater for use in the supply chain.						
15.	Lights are normally left on at daylight within our supply chain function.						
16.	Machines are normally left running unattended with no activity ongoing within our supply chain function sometimes.						
17.	Waste from your supply chain function sits for more than a week before collection.						
18.	The office set up for your employees takes notice of the employee's health, e.g., chairs that support upright posture, screens that support eye care						
19.	Your supply chain function takes notice of the use of resources (no wastages)						
20.	Your supply chain function puts all waste into one place without segregation.						
21.	Your supply chain function is keen on floors that would not make one slide and injure themselves.						

PART C: Environmental Supply chains (circular economy embedded)

Environmental supply chains with the circular economy embedded look into the whole supply chain in a regenerative manner where all materials and wastes are either used as raw material or a resource in any of the supply chain stages to avoid waste disposal to the environment for the well-being of society and economies.

*This section uses a six-point Likert scale where 1 is Strongly disagree, 2 is disagree, 3 is slightly disagree, 4 is slightly agree, 5 is agree, and 6 is strongly agree.

To what extent do you agree with the following environmental supply chain practices to have been implemented in your firm?

Environmental supply chain practices (circular economy embedded)	1	2	3	4	5	6
Design for the environment						
1. The supply chain function plans for the use of less materials in your products(Dematerialization)						
2. The supply chain function plans for materials with disassembly ability						
3. The supply chain function plans for materials and products that can be recycled						
4. The supply chain function plans for materials and products that can be recoverable						
5. The supply chain function plans for materials and products in line with regulatory compliance such as NEMA.						
6. The supply chain function plans for materials and products with no or less hazardous ingredients						
7. The supply chain function plans for materials and products which can be easily disposed of and with minimal environmental effect						
Green Procurement/ Green Purchasing						
1 The supply chain function procures materials with greater energy and water efficiency						
2. The supply chain function procures materials that utilize clean energy and technology						
3. The supply chain function procures materials that have controlled use or have no toxic substances. For example, for plastics, BPA is free.						
4. The supply chain function procures materials with improved recycling ability						
5. The supply chain function procures materials that have minimal packaging needs						
6. The supply chain function procures materials with extended durability						
7. The supply chain function does a supplier audit for environmental standards						
Green Manufacturing/Cleaner Production						
1. The production department reduces water and energy consumption right to operations						
2. The production department uses recyclable and biodegradable materials for production and packaging						
3. The firm is ISO 14001 certified for its production						
4. The production department substitutes materials with toxic substances with those of no or less toxic substances for production						
5. The production department puts into use just-in-time manufacturing						

6. The production department has safety measures for anyone working or visiting the factory floor						
7. The production department employs a work schedule of shifts to allow workers to get a break from the machines						
8. The production department provides protective gear for its workers against accidents						
9. The production department works towards zero defective products						
10. The production department reuses/recycles water in production for other use						
11. The production department uses raw materials well without wastage						
12. The production department is keen on energy usage/savings						
13. The production department employs total productive maintenance for its machineries						
14. The production department considers waste from the department as value for something else						
Environmental Logistics and Transportation						
1. The logistics and transportation department does direct delivery of products and materials						
2. The logistics and transportation department does well-planned vehicle routes						
3. The logistics and transportation uses vehicles which are energy efficient and with alternative fuels that have no or less emissions						
4. The logistics and transportation department groups orders together for the same destination						
5. The logistics and transportation department has a well-temperature-controlled system where applicable for cold chain products						
6. The logistics and transportation department is keen on good disposal of its vehicles for use by other parties						
Environmental packaging and Labeling						
1. The supply chain function is keen on downsizing packaging						
2. The supply chain department is keen on the recycling and reuse of the packaging						
3. The supply chain function is keen on standardized packaging						
4. The supply chain department is keen on recyclable pallet systems						
5. The supply chain department is keen on the use of materials with natural texture for its packaging, like the use of carton boards						
6. The supply chain department is keen on packaging that will be easier to open and store and use less space for storage						
7. The supply chain function is keen on well labeling its packaging, e.g., ISO 14000 certified this bag is a friend to the environment						
8. The supply chain department is keen on using natural colors for its packaging materials (brown, green, and blue) with a matte and non-glossy finish						
9. The supply chain department is keen on the use of packaging materials that are recyclable and free of excess layers and waste						
10. The supply chain department considers second-life packaging (use of packaging materials that can be converted into something else)						
Environmental Warehousing						
1. The supply chain department is keen on the reuse of older facilities						

2. The supply chain department is keen on efficient space usage for inventory storage						
3. The supply chain department is keen on the utilization rate for its space for inventory storage						
4. The supply chain department is keen on energy/water saving/improved indoor air quality in its warehousing facilities						
5. The supply chain department is keen on the usage of sensor bulbs and sensor doors that close when not in use						
6. The supply chain function has well-coordinated inventory management like the use of nonhazardous pesticides where applicable						
7. The supply chain is keen on well-coordinated inventory to give way to those that came earlier in-store to move out first						
8. The supply chain department is keen on training its warehousing workforce on best warehousing practices for the environment						
9. The supply chain department is keen on warehousing waste management for reuse/recycling or disposal						
Reverse Logistics						
1. The supply chain department is keen on the reuse of materials/water/facilities/vehicles/space/equipment/machineries etc						
2. The supply chain department is keen on the reduction of material usage/energy consumption/water consumption.						
3. The supply chain department is keen on the recycling of parts, materials, etc						
4. The supply chain function is keen on refurbishing old parts/products						
5. The supply chain department is keen on the use of old parts for remanufacturing						
6. The supply chain department has a product return collection centre from customers (e.g., for products that have reached the end of life, like fridges no longer in use for remanufacturing)						
7. The supply chain department has an awareness platform for customers on product returns for products that are faulty or have reached end-of-life						
8. The supply chain department is supportive of its customers on the use and maintenance of products bought from the company with easily available engineers across all regions and a call center for problematic issues.						
Environmental Supplier/Customer Collaboration						
1. The supply chain department is keen on building environmental trust in its customers and suppliers. For instance, encouraging suppliers to be environmentally certified and providing consistent environmental product quality to customers						
2. The supply chain department is keen on sharing well-coordinated supplier/customer environmental information. For instance, the quality of packaging, ingredients used, raw materials needed from suppliers, etc.						
Environmental Ethical Considerations						
1. Your supply chain function can tell how its suppliers produce raw materials or parts that are geared toward environmental safety (environmental transparency)						
2. Your supply chain function monitors for any loopholes in environmental risks						
3. Our supply chain function is open to its customers on the extent of a product's contribution to environmental and societal safety						

Environmental Leadership						
1. Your supply chain function leadership is keen on environmental supply chains						
2. Your supply chain leadership offers support for campaigns toward environmental supply chain						
3. Your supply chain leadership takes notice of changing regulations on environmental matters for supply chains						
4. Your supply chain leadership is keen on contributing to the United Nations Agenda 2030 on SDG 12-towards responsible production and consumption						
Overall Supply Chain on 5S Methodology (Sort, Set in order, Shine, Standardize and Sustain)						
1. Your supply chain function is keen on Sorting (Removing unneeded materials from the floor to make the floor visible and noticeable).						
2. Your supply chain function is keen on Setting in order (Putting everything in the right place to help employees minimize wasted time and effort).						
3. Your supply chain function is keen on a shiny workplace (a dirt-free, spotless, sterile, and organized environment that can boost employee morale and create a sense of ownership and belonging. It helps to lower down the accidents at the shop floor.						
4. Your supply chain function is keen on standardizing procedures for better environmental, societal, and economic well-being						
5. Your supply chain function is keen on maintaining standards and procedures toward better environmental, societal, and economic well-being						
Environmental Total Productive Maintenance						
1. Your supply chain function is keen on cleaning machinery and equipment after every use						
2. Your supply chain function is keen on servicing equipment, machineries, facilities, and vehicles on scheduled times						
3. Our supply chain function is keen on not placing weights on machines, equipment, etc.						
4. Your organization has a maintenance department to take care of machineries, equipment, etc., from the supply chain function						

PART D: Resilience and Sustainability of Supply Chains

*This section uses a six-point Likert scale where 1 is Strongly disagree, 2 is disagree, 3 is slightly disagree, 4 is slightly agree, 5 is agree, and 6 is strongly agree.

To what extent do you agree with the following statements regarding how your supply chain works towards resilient sustainability?

Resilience Fit	1	2	3	4	5	6
Adaptive Resilience						
1. Your supply chain function plans for uncertainties by developing a supply chain risk register						
2. Your supply chain reacts to risk disruptions through environmental supply chains						
Agile Resilience						
3. Your supply chain responds very quickly to risk disruptions						
4. Your supply chain understands the status of its supply chain environment and assets						
5. Your supply chain can adapt quickly to a disruption						

Risk management cultural resilience						
6. Your supply chain function identifies areas of risk exposure						
7. Your supply chain prepares on how to cope with foreseeable uncertainties						
Robust Resilience						
8. Your supply chain is very careful in the selection of environmental supply chains for managing risk disruptions						
Collaboration						
9. Your supply chain function has built trust and strategic partnerships on environmental product aspects with its suppliers and customers						
10. Supply chain environmental joint decision-making is essential for managing risk disruptions						
11. Supply chain environmental information sharing enhances a better response to risk disruptions						
12. Your supply chain function is keen on increasing its number of suppliers						
13. Your supply chain function is keen on diversifying the geographical location of its suppliers						
14. Your supply chain has/plans to have alternative suppliers in case of emergencies						
15. Your supply chain has/plans to have alternative production sites in case of emergencies						
16. Your supply chain stocks more inventory to cover for the uncertain times						
17. Your supply chain plans to assess risks imposed by suppliers and customers beyond tier-one						
18. Your supply chain plans on early detection of risk disruptions						
19. Your supply chain plans or has dual sourcing of raw materials						
20. Your supply chain has/plans to increase inventory of critical products						
21. Your supply chains have/planning for suppliers closer to home						
Sustainability Fit						
22. Your supply chain is keen on achieving near-zero carbon emissions						
23. Your supply chain is keen on achieving near-zero wastes						
24. Your supply chain is keen on resource utilization						
25. Your supply chain is keen on environmental supply chains toward climate resilience						
26. Your supply chain is keen on achieving the lowest total cost of ownership						
27. Your supply chain is keen on the safety of its employees						
28. Your supply chain is fair in the selection and treatment of its employees						
29. Your supply chain is keen on the health of its employees and customers						
30. Your supply chain is keen on low-carbon procurement						
31. Your supply chain is keen on climate resilience						

PART E: Environmental Supply Chains for Resilient Sustainability (Refer to Part C)

This part of the questionnaire relates to employing environmental supply chains for achieving resilient sustainability.

*This section uses a six-point Likert scale where 1 is Strongly disagree, 2 is disagree, 3 is slightly disagree, 4 is slightly agree, 5 is agree, and 6 is strongly agree.

To what extent do you agree with the following environmental supply chains for achieving resilient sustainability? (Refer to Part C)

Environmental Supply Chains for Resilient Sustainability	1	2	3	4	5	6
Design for the Environment for Resilient Sustainability						
1. planning for the use of less materials in your products(Dematerialization) enhances resilient sustainability						
2. Planning for materials with disassembly, recoverability, and recycling ability enhances resilient sustainability						

5. Plans for materials and products in line with regulatory compliance, such as NEMA, enhance resilient sustainability						
6. Planning for materials with less or less hazardous ingredients and materials that can be disposed of with minimal environmental effect enhances resilient sustainability						
Green Procurement/ Green Purchasing for Resilient Sustainability						
1 Procuring materials with greater water, energy, and material efficiency enhances resilient sustainability						
2. Procuring materials that have been produced through cleaner energy and technology enhances resilient sustainability						
3. Procuring materials with controlled use and no or less toxic substances enhances resilient sustainability						
4. Procuring materials with minimal packaging needs and with improved recycling ability enhances resilient sustainability						
6. Procuring materials that can be substituted and with extended durability enhances resilient sustainability						
7. Conducting a supplier audit for environmental standards enhances resilient sustainability						
Green Manufacturing/Cleaner Production for Resilient Sustainability						
1. Reduction of water, energy, and materials for production; use of recyclable and biodegradable materials for production and packaging enhances resilient sustainability						
2.ISO 14000 certification for production and the use of just-in-time manufacturing enhances resilient sustainability						
3. Substituting materials with toxic substances with those of no or less toxic substances for production and safety measures in place for anyone working or visiting the factory floor enhances resilient sustainability						
7. Employing a work schedule of shifts to allow workers to get a break from the machines, providing protective gear for workers against accidents, and working toward zero defects enhances resilient sustainability						
9. Employing total productive maintenance for machinery and equipment and considering waste as a material or part of production enhances resilient sustainability						
Environmental Logistics and Transportation for Resilient Sustainability						
1. Direct delivery of products and materials, well-planned vehicle routes, and grouping orders for the same destination enhance resilient sustainability						
2. A well-temperature-controlled system, where applicable for cold chain products and good disposal of vehicles for use by other parties, enhances resilient sustainability						
Environmental packaging and Labeling for Resilient Sustainability						
1. Downsizing packaging, recycling, and reuse of packaging enhances resilient sustainability						
2. Standardized packaging, use of recyclable pallet systems, and use of materials with natural texture for packaging, like the use of carton boards, enhance resilient sustainability						
3. Packaging that is and will be easier to open, store, and use less space for storage; and well labeling of packaging, e.g., ISO 14000						

certified of this bag is a friend to the environment and enhances resilient sustainability						
4. Use of natural colors for packaging materials (brown, green, and blue) with a matte and non-glossy finish, use of packaging materials that are recyclable and free of excess layers and waste enhances resilient sustainability						
5. Considering second-life packaging (use of packaging materials that can be converted into something else) enhances resilient sustainability						
Environmental Warehousing for Resilient Sustainability						
1. Reusing older facilities' efficient space usage for inventory storage enhances resilient sustainability						
2. Energy/water saving/improved indoor air quality in warehousing facilities enhances resilient sustainability						
3. The usage of sensor bulbs and sensor doors that close when not in use and well-coordinated inventory management, like the use of nonhazardous pesticides, enhances resilient sustainability						
4. A well-coordinated labeling of inventory to give way to those that came earlier in store to move out first, training of the warehouse employees on best environmental warehousing practices and warehousing waste management for reuse/recycle or for disposal enhances resilient sustainability						
Reverse Logistics for Resilient Sustainability						
1. Reduction of material usage/energy consumption/water consumption enhances resilient sustainability						
2. Use of old parts for remanufacturing, refurbishing of old parts, recycling of old parts, reusing, and reducing materials and products enhances resilient sustainability						
3. A product return collection centre from customers (e.g., for products that have reached the end of life, like fridges no longer in use for remanufacturing) enhances resilient sustainability						
4. An awareness platform for customers on product returns for products that are faulty or reached end of life enhances resilient sustainability						
5. Supporting customers on the use and maintenance of products bought from the company with easily available engineers across all regions and a call center for problematic issues enhances resilient sustainability						
Environmental Supplier/Customer Collaboration for Resilient Sustainability						
1. Building environmental trust in your customers and suppliers. For instance, encouraging suppliers to be environmentally certified and providing consistent environmental product quality to customers enhances resilient sustainability						
2. A well-coordinated supplier/customer environmental information sharing. For instance, the quality of packaging, ingredients used, quality of raw materials needed from suppliers, etc., enhances resilient sustainability						
Environmental Ethical Considerations						
1. Your supply chain functions environmental transparency to both suppliers and customers enhances resilient sustainability						
2. Monitoring of any loopholes for environmental risks within your supply chain enhances resilient sustainability						
Environmental Leadership						

1. Your supply chain leadership keenness on environmental supply chains enhances resilient sustainability						
2. Your supply chain leadership support toward campaigns on environmental safety enhances resilient sustainability						
3. Your supply chain leadership awareness of changing environmental regulations enhances resilient sustainability						
4. Your supply chain leadership contribution towards the United Nations Agenda 2030 on SDG 12-towards responsible production and consumption enhances resilient sustainability						
Overall Supply Chain on 5S Methodology (Sort, Set in order, Shine, Standardize and Sustain)						
1. Your supply chain function's keenness on Sorting (Removing unneeded materials from the floor to make the floor visible and noticeable) enhances resilient sustainability						
2. Your supply chain function's keenness on Setting in order (Putting everything in the proper place to help employees minimize wasted time and effort) enhances resilient sustainability						
3. Your supply chain function's keenness on a shiny workplace (a dirt-free, spotless, sterile, and organized environment which can boost employee morale and create a sense of ownership and belonging and also helps to lower the accidents at the shop floor enhances resilient sustainability						
4. Your supply chain function's keenness on standardizing procedures for better environmental, societal, and economic well-being enhances resilient sustainability						
5. Your supply chain function's keenness on maintaining standards and procedures toward better environmental, societal, and economic well-being enhances resilient sustainability						

Notes** Some sections not used in this thesis are omitted*

Appendix E: Other Research Findings

Appendix E1: PLS-SEM Measurement Model, Discriminant Validity, Bootstrap HTMT

	HTMT Value (Original Sample)
Econ Sus->CP	0.841
Env Sus->CP	0.874
Env Sus-> Econ Sus	0.474
GL->CP	0.656
GL-> Econ Sus	0.391
GL-> Env Sus	0.582
GP&DFE-> CP	0.878
GP&DFE-> Econ Sus	0.578
GP&DFE-> Env Sus	0.873
GP&DFE-> GL	0.785
IEM-> CP	0.825
IEM-> Econ Sus	0.437
IEM-> Env Sus	0.685
IEM-> GL	0.745
IEM-> GP & DFE	0.816
RES-> CP	0.519
RES-> Econ Sus	0.583
RES-> Env Sus	0.429
RES-> GL	0.443
RES-> GP	0.494
RES-> IEM	0.477
RES-> RL	0.641
	HTMT Value (Original Sample)
RL-> CP	0.575
RL-> Econ Sus	0.303
RL-> Env Sus	0.450
RL-> GL	0.636
RL-> GP & DFE	0.603
RL-> IEM	0.586
IEM-> CP	0.825
IEM -> Econ Sus	0.437
IEM -> Env Sus	0.685
IEM -> GL	0.745
IEM -> GP & DFE	0.816
Soc Sus-> CP	0.845
Soc Sus-> Econ Sus	0.820
Soc Sus-> Env Sus	0.519
Soc Sus-> GL	0.494
Soc Sus-> GP & DFE	0.609
Soc Sus-> IEM	0.485
Soc Sus-> RES	0.305
Soc Sus-> RL	0.401

Appendix E2: PLS-SEM Measurement Model, Latent Correlations

Latent Variable Correlations (Bootstrap)					
	Original Sample (O)	Sample Mean (M)	Standard Deviation STADEV	T Statistics	P Values
Econ Sus -> CP	0.674	0.672	0.080	8.447	0.000
Env Sus -> CP	0.725	0.720	0.076	9.593	0.000
Env Sus -> Econ Sus	0.373	0.376	0.089	4.191	0.000
GL -> CP	0.560	0.578	0.077	7.282	0.000
GL -> Econ Sus	0.310	0.329	0.095	3.261	0.001
GL -> Env Sus	0.523	0.528	0.119	4.415	0.000
GP & DFE -> CP	0.756	0.759	0.056	13.407	0.000
GP & DFE -> Econ Sus	0.465	0.468	0.104	4.476	0.000
GP & DFE -> Env Sus	0.771	0.768	0.057	13.577	0.000
GP & DFE -> GL	0.692	0.695	0.094	7.373	0.000
IEM -> CP	0.649	0.660	0.064	10.195	0.000
IEM -> Econ	0.333	0.345	0.094	3.552	0.005
IEM -> Env Sus	0.544	0.551	0.093	5.834	0.000
IEM -> GL	0.588	0.597	0.086	6.841	0.001
IEM - GP &...	0.653	0.662	0.070	9.386	0.000
RES -> CP	0.513	0.511	0.100	5.114	0.000
RES -> Econ Sus	0.458	0.454	0.116	3.939	0.000
RES -> Env Sus	0.436	0.428	0.110	3.964	0.000
RES -> GL	0.488	0.499	0.104	4.684	0.000
RES -> GP & DFE	0.510	0.508	0.105	4.836	0.000
RES -> IEM	0.470	0.475	0.098	4.783	0.000
	Original Sample (O)	Sample Mean (M)	Standard Deviation STADEV	T Statistics	P Values
RES -> RL	0.643	0.645	0.064	10.328	0.000
RL -> CP	0.498	0.502	0.099	5.057	0.000
L -> Econ Sus	0.253	0.262	0.112	2.265	0.011

RL -> Env Sus	0.412	0.401	0.144	2.866	0.002
RL -> GL	0.596	0.599	0.113	5.255	0.000
RL > GP & DFE	0.563	0.563	0.113	4.960	0.000
RL -> IEM	0.492	0.507	0.096	5.125	0.000
Soc Sus -> CP	0.733	0.731	0.069	10.582	0.000
Soc Sus -> Econ Sus	0.631	0.620	0.102	6.171	0.000
Soc Sus -> Env Sus	0.444	0.444	0.101	4.392	0.000
Soc Sus -> GL	0.437	0.456	0.087	5.007	0.000
Soc Sus -> GP & DFE	0.529	0.535	0.099	5.339	0.000
Soc Sus -> IEM	0.386	0.403	0.104	3.701	0.000
Soc Sus -> RES	0.308	0.304	0.117	2.637	0.004
Soc Sus -> RL	0.366	0.372	0.115	3.193	0.001

Appendix E3: PLS-SEM Structural Model, R Square and Adjusted R Square Values

R Square Values						
Indicator	Original Sample (O)	Sample Mean (M)	Standard Deviation (STADEV)	T Statistic (O/STADEV)	P Values	Validity
Res	0.507	0.550	0.061	8.292	0.000	Supported
EconSus	0.477	0.501	0.102	4.660	0.000	Supported
EnvSus	0.645	0.667	0.074	8.703	0.000	Supported
SocSus	0.542	0.559	0.094	5.774	0.000	Supported
Adjusted R Square Values						
Indicator	Original Sample (O)	Sample Mean (M)	Standard Deviation (STADEV)	T Statistic (O/STADEV)	P Values	Validity
Res	0.470	0.516	0.066	7.136	0.000	Supported
EconSus	0.449	0.474	0.108	4.167	0.000	Supported
EnvSus	0.626	0.649	0.078	8.022	0.000	Supported
SocSus	0.523	0.541	0.098	5.343	0.000	Supported

Appendix E4: PLS-SEM Structural Model, F Square Values

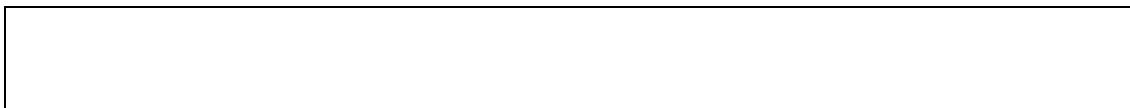
	Original Sample (O)	Sample Mean (M)	Standard Deviation (STADEV)	T Statistics (O/STADEV)	P Values	Validity
CP -> Econ Sus	0.496	0.531	0.267	1.858	0.032	Supported
CP -> Env Sus	0.130	0.150	0.119	1.095	0.137	Unsupported
CP -> RES	0.039	0.055	0.053	0.737	0.231	Unsupported
CP -> Soc Sus	0.547	0.560	0.271	2.014	0.022	Supported
GL -> Econ Sus	0.000	0.011	0.015	0.009	0.497	Unsupported
GL -> Env Sus	0.000	0.017	0.025	0.016	0.493	Unsupported
GL -> RES	0.002	0.017	0.025	0.080	0.468	Unsupported
GL -> Soc Sus	0.007	0.017	0.020	0.359	0.360	Unsupported
GP &DF -> Econ Sus	0.000	0.013	0.020	0.003	0.499	Unsupported
GP &DF -> Env Sus	0.272	0.277	0.153	1.777	0.038	Supported
GP &DF -> RES	0.002	0.017	0.025	0.060	0.476	Unsupported
GP &DF -> Soc Sus	0.008	0.017	0.023	0.362	0.359	Unsupported
IEM -> Econ Sus	0.022	0.036	0.041	0.530	0.298	Unsupported
IEM -> Env Sus	0.000	0.019	0.027	0.002	0.499	Unsupported
IEM -> RES	0.022	0.031	0.037	0.597	0.275	Unsupported
Moderating 1-> RES	0.055	0.055	0.047	1.162	0.123	Unsupported
Moderating 2-> RES	0.067	0.080	0.068	0.976	0.165	Unsupported
RL-> Econ Sus	0.005	0.013	0.017	0.304	0.380	Unsupported
RL-> Env Sus	0.006	0.030	0.042	0.151	0.440	Unsupported
RL-> RES	0.257	0.267	0.137	1.880	0.030	Supported
RL-> Soc Sus	0.000	0.009	0.014	0.005	0.498	Unsupported

Appendix E5: PLS-SEM Structural Model, Path Coefficient Values

Indicators	Original Sample (O)	Sample Mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	P values	Validity
CP -> Econ Sus	0.822	0.817	0.132	6.238	0.000	Supported
CP -> Env Sus	0.346	0.342	0.140	2.476	0.007	Supported
CP -> RES	0.236	0.247	0.140	1.679	0.047	Unsupported
CP -> SocSus	0.772	0.751	0.128	6.033	0.000	Supported
GL -> Econ Sus	-0.013	-0.000	0.119	0.105	0.458	Unsupported
GL -> Env Sus	-0.018	-0.009	0.123	0.147	0.442	Unsupported
GL -> RES	-0.050	-0.029	0.151	0.331	0.370	Unsupported
GL -> SocSus	0.085	0.093	0.094	0.904	0.183	Unsupported
GP &DF -> Econ Sus	-0.010	-0.007	0.154	0.063	0.475	Unsupported
GP &DF -> Env Sus	0.560	0.548	0.147	3.798	0.000	Supported
GP &DF -> RES	0.050	0.033	0.171	0.293	0.385	Unsupported
GP &DF -> Soc Sus	-0.109	-0.096	0.133	0.822	0.206	Unsupported
IEM-> Econ Sus	-0.153	-0.161	0.121	1.267	0.103	Unsupported
IEM->Env Sus	-0.006	0.012	0.119	0.047	0.481	Unsupported
IEM-> RES	0.156	0.141	0.124	1.256	0.229	Unsupported
RL-> Econ Sus	-0.068	-0.066	0.091	0.743	0.260	Unsupported
RL-> Env Sus	-0.062	-0.093	0.096	0.644	0.258	Unsupported
RL-> RES	0.471	0.471	0.104	4.532	0.000	Supported
RL-> Soc Sus	-0.007	-0.002	0.087	0.085	0.466	Unsupported

Appendix E6: Confirmatory Tetrad Analysis

CP	CI Low adj.	CI Up adj.
1: CP10YS4,CP2Y,CP4Y,CP6Y	-0.160	0.078
2: CP10YS4,CP2Y,CP6Y,CP4Y	-0.308	0.099
4: CP10YS4,CP2Y,CP4Y,CP7Y	-0.078	0.243
6: CP10YS4,CP4Y,CP7Y,CP2Y	-0.981	0.201
10: CP10YS4,CP2Y,CP4Y,CP9YS3	-0.109	0.319
13: CP10YS4,CP2Y,CP6Y,CP7Y	-0.056	0.205
19: CP10YS4,CP2Y,CP6Y,CP9YS3	-0.056	0.190
25: CP10YS4,CP2Y,CP7Y,CP9YS3	-0.197	0.247
30: CP10YS4,CP8YS2,CP9YS3,CP2Y	-0.306	0.289
34: CP10YS4,CP4Y,CP6Y,CP8YS2	-0.112	0.095
38: CP10YS4,CP4Y,CP9YS3,CP6Y	-0.327	0.194
40: CP10YS4,CP4Y,CP7Y,CP8YS2	-0.108	0.288
50: CP10YS4,CP6Y,CP8YS2,CP7Y	-0.156	0.128
55: CP10YS4,CP6Y,CP8YS2,CP9YS3	-0.226	0.082
GL	CI Low adj.	CI Up adj.
1: LL4Y,LL5Y,LL6Y,LP1Y	-0.188	0.123
2: LL4Y,LL5Y,LP1Y,LL6Y	-0.488	0.265
4: LL4Y,LL5Y,LL6Y,LP4Y	-0.149	0.360
6: LL4Y,LL6Y,LP4Y,LL5Y	-0.370	0.282
9: LL4Y,LL6Y,LP6Y,LL5Y	-0.409	0.368
10: LL4Y,LL5Y,LL6Y,LW1Y	-0.309	0.387
13: LL4Y,LL5Y,LL6Y,LW5Y	-0.139	0.539
17: LL4Y,LL5Y,LW6Y,LL6Y	-0.316	0.489
20: LL4Y,LL5Y,LP4Y,LP1Y	-0.187	0.306
26: LL4Y,LL5Y,LW1Y,LP1Y	-0.062	0.455
29: LL4Y,LL5Y,LW5Y,LP1Y	-0.106	0.396
33: LL4Y,LP1Y,LW6Y,LL5Y	-0.230	0.289
41: LL4Y,LL5Y,LW5Y,LP4Y	-0.419	0.525
47: LL4Y,LL5Y,LW1Y,LP6Y	-0.337	0.648
49: LL4Y,LL5Y,LP6Y,LW5Y	-0.309	0.416
51: LL4Y,LP6Y,LW5Y,LL5Y	-0.385	0.389
57: LL4Y,LW1Y,LW5Y,LL5Y	-0.270	0.287
109: LL4Y,LP1Y,LP4Y,LP6Y	-0.296	0.278
113: LL4Y,LP1Y,LW1Y,LP4Y	-0.121	0.159



133: LL4Y,LP1Y,LW1Y,LW6Y	-0.191	0.311
137: LL4Y,LP1Y,LW6Y,LW5Y	-0.212	0.314
149: LL4Y,LP4Y,LW5Y,LW1Y	-0.164	0.407
151: LL4Y,LP4Y,LW1Y,LW6Y	-0.154	0.416
161: LL4Y,LP6Y,LW6Y,LW1Y	-0.307	0.322
165: LL4Y,LW5Y,LW6Y,LP6Y	-0.210	0.120
174: LL5Y,LP1Y,LP6Y,LL6Y	-0.079	0.193
231: LL5Y,LP6Y,LW5Y,LP1Y	-0.340	0.341

GP DF	CI Low adj.	CI Up adj.
1: GDF2,GP1,GP6,GP7	-0.396	0.129
2: GDF2,GP1,GP7,GP6	-0.129	0.110
4: GDF2,GP1,GP6,GPDF1	-0.454	0.200
6: GDF2,GP6,GPDF1,GP1	-0.163	0.411
9: GDF2,GP6,GPDF4,GP1	-0.075	0.155
10: GDF2,GP1,GP6,GPDF5	-0.473	0.120
13: GDF2,GP1,GP6,GPDF6	-0.465	0.143
17: GDF2,GP1,GPDF9,GP6	-0.427	0.153
20: GDF2,GP1,GPDF1,GP7	-0.190	0.114
26: GDF2,GP1,GPDF5,GP7	-0.093	0.163
29: GDF2,GP1,GPDF6,GP7	-0.208	0.114
33: GDF2,GP7,GPDF9,GP1	-0.537	0.155
41: GDF2,GP1,GPDF6,GPDF1	-0.233	0.131
47: GDF2,GP1,GPDF5,GPDF4	-0.056	0.144
49: GDF2,GP1,GPDF4,GPDF6	-0.228	0.089
51: GDF2,GPDF4,GPDF6,GP1	-0.061	0.165
57: GDF2,GPDF5,GPDF6,GP1	-0.317	0.103
109: GDF2,GP7,GPDF1,GPDF4	-0.083	0.081
113: GDF2,GP7,GPDF5,GPDF1	-0.094	0.180
133: GDF2,GP7,GPDF5,GPDF9	-0.022	0.049

137: GDF2,GP7,GPDF9,GPDF6	-0.492	0.156
149: GDF2,GPDF1,GPDF6,GPDF5	-0.184	0.303
151: GDF2,GPDF1,GPDF5,GPDF9	-0.060	0.067
161: GDF2,GPDF4,GPDF9,GPDF5	-0.371	0.057
165: GDF2,GPDF6,GPDF9,GPDF4	-0.349	0.070
174: GP1,GP7,GPDF4,GP6	-0.133	0.206
231: GP1,GPDF4,GPDF6,GP7	-0.074	0.089

RL	CI Low adj.	CI Up adj.
1: RL1,RL2,RL3,RL4	-0.115	0.270
2: RL1,RL2,RL4,RL3	-0.163	0.311
4: RL1,RL2,RL3,RL5	-0.152	0.263
6: RL1,RL3,RL5,RL2	-0.484	0.113
10: RL1,RL2,RL3,RL7	-0.245	0.340
13: RL1,RL2,RL4,RL5	-0.076	0.357
19: RL1,RL2,RL4,RL7	-0.123	0.574
25: RL1,RL2,RL5,RL7	-0.353	0.436
30: RL1,RL6,RL7,RL2	-0.116	0.439
34: RL1,RL3,RL4,RL6	-0.083	0.310
38: RL1,RL3,RL7,RL4	-0.050	0.596
40: RL1,RL3,RL5,RL6	-0.210	0.417
50: RL1,RL4,RL6,RL5	-0.444	0.291
55: RL1,RL4,RL6,RL7	-0.637	0.220