Integrating Twin Logistics for a Sustainable Economy: Exploring the Synergies of Digital and Green Logistics in Sri Lanka

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Abstract:

As the global demand for sustainability rises, logistics firms face immense pressure to adhere with sustainable logistics practices along with digitalization. This study examines the intersection of digital transition and green transition, know as the "twin transition" in relation to the practices of logistics and supply chain industry of Sri Lanka aiming to explore synergies that leads to a sustainable economy. Understanding these twin transition synergies will help the firms in facing regulatory, market and stakeholder pressures while acquiring sustainability in the resource-constraint setting of Global South.

The Technology-Organization-Environment (TOE) framework by Tornatzky & Fleischer (1990) provided the basis for investigating the strategic relevance, operational synergies and coping and utilization of challenges and enablers of twin transition, with regard to four Sri Lankan logistics related firms, namely, Yamaha Music Centre, Eurokitchens Trading & Contracting, MAC Holdings and LAUGFS Holdings. By adopting a qualitative approach, using semi-structured, in-depth interviews with twelve industry experts from above four firms, the research successfully identified key drivers, barriers, twin transition synergies and strategic implications of twin logistics implementation in Sri Lanka. The study incorporated thematic analysis and a multiple case-study approach, categorizing the data in terms of TOE framework against each of the research questions mentioned above.

The study evaluated the key variables influencing twin transition; technological innovations, environmental sustainability practices and organizational operational efficiencies using the TOE framework and proposed a novel twin transition synergy framework at the end. The study revealed that the digital transition is prioritized over green transition in Sri Lanka and that the green transition births mostly as a byproduct of efficient digital tools. Nevertheless, every firm accepted the complementarity of digital and green logistics practices but showcased different levels of unbalanced synergy levels weighing more towards the digital arm of logistics. The prominent green outcomes included waste reduction, paperless workflows and reduced emissions and barriers included cultural resistance, regulatory and stakeholder pressure vacuums and internal-external strategy misalignment whereas enablers included partnerships, proper training and leadership visions. The study concluded that the strategic alignment of both internal and external environments, supportive national policy for regulating regulatory and demand vacuums and proper trainings could overcome the above barriers and lead Sri Lanka towards a sustainable, twin transitioned economy. Therefore, this study contributes to the academic discourse by innovating a novel "twin transition synergy framework" guiding how to effectively integrate digital and green logistics for a more resilient and error-proof supply chain in the unique context of Global South.

Keywords: Digital Logistics, Green Logistics, Supply Chain Management, Twin Transition, Sri Lanka, Developing Economies, Global South, Sustainable Supply Chains

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1. INTRODUCTION

In the rapidly evolving global economy of today's world, sustainability is given utmost importance as a strategic imperative, rather than being considered just an appealing option. Emerging business leaders are increasingly seeking sustainable alternatives to the traditional linear business model of "take, make, dispose", which has accustomed since the Industrial Revolution of the 18th century. Therefore, this traditional model often gets challenged by the need to separate economic growth from the environmental degradational elements as they go hand in hand in most cases. As a result of this, transitioning into a circular economy has emerged as a key trend and strategy towards sustainability, paving its way into a closed-loop system of resource efficient, waste eliminated and supportive of regenerative processes. It gives the firms the benefits of minimizing environmental impact, eradicating resource depletion while providing a robust solution against growing pressure from stakeholders to implement circularity and sustainability in its operations (Geissdoerfer et al., 2017).

But this transition is not that simple, it requires innovative logistics solutions to overcome the challenges in facilitating closed-loop supply chains through efficient resource management throughout the production, consumption and logistics systems. In other words, it is a turnaround of the whole production system of a firm while the day day-to-day operations still run on as usual. Therefore, reconfiguration of supply chain and logistics practices stands out as a critical point, as it requires the firms to not only manage the material flows of the closed-loop systems but also to enable the reverse logistics principles of recycling, reusing and remanufacturing to keep the supply chain resilient (Beames et al., 2021). To achieve these objectives, firms must realize the importance of innovating both on the technological and environmental foresight.

In light of this, "twin transition", which comprises of integrated adoption of digital and sustainability transformations, comes into play as a key innovation of circular economic implementation towards a sustainable future (Tabares et al., 2025). It is noteworthy that the principles of circular economy are scarcely used in the Sri Lankan industries (K.D.M. Bimsara et al., 2024) and therefore, this study will not focus on the subject concept but will work towards finding common grounds where twin transition can be used to achieve a desirable future which includes the circular economic and sustainability concepts.

According to the world economic forum, the term "twin transition" means a sweet spot between the digital transition and sustainability transition where digital amplifies sustainability; and is an aspect which unlocks a whole new dimension of efficiency and productivity when works together rather than operated in isolation (Sjoerd Blüm, 2022). In the subject study, by terms of green logistics or sustainability transition in relation to logistics,

the researcher aims to explore eco-friendly practices like sustainable, low-emission transportation, eco-friendly packaging, carbon footprint reduction and reverse and circular economy-aligned logistics with energy efficient warehousing while as of digital logistics or digital transition in relation to logistics, the researcher aims to explore tools such as blockchain digital ledgers, digital twins and simulations, AI and IoT driven optimizations, robotics driven/automated systems and systems with visibility, transparency and predictive maintenance capabilities which give out optimum decision making benefits to the businesses (Chauhan et al., 2022; Moshood et al., 2021).

Combining the two domains of digital and green logistics is not only logical but is very necessary since the subject integration increases the operational efficiency of the firm while consequently reducing the environmental impact it creates in terms of waste and emissions. It creates a strategic advantage for the firms which navigate increasingly complex, extremely competitive and tightly regulated business environments in the modern day. The synergistic effect that we talk about in this study, is mainly important for emerging economies in the Global South, like in Sri Lanka. Although Sri Lanka face infrastructural and financial constraints in the implementation of a sustainable economy, they also undergo the same, if not increasing pressures towards aligning with the global sustainability goals. In which case, integrated adoption of digital and green logistics or the twin transition, offers the most dependable, scalable and cost-efficient pathway for Sri Lankan economy towards a sustainable economic growth.

1.1 Research Problem

In advancing the transition towards sustainable economy, an important place is given to the role of logistics and supply chain management for the adoption of circular practices benefiting many industries. At the emergence of circular economy, it helped the organizations to optimize waste management, minimize resource depletion, boost resource efficiency and reduce the environmental impact, assisting businesses in attaining supply chain resilience and sustainable supply chain networks (Ghisellini et al., 2016). With the emergence of innovative logistics operations, reverse logistics and closed loop supply chains, organizations which prioritize excelling in both digital and green logistics were naturally given upper hand to reach their sustainability goals early on. Therefore, as an innovative solution, twin transition in logistics was increasingly recognized and used as a powerful tool in achieving the sustainability goals for many businesses (Neri et al., 2024; De Jesus, Alves and Mendes, 2024).

In such cases, understanding the synergies between these digital and green logistics and how they can contribute towards circular economic principles of recycling, reuse and remanufacturing poses a much-needed question to be answered in the current timespan for

the Global South. This is because, though circular economic principles are not very popular in these regions, it is still essential for the Global South to pave for it in the coming future. Though we find some research done on these two aspects separately (eg.: Gavronski et al., 2011; Ubeda et al., 2011; Liu et al., 2020 & Borowski, 2021 etc.), most of the time we find the studies on the joint application of these domains are fragmented. While green logistics is being studied for its environmental benefits (eg.: Gavronski et al., 2011; Ubeda et al., 2011), digital logistics is studied for its technological and efficiency gains (eg.: Liu et al., 2020; Borowski, 2021). A much smaller number of studies explore their combined impact on sustainability challenges and logistics efficiency (eg.: Bag et al., 2020, Bae et al., 2024, Lai et al., 2023, Rehman et al., 2023 etc.).

In developing economies like Sri Lanka, the research gap in this area is clearly visible, as there are only handful of studies on how digitalization could be used to enhance green logistics practices to attain a sustainable economy, for the benefit of the future (Mudalige, n.d.; Aluthge & Mendis, n.d.). Reasons for this include uneven digital maturity, lack of understanding on circular economy, resistance to change and lack of regulatory frameworks (Moganaraj et al., 2024). Further to that, limited infrastructure, financial constraints, regulatory barriers and evolving digital readiness poses much threat to the developing countries in climbing the sustainability ladder as they are not very literate on how they could practically integrate the two domains of digital and green logistics effectively (Aluthge & Mendis, n.d.). Therefore, though not documented widely, it is evident that there is a lack of awareness among the local firms regarding advanced digital tools, how they can reinforce sustainability goals and how green logistics practices can be enhanced through digital logistics practices effectively (Mudalige, n.d.).

Because of the above reasons, addressing this research problem deem timely and crucial for the developing economies of Global South right now. Therefore, by doing this study the researcher aims to fill up a gap by examining the synergies, opportunities and challenges experienced by firms engaged in logistics and supply-chain industry in Sri Lanka, as an attempt to align digital technologies with green initiatives for the betterment of the country.

1.2 Research Objectives and Questions

When digital and green logistics are integrated, they create a synergy that enhance the effectiveness of each practice. While digital logistics tools can be used to enhance sustainability with the use of real-time monitoring systems, accurate data analysis and more effective resource optimization approaches, green logistics provides the strategic framework for using these digital tools in order to reduce waste, optimize energy usage and minimize emissions. Exploring these synergies is important and worthwhile because of their potential to create a

dual benefit for the businesses, where they can achieve both environmental benefits through sustainability practices and cost savings through efficiency gains. Further to that, these synergies help organizations to compete in a rapidly changing regulatory environment, meet their consumer demand for sustainable practices all the while positioning themselves as leaders in the transitioning towards a sustainable economy (Markuceviciute-Vincke et al., 2024).

The findings of this research aim to contribute to the broader industrial and academic discourse on sustainable logistics, in identifying the best practices for leveraging twin transitions in an economically developing era for the Global South. In the Sri Lankan context, this integration could serve as a catalyst for transitioning towards a circular and sustainable economy amidst the financial and infrastructural constraints. Now let's look at how the research problem can be divided further into research questions to gain better insights and solutions to serve the research purpose.

1. Why is the integration of digital and green logistics practices strategically relevant for firms aiming for sustainability in Sri Lanka?

This question aims to explore the relevance of studying and investigating the synergies between twin transition in current timespan. Considering the increasing global pressure for regulatory mandates, vigorous technological advancements and corporate sustainability commitments, why it is important right now to bring out this topic? This is because the governments around the world are tightening their grips around environmental regulations, pushing businesses to adopt green logistics solutions (According to Alexandr Khomich, 2024, EU's goal for carbon emission reduction is by 55% by the year 2030) while digital transformations keep reshaping supply chains, offering immense opportunities for businesses to attain sustainability. The intersection of these two trends helps us realize why it is essential to study their synergies, as businesses must focus on navigating these challenges strategically to optimize their operational efficiencies, especially nowadays, more than in the past. The carbon footprint of most industries was much less in past than the present, where it's reportedly added 36.2 gigatons of CO_2 emissions to the atmosphere only in year 2021 according to a report by European Commission, 2022. Therefore, addressing this research gap will provide answers and strategic guidance for organizations aiming to align their supply chain and logistics practices with sustainable economic principles accordingly.

2. How can the integration between digital and green logistics practices enhance sustainable logistics operations in Sri Lankan firms?

Digital technologies such as IoT, AI, blockchain and big data analytics play a key role in optimizing sustainable supply chain networks (Chauhan et al., 2022), while green logistics enable businesses to navigate sustainability related barriers focusing on the environmental aspects of logistics, when transitioning towards a sustainable economy (De Jesus, Alves and Mendes, 2024). Therefore, we can say that the integration of these two digital and green logistics undoubtedly offers efficiency and sustainability to businesses by leveraging on advanced technologies. This question will investigate how digital logistics solutions such as AI and blockchain enable real-time data monitoring, improve traceability and optimize resource utilization of the logistics practices and thereby enhance green logistics initiatives like carbon footprint reduction and sustainable transportation (Moganaraj et al., 2024). The synergy between the two creates a closed-loop supply chain, ensuring that products, materials and resources circulate efficiently within the supply chain for as long as possible while minimizing waste and emissions (Tehrani & Gupta, 2021). Exploring these synergies provides insights into how logistics systems can be redesigned to support digital and sustainable objectives effectively in order to attain sustainable supply chains.

3. How to cope with the challenges and how to utilize opportunities, that the firms face when implementing digital and green logistics to attain sustainable operations?

This question aims to identify ways of mitigating the practical barriers of twin transition. It investigates the challenges such as regulatory constraints, cost implications and the complexities that arise when integrating green practices and digital solutions into existing supply chain structures (Ieva Markuceviciute-Vincke et al., 2024). While green logistics demand sustainable changes in packaging materials, transportation systems and warehousing, digitalization demands for robust infrastructure, digital literacy and tech savvy workforce (Agrawal et al., 2023). Therefore, this question will examine factors such as high initial investment costs, technological complexities, lack of infrastructure, need for new regulatory compliances and best practices studied from industries leading in sustainable logistics currently in their fields. While the opportunities such as cost savings, improved customer trust and enhanced transparency can easily outweigh the above said challenges, twin transition also leads itself in identifying the key enablers of transformation through industry collaborations, support for policies and technological innovations (European Commission, 2022). In conclusion, this study aims to highlight and catalyse the best practices as a framework for successful implementation of twin logistics transition in driving sustainable economic transformation in the developing economy context.

By focusing on the integration of digital and green logistics, firms can create competitive advantages, new opportunities for innovation and contribute to the sustainable development goals of development-oriented society. As explained above in each question, this research aims to identify and analyse these synergies, providing insights into how firms can strategically leverage twin logistics to drive sustainability and operational success. In the Sri Lankan context, these competencies will help the country to achieve its sustainable economic goals in the near future and help to identify the country's organizational, technological and environmental enablers and barriers (Tornatzky & Fleischer, 1990). The researcher will use this knowledge of enablers and barriers of twin logistics, to propose a framework for the successful integration of digital and green logistics synergy in the resource-constrained setting of Global South.

Given the above context, the main catalyst of this study is to discover how the synergy between digital and green logistics transformation can be strategically utilized to assist developing economies like Sri Lanka to achieve their sustainable economic goals. This study structures around bridging between the theoretical and empirical knowledge gaps relating to the twin logistics transition and will navigate and explore how logistics and supply chain focused firms in Sri Lanka integrate digital logistic practices (technologies) and green logistics practices to enhance sustainability and competitiveness of its economy. The study will investigate the synergies of twin logistics transition in order to identify the key challenges and enablers faced by Global South, in attaining a sustainable economy similar to what the global North has achieved by adhering with circular economy principles (Geissdoerfer et al., 2017).

The empirical insights for this research will be gained from firms and industries actively implementing twin logistics strategies in the current timespan. This empirical data will be drawn mainly from the experiences of industry experts, who are logistic firms, importers and exporters utilizing both digital and green logistics in their day-to-day business operations. By analyzing the twin logistics transition's effectiveness and challenges, through the study of intersection between Industry 4.0 technologies (such as AI, IoT, big data and blockchain) and environmentally friendly logistics practices (such as sustainable packaging, warehousing and transportation) according to Patyal et al., 2022, the study will offer actionable insights for organizations and policymakers who are eager to implement sustainable logistics solutions in their future business endeavors (Rafael, 2024).

1.3 Delimitations of the Study

We can identify several delimitations that help to shape the boundary of the study's scope. The main aspect is that the research is limited to Sri Lanka, aiming for developing economies of Global South. Therefore, the findings of this research cannot be generalized or aimed at the

more developed economies in the global North with advanced digital and sustainable infrastructure and literacy. Also, the study is based on logistics service providers and import-export firms engaged in a variety of logistics operations within international and domestic trade levels. Therefore, the study's findings maybe or may not be applicable to other industries who do not focus on supply chain resilience or outsource their operations to 3PL (3rd party logistics) providers. While we talk about circular economy principles, the study does not necessarily focus on circular economic principles, as Sri Lanka is not heavily relying on the circular aspects in its economic structure (Delegation of the European Union to Sri Lanka and the Maldives, 2025). In spite, the study primary focuses on sustainability in economics in relation to twin logistics transition, considering that the country is relatively at in an early stage of adoption with regard to the concept of circular economy (Aluthge & Mendis, n.d.). The study, also, does not go deep into the broader digitalization aspects, but rather focus more on digital technologies relevant to logistics and supply chain industry like IoT, blockchain, data analytics and automation technologies. It relies on semi-structured interviews and cross-case analysis between firms in a qualitative, methodical approach and do not involve any survey models or large-scale statistical data as in a quantitative research approach. The study is conducted aiming the current situation and recent developments within past five years of history in the Sri Lankan economic context and do not rely heavily on historical data analysis.

1.5 Structure of the Study

The thesis is structured into six main chapters starting with the introduction in chapter 1. It gives a holistic background, the research problem, purpose and the objectives of the study. The second chapter focuses on the literature review, exploring the key concepts that are prevailing in the current literature regarding the topics of digital and green logistics, the synergy between these twin logistics and the Technology-Organization-Environment (TOE) framework (Tornatzky & Fleischer, 1990) which acts as a guiding theory for the thesis. The third chapter brings out the methodology section, detailing the design and setting of the research, data collection methods and analysis method of the research. In the fourth chapter, the empirical findings are presented aiming to bring out the main findings obtained from each case of the interviews preformed and the unique findings brought out from the cross-case analysis between the firms. In the fifth chapter, which is the analysis and discussion, those findings will be further analysed and interpreted so that some explanations could be obtained from the existing theories in the literature and discuss the implications that might arise with the interpretations that are against the current theories. In the last and 6th chapter, the contributions from the findings will be summarized and a novel framework which could be illustrated from the research findings will be drawn out which ought to highlight the managerial implications and future research directions for the benefit of academia in future.

2. LITERATURE REVIEW

This subject study is conducted to explore the synergies between digital and green logistics practices of twin logistics transition and let's evaluate the existing and emerging theoretical perspectives in the academia related to the subject topic. In developing economies like Sri Lanka, digital and green logistics take a transformative approach in promoting itself on a new level of sustainable economic growth in contrast to the other parts of the world which are fully or under-developed. This evaluation will provide a structured framework that provides an explanation for theories and relationships between various variables in the study that are to be utilized in the coming chapters.

Internet of Things (IoT), artificial intelligence (AI), blockchain and big data analytics are widespread digital technologies that are prioritized by present day organizations to optimize their logistics operations, whereas the businesses also focus on incorporating green logistics to minimize carbon emissions, optimize resource usage and enhance energy efficiency, in order to reduce their environmental footprint. Both these aspects together create a synergy that levels up the logistics operations towards sustainable supply chain innovation. Through the research done in this field, it was evident that digital transformation can trigger greener operations via the promotion of visibility, control and predictive capabilities in logistics operations (Bag et al., 2020, Lai et al., 2023). Although the adoption of these twin technologies is still at a birth state in the Sri Lankan economy, industry reports and academia show that there is a growing trend among logistics focused firms around the world to align their digital investments with sustainability goals, amidst the rising inflation and global pressures for environmental compliance, consequently affecting Sri Lankan economy as well.

Therefore, the theoretical framework of this research is structured to define key concepts, explain the relationships between key variables and establish observations, focusing on the twin transition synergies. It is also designed to validate the synergies between digital and green logistics practices and how these aspects can both enhance and be enhanced by each other while ensuring alignment with the research objectives. The key concepts in this research can be explained as follows for the readers to get familiar with the key terms used in the coming chapters. Twin transition refers to the combined integration of digital logistics, which is the use of digital tools to enhance the efficiency and visibility of logistics operations, and green logistics which are the strategies used to reduce environmental impacts such as energy-efficient transportation and sustainable packaging methods. Circular Economy, refers to an economic system focused on minimizing waste and maximizing the reuse of resources while circulating the raw materials inside the supply chain as long as possible through strategies like recycling and re-manufacturing.

A framework will be used as a guiding theory to identify and elaborate on factors influencing the synergy between digital and green logistics, such as technological advancements, regulatory frameworks and consumer demand for sustainability in this study for the better evaluation of the research questions. This framework will serve as the foundation for developing thematic analysis related to the integration of twin logistics and their impact on sustainability and operational efficiency. It will also provide a rationale for systematically evaluating the relationships between technological innovations such as AI and IoT, environmental sustainability such as reduced carbon footprint reduction and organizational operational efficiencies such as cost reduction and efficient workflows. The research is aimed to explore how these factors interact and contribute to the success of integrated digital and green logistics synergies. The researcher has found that the most suitable framework that the study could use for this cause is the Technology-Organization-Environment (TOE) Framework by Tornatzky & Fleischer (1990). Therefore, the study will use it as the main guiding theory to guide and evaluate the study in a systematical manner. As a widely used framework in innovation and technology adoption, let's see how the TOE framework provides a strong foundation to understand and analyse a firm's technological, organizational and environmental attributes successfully.

2.1 Technology-Organization-Environment (TOE) Framework

The Technology-Organization-Environment (TOE) framework by Tornatzky & Fleischer (1990), is a comprehensive model which demonstrates how technology adoption is influenced by both environmental and organizational factors in firms. It suggests that the three interrelated dimensions of technology, organization and environment greatly affects how an organization would respond and engage in innovation.

This framework is widely used in academia for its relevance and flexibility in demonstrating complex scenarios associated with technology adoption and sustainability related innovations. Unlike the theories discussed in previous topics, the TOE framework can evaluate the role of internal capabilities of an organization in the context of green and digital logistics such as its technological infrastructure, organizational culture and external pressures such as regulations and market demand in driving novel digital solutions which also supports green logistics. It is evident that if these factors are correctly aligned, firms can effectively implement digital tools that enhance environmental sustainability. In below figure, you can see the TOE framework and let's discuss on the twin transition in relation to this framework further under the next topic.

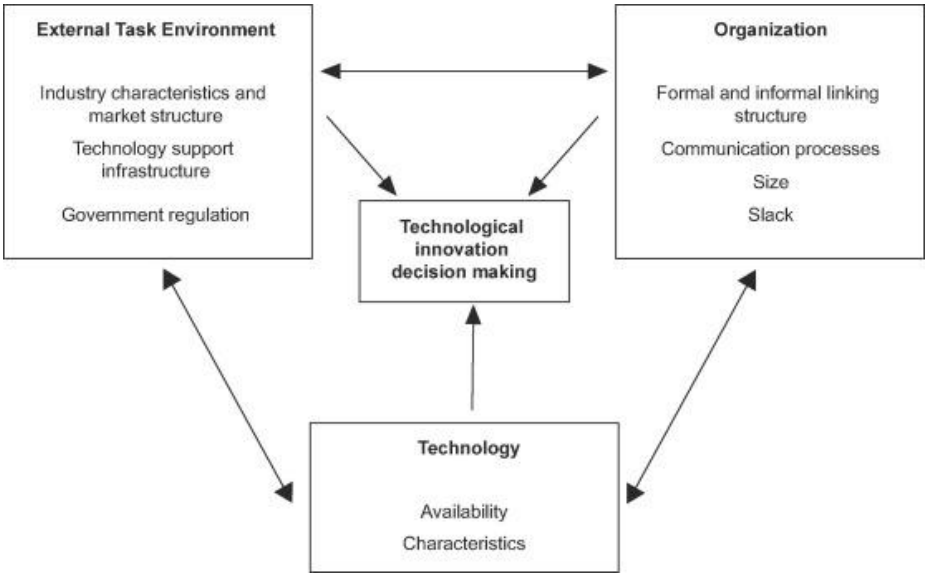

Figure 1 TOE Framework by (Tornatzky & Fleischer, 1990)

2.2 Twin Transition: Integration of Digital and Sustainability Transitions

According to the studies, the digital and green transitions in the logistics and supply chain field reinforce and enhance each other in many ways. In the Global South, the combination of digital and green solutions pave way for smart and sustainable logistics practices as the infrastructure limitations in developing countries require strategic steps consisting with both innovative approach and environmental priorities (Rehman et al., 2023). For example, blockchain digital ledger technology allows better recycling and maintenance by allowing material tracing in the economies where circular economic principles are prominent. And digital twins provide virtual twins of the physical machines and vehicles, allowing better observance on traffic flows, reducing traffic jams and emissions in urban cities (*The Twin Green & Digital Transition: How Sustainable Digital Technologies Could Enable a Carbon-Neutral EU by 2050*, 2022). Among these sustainable advantages, twin logistics can also cause a lot of disturbances for the environment as some of the technologies produce a lot of waste and sometimes are very resource intensive. For example, AI has been accused of being the center of energy wastage and climate change as it uses massive amounts of electricity and water resources for generating and cooling down its plants (Yao, 2024). Also the hybrid technologies prevailing in the modern vehicles are known to be encouraging the users to use their private vehicles more often due to its cheap and energy efficiency features leading to more traffic in urban contexts; and remote working has been known to encourage workers to establish their own home offices making the domestic electricity consumption go drastically up, though it was first promoted to reduce the corporate energy consumption during the Covid

pandemic (*The Twin Green & Digital Transition: How Sustainable Digital Technologies Could Enable a Carbon-Neutral EU by 2050*, 2022). Therefore, it is evident that amidst several advantages and disadvantages, proactive and integrative measures need to be taken in order to get the best outcome out of the digital and green logistics transitions in the modern era.

Now let's explore how these two domains can be used to optimize the sustainable logistic transformation in the developing economy context of Sri Lanka. As per Chauhan et al. (2022) and Moshood et al. (2021), digital technologies like artificial intelligence (AI), digital twins, blockchain and Internet of Things (IoT) allow firms to promote real-time visibility, traceability, predictive analysis as well as improved decision-making capabilities. In the logistical context these competencies enable firms to optimize route planning, resource utilization and process automation. On the other hand, as per Ubeda et al. (2011) and Gavronski et al. (2011) green logistics practices such as eco-friendly packaging and transportation, energy-efficient warehousing and carbon offsetting helps to achieve the sustainability goals by reducing the carbon footprint and the environmental impact of firms.

Therefore, naturally it is expected to illustrate a high efficiency in both the dimensions when both these digital and green logistical aspects are combined because when it is integrated the synergistic effect that is created by the digital and green logistics will enhance its impact than when it is performs in isolation in the organizational context. For example, AI can be used to supervise the efficiency of a reverse logistics operation which is a green practice and blockchain can be used to promote transparency in sustainable sourcing, production and recycling processes (*Blockchain for Transparent and Sustainable Supply Chains*, 2025). Also, digital twins can be used to simulate a virtual environment where the energy consumption scenarios of a production line can be hypothesized digitally and managed, enabling organizations to adopt greener practices more proactively making it a valuable addition for sustainable economic models that leverage on circular economic principles, closed-loop supply chains and reversed logistics (Preut et al., 2021).

In the context of Global South where there are many infrastructure and financial constraints to the integration of twin transition, twin logistics can still be useful in a way to offer scalable and adaptive solutions for firms. For example, digital tools can be used as alternatives for limited manual oversight and green practices can be used to comply with the emerging environmental and sustainability regulations. But this integration of digital and green logistics in the Sri Lankan context will pose much challenge like the lack of digital literacy and infrastructure, organizational resistance to change, limited institutional support as per studies by Mudalige, n.d. and Aluthge & Mendis, n.d. Therefore, integration of digital and green

logistics practices should not only be viewed as an independent and isolated initiatives but also be considered as independent strategical approach that should be co-designed and co-implemented to maximize its outcome in sustainable and resilient supply chains.

Digital Logistics

According to Moshood et al. (2021) and Chauhan et al. (2022) supply chain visibility and operational efficiency can be enhanced by digital logistics specifically through technologies like digital twins, big data, IoT, Blockchain and AI which are known by the term Industry 4.0 technologies. Out of these technologies digital twins, or cyber-physical logistics systems allow firms to simulate, monitor and optimize their operations virtually without having to physically interfere (Moshood et al., 2021). It also helps firms with predictive maintenance, intelligent returns handling and closed-loop monitoring, adding irreplaceable value to circular supply chains. Further to that, blockchain and IoT technologies help firms to strengthen their data-driven logistics ecosystems in attaining sustainability in their operations (Preut et al., 2021).

These technologies altogether assist businesses in real-time tracking, automated planning and data-driven decision-making in reshaping their supply chain networks and help firms to map out their material flows, monitor environmental performances and optimize reverse logistics processes making circular supply chains more feasible and scalable to operate. According to Chauhan et al. (2022), these technological upgrades are merely not just another technological upgrade that we see on a day-to-day basis, but rather a foundational enabler of sustainable innovation which are scalable on only higher environmental performance metrics.

Green Logistics

According to Gavronski et al. (2011) and Ubeda et al. (2011), route optimization, fuel-efficient fleets, reverse logistics, eco-friendly packaging and carbon offsetting are the main ways that green logistics that are being used in the industries to minimize the environmental impact of logistics operations. This is a new sector in the Sri Lankan economy that is rapidly gaining popularity with many multi-national firms leading by example to establish environmentally friendly and sustainable initiatives to mark their presence in the growing market of eco-conscious consumers. In the case study of Eroski by Ubeda et al. (2011), the authors navigate the journey of a Spanish retail chain and how they integrate green logistics practices into its supply chain by optimizing its transportation routes, leveraging backhauling and redesigning packaging systems to reduce emissions and operational costs of its existing supply chain. The case study provides a valuable, practical and step-by-step implementation process of a sustainable logistics system that a booming economy like Sri Lanka can learn from, and how to use strategic coordination and efficiency improvements rather than high-end technologies

to reach its targets in attaining a sustainable economy. However, while the case study makes much more sense in the European context, it will need some more infrastructural and monetary assistance to be fully successful in the developing economy context of Sri Lanka. But overall, Eroski's model serves as a very important reference point for the retail industries seeking gradual but systematics sustainability gains through logistical reconfiguration and commitment to their environmental goals.

2.3 TOE Framework for Integrating Twin Logistics

As the main purpose of this study is to explore the impact of digital and green logistics in the sustainable economic transition of Sri Lanka, the study incorporates the Technology-Organization-Environment Framework as an umbrella to cover all the aspects of twin logistics and how it can be strategically integrated to achieve the said outcome. Tornatzky & Fleischer (1990)'s TOE framework is a widely adopted model for theoretical investigations of innovative and technological research and provides a strong and solid foundation for evaluating technical, organizational and environmental capabilities, attributes and pressures in the adoption of innovations such as sustainability principles or Industry 4.0 technologies within firms. According to this research, the TOE framework is used to analyze the synergies in integrating digital logistic technologies and green logistics practices as a means of promoting sustainable economic implementation. Not only are these twin logistical aspects interdependent, but they also influence each other across the three Technological, Organizational and Environmental dimensions extending to contextualize the twin transition creating a unique socio-economic and infrastructural goal for the Global South.

2.2.1 Justification for the Adoption of TOE Framework

Although the traditional TOE model by Tornatzky & Fleischer (1990) acts as a foundation for adoption of innovation, in this study we use the TOE framework to capture the independent and synergetic nature of digital and green logistic innovations in the economic framework of Global South. As most prior research uses TOE framework for separate green or digital domains like sustainability, ICT and supply chain innovations (Chauhan et al., 2022; Bag et al., 2020), this research brings out the bridge between several domains closer through the study of twin transitions using a holistic approach (Tabares et al., 2025; Rehman et al., 2023). Also, this study brings out the importance of synergetic collaboration of twin logistics in the developing economies of Global South, under the TOE framework's explanatory strength in analyzing novel innovation adoption. These strengths of the TOE framework will be necessary for overcoming the challenges in optimizing technological, organizational and environmental aspects of the said economies (Rafael, 2024). Therefore, this extended version of the TOE framework will not only explore the synergies between digital and green logistics but also

provides a systematic guiding structure to pinpoint challenges, recommended managerial and government interventions and readiness for change which are of utmost importance with respect to the sustainability of economies of Global South similar to Sri Lanka.

2.2.2 Technology Context

The technological context associates with the internal and external digital capabilities of a firm as of what currently runs inside the firm and what else could be adopted from the market that could make a difference in operational performance of the firm. The key considerations of this aspect are the relative advantage or the perceived value of the technology over existing practices inside the firm, how complex or easy the technology to be implemented in the firm, as well as how compatible the new technology is with the existing systems, workflows and organizational culture and values (Tornatzky and Fleischer, 1990).

In the context of twin logistics integration, this domain could showcase how the joint potential of various digital technologies can be used to improve the operational efficiency while reducing the environmental impact. Technological tools, adoption of innovations and infrastructural facilities belong in this category and as specific to the logistics sector, main technological tools that include are the blockchain ledger, IoT and digital twins which offer visibility, traceability and operational efficiency for the circularity in supply chains (Chauhan et al., 2022; Moshood et al., 2021). There are also green technologies such as carbon offsetting systems, eco-packaging production lines and electric fleets which adhere to the stainability agenda of the firms (Ubeda et al., 2011; Gavronski et al., 2011). In the context of developing economies, however, advanced technologies like above are not very likely to be adopted due to the lack of technical resources and complexity in adoption to the existing systems (Borowski, 2021). This is because advanced technologies like AI require massive expertise, energy and investments which will be limited in the Global South compared to the Global North (Yao, 2024). But unarguably technology domain of the logistics sector plays a crucial role in evaluating and assessing cost-effectiveness, sustainability impact and technological compatibility in advancing the twin transition for the Sri Lankan firms.

2.2.3 Organization Context

The organizational context of the TOE framework by Tornatzky and Fleischer (1990), associates with the internal factors that determine the organizational readiness and ability for new technology adoption. The key considerations of this dimension are the top management and the leadership support for innovation, availability of financial resources and expertise, availability of skilled human resources who are willing to adapt with the novel innovations and the organizational culture and structure which depicts openness to collaborate and innovate in changing environments (Tornatzky and Fleischer, 1990).

In the context of twin logistics integration, these internal capabilities of a firm will affect heavily on the integration of digital and green logistics, and it will decide whether the firm is equipped with necessary resources and structure required for the successful transition from the existing systems. If the firm have high resistance to change, misaligned goals and lack of skills, it could hinder the successful transition and lead to an utter failure on the sustainability mission.

As said above, this domain of TOE framework leverages on the internal factors of a firm such as the resource availability, employee capabilities, leadership and culture of the organization. From those, the factors affecting the success of twin logistics implementation are mainly the human resource skills, financial capacity of the firm and the organizational readiness for change (Bag et al., 2020). If we think about the situation of an unskilled workforce who were to operate the AI-based route optimization of a transport system, it will lead to utter failure despite the superiority in the technology used (Baxter & Sommerville, 2011). Therefore, it can be said that the crucial factors like organization-wide culture of innovation and top management support play a major role in the sustainability orientation and implementation of twin logistics in a firm (Barney, 1991; Klassen & Whybark, 1999). In summary we can say that in Sri Lanka, the firms which adopt green logistics competencies early will be able to create long-term competitive advantage over their competitors as those competencies will become valuable resources for them when the economy starts to adopt twin logistics gradually in the future (Hart, 1995; Gavronski et al., 2011).

2.2.4 Environmental Context

The environmental context is associates with the external factors which influence the firm's innovation decisions and the key considerations include regulatory background such as laws, standards and policies that either mandates or promotes innovation, market dynamics including customers, competitors and industry norms, availability of technological infrastructure such as systems, platforms and broadband access, as well as the availability of collaborative partnerships that foster knowledge transitions and innovation diffusion (Tornatzky and Fleischer, 1990).

In the context of twin transition in the Sri Lankan economic background, these regulatory factors play a crucial role, since the regulatory uncertainties, evolving customer behaviours and infrastructure constraints could drastically shape the firm's ability or disability to successfully adopt the twin logistics transition. As said above, this domain refers to the market dynamics, government regulations, availability of infrastructure, industry characteristics and competitive environment of a business ecosystem. Various regulatory mandates like EU's carbon reduction goals to reduce the greenhouse gas emissions by 55% by year 2030 and to

achieve carbon neutrality by 2040 (European Commission, 2022), pressurize the organizations to adopt green logistics practices while the rapid digital transformation promotes transparency and traceability driven by the market demand in the present era (*Blockchain for Transparent & Sustainable Supply Chains*, 2025). In the context of Sri Lanka, although we can see a good technological adoption, we can also see a deficit in advanced digital literacy, weak policy enforcements and limited infrastructure facilities restraining the successful adoption of green and digital logistics practices within industries (Mudalige, n.d.; Aluthge & Mendis, n.d.). Amidst these challenges, we can see that the international collaborations and investments such as the EU's Global Gateway, are clearing the path for Sri Lankan economy to implement digital and green transitions step by step in the major industrial sectors (EEAS, 2025).

2.2.5 Identified Research Gaps

Although this research area of digital and green logistics is gaining much attention in the current timeline, the intersection of said aspects remains unexplored, especially in the context of developing economies in the Global South. Most of the studies either focus on digital logistics (Liu et al., 2020; Chauhan et al., 2022) or green logistics (Gavronski et al., 2011; Ubeda et al., 2011) exclusively giving limited attention to their combined effect in delivering sustainable outcomes.

There are several gaps that have been identified with reference to the subject area like the lack of holistic frameworks to analyze and evaluate the synergy between digital and green logistics specifically in the circular economy area and limited empirical studies which focus on real world scenarios of twin logistics implementation. Especially in the Global South including Sri Lanka we can find a lack of these studies where the socio-economic and infrastructural challenges pose much restriction than to the Global North economies. There is also lack of attention given to the barriers and enablers which often lead to the undermining of the success of twin logistics implementation. These barriers are often organizational resistance, regulatory ambiguity and digital illiteracy that hinder the adoption of twin logistics in the emerging and developing markets and the enablers are usually the leadership and top management support, external partnerships and interdepartmental collaborations which often get overlooked or ignored. There are also underdeveloped theoretical models of the combining effect of sustainability and innovative adoption perspectives such as how the TOE framework by Tornatzky & Fleischer (1990) can be adapted in case of twin logistics transitions where the subject study volunteered to explore the same in place.

As mentioned above this study will address the said gaps and challenges by empirically exploring how Sri Lankan supply chain and logistics focused firms could adopt and implement

digital and green logistics, what challenges and opportunities they have in line and what new lessons can be learnt and derived for future policies and practices. By doing so, this study aims to contribute to the practical insights and theory development in the dimension of sustainable logistics and supply chain management.

2.4 Synthesis of the Literature Review

The above literature review emphasizes the importance of digital logistics and green logistics practices for a sustainable supply chain transformation. The study drew well established insights from the existing literature to elaborate the potential synergies and challenges incorporated with the twin logistics integration. The review showcased the importance of IoT, automation and data analytics integrated logistics practices and the environmental and sustainability impact through green logistics practices such as waste reduction, emission reduction and eco-friendly packaging. Together these two aspects showcased the potential in creating an efficient, productive and sustainable transformation for the logistics and supply chain operations.

Even though the studies suggested that digitalization triggers sustainability, the combined effect of green transition and digital transition, or the twin transition remains underexamined. Especially in Global South it is treated as two separate domains rather than integrated. The lack of insight into the synergistic effect of these two domains to support and develop a sustainable economy creates a gap in literature as well as in the practical world amidst the rising pressure for Global South to modernize their logistics practices and go green at the same time.

The review identifies the conceptual and theoretical gap which is the unavailability of a holistic framework to address the synergy of twin logistics transition in Global South for attaining a sustainable economy. The existing models only address the issues in circular economic context and seldomly on the twin logistics integration context and the lack of guiding frameworks makes the topic farther from getting studied systematically. Another gap identified is the empirical data limitations from the developing economy context, where most of the studies focus on the Western or Northern economy and the lack of studies focused on developing or under-developed economies pose much challenge to the upbringing of crucial perspectives to these underprivileged economies. Even if these insights are brought to the South, the lack of infrastructural, socio-economic and regulatory support in Global South acts as huge barriers in modernizing the traditional logistics practices in the Southern economy.

The next gap identified is the ignorance of contextual barriers like organizational resistance, lack of awareness, lack of literacy and regulations and enablers like partnerships, leadership vision and stakeholder pressures that could elevate the degree of adherence of the economies

with sustainable transformations. If these factors are identified correctly and nurtured accordingly the Southern economy could benefit from investing in the right direction at the right time, rather than just following the day-to-day trends in the global market.

Even if frameworks like Technology-Organization-Environment (TOE) by Tornatzky & Fleischer (1990) are available to address these gaps to some extent, we see lack of applications of it in the real-world context due to various factors like motivational issues and regulatory vacuums. Also, it was evident that though the frameworks address the technology adoption context it doesn't necessarily address issues in the twin transition context. Therefore, the next gap identified is the lack of proper frameworks and rare application of available resources in the development of sustainable economies in Global South and this could be curated by the extension and contextualization of the TOE framework to also address the sustainability issue or by the introduction of a novel framework which could address both the green and digital arms simultaneously.

The final gap uncovered by the subject review is the limited attention given to the linkage of the circular economy and twin transition in the sustainability promotion. Even though the review suggests that digital tools can be used to promote circularity in supply chains, there seems to be lack of theoretical and empirical findings related to this especially in the developing economic context. Since circular economy which is part of the green transition is still at a developing state in Southern economy, it is inevitable that this aspect gets neglected along with the concepts of closed-loop systems, reverse logistics and resource circularity in resource constrained environment of the Global South.

Therefore, in addressing the above gaps, the study aims to perform a context-sensitive examination on the Sri Lankan economy, as to how the Sri Lankan firms commemorate to digital and green logistics aspects and the integration of same to develop a framework that is applicable for the similar economic conditions in the Global South. By using the TOE framework (Tornatzky & Fleischer, 1990) as a guiding lens throughout the study, the thesis aims to contribute to the theory building and offer practical insights into the developing field of twin logistics integration for a sustainable economic development in the Global South. The framework would demonstrate the challenges and enablers, practical insights that can reform policies and corporate strategies as well as innovative findings of the twin transition synergy along with the dynamic shape of the integration of digital and green arms in the Sri Lankan economy.

3. METHODOLOGY

This chapter introduces the study's methodological approach, which mainly aims to explore the synergies, opportunities and challenges faced by the Sri Lankan logistics sector when integrating digital and green logistics for a sustainable and circular economic implementation. The study is conducted to understand the strategic, organizational, and operational challenges involved in synthesizing digital and green logistics practices.

The study consists of both abductive and deductive approaches in its research design. Due to the exploratory and abductive nature of the research, the study uses a qualitative research methodology, which involves case studies and industry analysis, emphasizing real-world practices. The qualitative approach provides flexibility to explore various kinds of real-world scenarios and offers good insights as to how firms can apply these practices in real-life business settings. It also provides a data-rich contextualized nature to contemporary cases (Yin, 2018). The methodology goes for an interpretivist paradigm, recognizing the socially constructed nature of reality and understanding the situations from the perspective of people who experience them in their day-to-day life in the logistics and supply chain field.

For this purpose, purposely selected industry professionals, based on their organization roles and experience related to logistics, were interviewed according to the research objectives. All the interviewees selected held strategic, managerial or operational positions mainly within the logistics and supply chain or the related fields of finance, IT or service departments. They were usually the strategic leaders, managing directors, accountants, IT heads and logistics managers and directors who have worked in the logistics industry for a considerable amount of time, which made the study's information richer and of required quality.

As per above, data-rich, in-depth interviews of 45-60 minutes range were performed with the interviewees and follow-up interviews were performed with the key participants who disclosed interesting insight on the given subject. The participants selected were of Yamaha Music Centre (Yamaha), Eurokitchens Trading and Contracting (EKTC), MAC Holdings (MAC) and LAUGFS Holdings (LAUGFS) and their insights were gathered to perform firm-level cross-case analysis in the latter part of the analysis chapter.

To complement the abductive research, a deductive approach is also used to examine how existing theories can be used to explain the integration of both digital and green logistics and their combined impact on operational efficiency and sustainability. Thus, the Technology-Organization-Environment (TOE) framework was taken as the guiding theoretical lens for the deductive approach used in the study.

The study undergoes an in-depth exploration of the synergies, challenges and strategic implications involved in integrating digital and green logistics practices in a developing economic context. Due to this methodological strategy, it allows us to get an in-depth understanding of how twin logistics can be operationalized in practice, the firms could cope with the barriers and what implications may arise from the implementation of these strategic actions.

The research used semi-structured interviews as primary data with key stakeholders and professionals in the logistics and supply chain industry. The secondary data was obtained from institutional and organizational websites and credible online sources to validate and contextualize the primary findings. This method is specifically chosen for its ease for theory building and testing in real-life incidents (Eisenhardt, 1989; Yin, 2018).

As per Eisenhardt (1989), researchers can generate more generalizable and testable theories through multiple case study methods by examining the cases that occur around different settings and the author recommends using multiple data sources to build trustable outcomes. According to Yin (2018), multiple case studies can be used for cross-case comparisons and allow generalization of analytical findings, both of which are beneficial for this study of exploring synergies and tensions between multiple organizations' logistics operations. Data would be analyzed using thematic and framework analysis using the NVivo software, ensuring systematic interpretations aligned with theory. The chapter consists of six sections: research design, sample, data collection, data analysis, data quality and ethical considerations.

3.1 Research Design

The study undergoes a qualitative exploratory design which is suitable for addressing real-world complex problems with an understanding on the logistics and supply chain context (Creswell & Poth, 2018). The main goal of this is to identify how the digital and green logistics are integrated in Sri Lankan logistics and supply chain focused organizations and how the twin logistics transitions help to achieve sustainable and circular supply chain outcomes in a developing economy like Sri Lanka.

The study follows a deductive approach with the TOE framework by Tornatzky & Fleischer (1990) as the guiding theoretical lens. According to Baker, J. (2011), this framework is widely applied in the area of innovation research in logistics and supply chain industry and it ensures that the research is theory-driven, pragmatic and rich in capturing qualitative and nuanced data from the industry practitioners who are proactively engaged in implementation of green and digital logistics in their day-to-day operations (DeGroote & Marx, 2013). Semi-structured interviews are used as primary data to dig deeper into the participants' experiences while maintaining the consistency (Kallio et al., 2016) and secondary data was obtained from

institutional and organizational websites and credible online sources to strengthen the validity of the factual presentations (Bowen, 2009).

A multiple case study method will also be applied for an in-depth exploration among various organizational settings (Yin, 2018), including import and export firms, freight forwarding firms and import and distribution firms, each case contributing uniquely to the topic of twin logistics implementation providing different perspectives on the enablers and barriers of successful integration. It provides a comparison between various organizational contexts, helping to identify patterns and context-specific variations across different case studies (Eisenhardt, 1989), hence contributing to the abductive research design which is specifically suitable for theory building in emerging research areas (Timmermans & Tavory, 2012).

The design of the research is objective of finding the synergies, challenges and opportunities in integrating twin logistics in the Global South, focusing on the Sri Lankan logistics field, contributing to development of both academic theory-building and practical industry knowledge in the subject research area (Pagell & Shevchenko, 2014).

3.2 Research Setting

As a developing country in the lower middle-income category (World Bank, 2023), Sri Lanka has a rapidly growing economy in par with global trade and its regional supply chain networks. Although the country has a solid technological development and literacy towards the urbanized regions, the sub-urban and regional areas still lack what it needs to be called a 'digitally developed' country. The support from the government towards development of digital infrastructure has been seen an increment in the recent years but the support for environmental sustainability remains at a minimal level. However, the political and economic instability in last few years (Economic Report 2023 - 2024 Sri Lanka, 2023) has bought a huge constrain in the development of the country in various levels and this has led to the exploration of cost-effective logistics solutions by many firms to undercut the unnecessary costs and import restrictions that prevailed with the dollar shortage in the country. In this background, the rapid advancement of the digital aspect of the country is upped by the government and as well as the private sector firms of the country while the green aspects lag behind, due to its irrelevancy with the current economic background, high cost of implementation and lower customer demand and regulatory push within the country.

3.3 Sample

The study incorporates a multiple-case sampling approach to select four logistics related firms in Sri Lanka who are actively engaged in or transitioning towards digital and green logistic practices. The selection was done using theoretical and purposive sampling strategy

(Eisenhardt, 1989) in order to employ cases which are highly relevant with the research objectives and showcases the potential to generate rich empirical insights. The researcher already has a prior professional relationship with all the four firms making it easier to access the right employee with the required knowledge structure in par with the research purpose. It provided contextual familiarity and the insider perspective for the research, in capturing operational realities and strategic imperatives of the twin logistics transition inside the subject firms (Brannick & Coghlan, 2007).

The selected firms were from import-export, freight forwarding and retail logistics sectors that are already applying or experimenting with advanced technologies such as AI, IoT, blockchain, digital twins and sustainable logistics practices within their organizations. Also, these firms were of small, medium, large and very large enterprise categories when categorized under their business models and hence, there was a visible sectoral diversity between the operational settings of the firms. This provided a good comparative analysis between different logistics landscapes and undoubtedly led to the rich analytical context and transferability of the findings of this study (Yin, 2018).

From the above four firms, a sample of 12 participants was taken using purposive selection strategy and criterion-based sampling technique (Palinkas et al., 2015). The selection was based on strategic roles on organizational operations and managerial expertise of the professionals who have relevant experience in logistics and supply chain industry. The selected informants reciprocated active involvement with supply chain and logistics operations directly or indirectly and hands-on experience with digital and green logistics implementation within their respective departments in the organizations. This purposive sampling approach allowed the study to gather more experience-related information-rich data that can provide deeper insight into the integration of twin transition in real-life (Patton, 2015). The informants were holding supply chain director, supply chain manager, logistics manager, group IT manager, general manager, group managing director, business development manager, service manager and finance manager positions in the selected firms. Through this diverse but focused sample selection, the study focused on gathering comprehensive perspectives, while maintaining thematic consistency of the research objectives, across different organizational contexts. Since the sample selection was done with a combination of strategically selected informants and firms across various industries, the dynamic nature of the data allowed the thesis to perform cross-case comparative analysis while identifying patterns and maintaining thematic alignment of the study's findings, providing a vast approach into the sustainable economic transition of Global South via twin logistics implementation.

Table 1 Informants' Details

Firm	Informant	Position	Sector	B2B/B2C
Yamaha Music Centre	Informant 1	General Manager/ Director	Import/Export/ Retail	B2C & B2B
	Informant 2	Manager – Supply Chain and Logistics	Import/Export/ Retail	B2C & B2B
	Informant 3	Service Manager	Import/Export/ Retail	B2C & B2B
Eurokitchens Trading & Contracting Pvt Ltd	Informant 1	Group Managing Director/ CEO	Import/Export/ Retail	B2C & B2B
	Informant 2	Manager – Supply Chain	Import/Export/ Retail	B2C & B2B
	Informant 3	Finance Manager	Import/Export/ Retail	B2C & B2B
MAC Holdings Pvt Ltd	Informant 1	Group IT Manager	Import/Export/ Freight Forwarding	B2B
	Informant 2	Business Development Manager	Import/Export/ Freight Forwarding	B2B
	Informant 3	Deputy Manager – Finance	Import/Export/ Freight Forwarding	B2B
LAUGFS Holdings Pvt Ltd	Informant 1	Director – Supply Chain	Import/Export/ Retail	B2B
	Informant 2	Manager – Supply Chain and Logistics	Import/Export/ Retail	B2B
	Informant 3	Executive – Supply Chain	Import/Export/ Retail	B2B

3.4 Data Collection Process

For understanding how logistics related firms in Sri Lanka implement digital and green logistics, data was collected using a combinations of primary and secondary data sources. Primary data was collected through semi-structured interviews arranged with industry experts, logistics managers and executives from firms who are currently working using both the digital and green logistics initiatives. These interviews provided insights into their experiences, practices, challenges and strategic decisions involved in integrating twin logistics concepts. The interviews were done for 45-60 minutes durations and was be conducted via Microsoft Teams video conferencing platform. The interview process was flexible, encouraging an in-depth discussion, exploring the participant's responses while maintaining a consistent

theme aligned to the main guiding theory, the TOE framework by Tornatzky & Fleischer (1990). Subject interviews were recorded with the participant's full consent and later transcribed and analysed.

Press releases, reports about the case firms were used to validate the interpretations drawn from the primary data collected through the interviews and it served as a triangulation strategy to further validate the findings (Bowen, 2009). By comparing and contrasting the participants' insights with the previous findings in literature, case studies and reports, the researcher was able to enhance credibility of the derived conclusions at the end of the study (Creswell & Poth, 2018). Since the sampling is based on purposive sampling based on the participant's experience in the digital and green initiatives, initial contact was done via email supported by formal consent and a brief introduction to the research topic and purpose. In cases where the informant doesn't showcase enough experience or exposure to the research topic, snowball sampling was also used to identify new informants who adhered with the selection criteria of the study (Patton, 2002).

The interview guide of the study (appendix 3) is designed to capture in-depth responses related to the twin logistics transition guided under the three main areas of TOE framework by Tornatzky & Fleischer (1990), namely, technology, organization and environment. As mentioned in the above section the questions are semi structured, allowing maximum freedom for the flow of discussion and follow-up questions according to the participant's unique responses. After the main interview, a follow up interview was done with selected participants to capture the novel insights that ignited from the first-round of interviews. The responses for these questions were coded and categorized during the data analysis stage to identify and explore recurring patterns, unique insights, strategic themes and possible gaps for future research.

3.5 Data Analysis

The research used thematic analysis using the NVivo software in order to identify recurring themes and patterns in the qualitative data collected. This method helped classify and interpret the data in a way that is aligned with the theoretical framework. Braun and Clarke's (2006) six step process of (1) familiarization with the data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes and (6) producing the report was used to guide the analysis. The analysis was aligned with the TOE framework by Tornatzky & Fleischer (1990) and guided through the technological, organizational and environmental domains with regard to the twin logistics implementation. Codes were generated for maintaining consistency and NVivo tool was used to support the coding and organizing data. Also, the research took a comparative case study approach by

examining and analysing how different organizations implement digital and green logistics in their own context. This approach facilitated the identification of best practices and common challenges across various industries. Framework analysis was also used to ensure that the findings are systematically and comparatively analysed in relation to the TOE framework, ensuring that the research questions were well addressed. This helped in creating a matrix which links research questions with the interview data and theoretical framework, introducing a combination of inductive theme generation and deductive framework mapping, enhancing the depth of the analysis.

3.6 Quality of the Data

The study used triangulation to ensure validity using cross-referencing findings from different data sources such as interviews and online credible web-based sources to check and verify the validity of the results. To improve reliability, industry professionals were consulted to validate the interpretations and conclusions drawn from the data. This helped ensure that the findings were reflective of real-world practices and challenges. The study ensured that key concepts and variables are clearly defined and consistently used throughout the research to enhance the clarity and reliability of the findings. The design, data collection methods and analysis methods of the research were clearly documented to support transparency and replicability and followed the trustworthiness criteria (credibility, transferability, dependability and confirmability) suggested by Lincoln and Guba (1985) to further enhance the trustworthiness of the findings (Table 2). This research is designed to provide valuable insights into how digital and green logistics can be harmonized to drive sustainability by integrating a strong theoretical foundation with an empirical approach in sustainable economic transitions. As a result, it is deemed to contribute to both academic knowledge and practical applications in the field.

Table 2 Trustworthiness Criteria

Trustworthiness criteria	Definition	Application in the Study
Credibility	Confidence in the truth and accuracy of the findings and representation	Will be accomplished through three focus points in data collection process. 1) Purposeful sampling for information-rich cases, 2) Sufficient time and in-detail discussions to encourage informant trust and engagement, 3) Triangulation done through interview recording, case studies and websites.
Transferability	To which extent the findings can	The findings are to be used guide future researchers and marketers in developing economies when integrating twin transitions. The study will provide theoretical knowledge

	be applied in other settings	and expert opinions for generalizing and contextualizing the empirical findings.
Dependability	Consistency and stability of data over time and other conditions	Will be ensured through transparent research method and documentation process throughout the study. Systematic coding, cross-case comparison and methodical approach will increase the dependability of findings.
Confirmability	To which degree the findings are shaped by respondent without researcher bias	Since the findings are derived through participants' personal experiences and perspectives, triangulation of data sources with open-ended, flexible interview questions will be used for the confirmability of the study. Adaptive follow-up questions will be used organically from the informant's direction of discussion minimizing researcher bias.

3.6.1 Ethical Issues

This study follows the Hanken School of Economics' Research Data Management (RDM) policy and adhere to ethical guidelines of qualitative research including confidentiality, informed consent and voluntary participation. This includes responsible handling, storing and sharing of the research data in order to ensure the ethical, legal and academic standards. Ethical approval will be taken from the ethics committee or the review board of the Hanken School of Economics. Each participant will be given an informed consent form outlining the study's purpose. Rights of the participants and how the data will be used. Participants will be assured that their identities or details relating to their identities will not be disclosed under any circumstances in the thesis or any related publications. Data will be stored only by the researcher on a password protected device which is only accessible by the researcher and recordings will be transcribed, anonymized and deleted after maximum 1 year of the analysis. Participants will also be given the chance to withdrew from the study at any given time without having to face any consequences. By taking all these measures, the study is bound to ensure the safety, rights and dignity of all the participants involved in the study.

3.6.2 AI Reflection

In accordance with the Hanken AI guidelines, this research has been done using a transparent use of AI and generative tools such as ChatGPT and Grammarly, only in supporting the structure of the chapters and improving the language and grammatical errors where necessary. It is not used for generating original empirical data, interviewing, analysing or concluding on behalf of the researcher.

4. EMPIRICAL FINDINGS

The key findings derived from the qualitative research methodology is presented in this chapter. The interviews from the participants were analysed on the firm-level, and the main goal of this chapter was to identify the organization-wide patterns in the integration of twin logistics in Sri Lanka. NVivo software was used to perform thematic coding adhering with the Technology-Organization-Environment (TOE) framework by Tornatzky & Fleischer (1990).

The findings were sorted around three themes guiding the research questions of the study, namely, identifying strategic relevance of twin transition, synergies between digital and green logistics and barriers and enablers of twin transition. The first theme is set to explore the relevance and importance of twin transition for the firms which strive for sustainability in a developing economy amidst the rising global pressure for adhering with environmental regulations and technological advancements. The second theme explores synergistic effect between digital logistics and the green logistics practices and how they assist to improve the overall logistics operation in the Sri Lankan economy. The final theme explores the challenges as well as opportunities faced by the Sri Lankan firms in navigating twin transition amidst various barriers and enablers, encouraging and discouraging the implementation of best practices and sustainable logistics strategies in terms of both the green and digital transition of logistics. The findings from this study will help the reader to understand the intersection of digitalization and environmental responsibility that the Sri Lankan economy and the logistics stakeholders are currently undergoing.

Foe the ease of evaluating the findings, participants are coded in terms of their organizational roles, for example, participant 1 from all the organizations consists of top management employees, participant 2 consists mostly of logistics managers and participant 3 consists mostly of finance managers of the organizations who are directly or indirectly related to logistics services of respective firms. Now let's explore, as per the cross-case analysis performed, what details and patterns were prominent amongst the four case firms, that were analysed under the study's three research questions.

4.1 Yamaha Music Centre

Subject small-medium enterprise shows good digital readiness with digital tools like Microsoft NAV ERP, barcoding systems and shipment dashboards, and displays strategic intention to implement AI and IoT related automations in the future. Although, the firm is not much sustainability oriented, it's proactive in following the path of its oversea principals in Japan, to attain certain levels of sustainability standards for upkeeping their brand reputation.

4.1.1 (RQ1) Strategic Relevance of Twin Transition

Yamaha identifies the increasing global pressure for digital and green alignment but still lacks motivation towards initiating a sustainability agenda. Green logistics practices in this firm are rather unintentional or incidental since the leadership mainly prioritize the efficiency and competitiveness of the organization through digitalization and cost effectiveness, and sustainability is considered rather a compliance than a strategic imperative.

"Digitalization is slightly above green logistics in Sri Lanka. Digitalization is a bigger subject at the moment..."

"Without changing to the digital world, we cannot maintain our sustainability."

These quotes from Yamaha participants highlight the Global and National pressure for digital transformation in Sri Lanka and the prioritization of digital versus green logistics in the country. Although Yamaha participants accept that sustainability is an essential imperative for future, they face several demotivators such as the customer demand vacuum and infrastructure deficiencies that affect the adaptation of a proper green agenda.

4.1.2 (RQ2) Synergies Between Digital and Green Logistics

The digital tools used in Yamaha such as ERP and shipment dashboards enable them with the main green benefits such as paper and emission reduction and they also use partnerships to promote sustainable deliveries through optimized route planning to their clients. Even though they face several setbacks through high costs for packaging and courier services, Yamaha still appreciates the green benefits that they could acquire via adhering with their oversea principal's sustainability standards.

"Technology has also reduced paper use"

"...these deliveries are managed by third-party courier companies. These companies look at trends and plan their trips. These are some examples of how digitalization and green goals work together."

While internal green KPIs are not yet in action, as said above, Yamaha supports the synergy of twin logistics rather unintentionally and via partnering. Since the green arm of Yamaha is not much prominent, we could say that the synergy between the digital and green logistics in Yamaha is rather unbalanced compared to the other three firms. This is because they show stronger focus on digitalization due to its operational benefits and neglect the high-cost sustainability efforts which are not in demand according to their current customer base.

4.1.3 (RQ3) Barriers and Enablers of Twin Transition

Case Yamaha showcases digital illiteracy among its staff, lack of digital infrastructure and lack of proper trainings as the main barriers that it faces while twin transitioning. They also show concern on the data privacy issues arising from weak digital infrastructure, flagging concern on their future digital upbringing.

“The basic thing is staff training. We have to change mindsets to work efficiently with these new technologies.”

"Sri Lanka is just starting to use QR codes, and digital payments are only recently coming into the country. It is very new to most Sri Lankans. But training has to come. Subjects like ICT, which were not part of the Sri Lankan curriculum before, are now included, but the level of ICT education is still questionable."

"Some firms don’t like to change their procedures. They request printed invoices or checks."

The above quotes from Yamaha participants demonstrate that even with proper training there would still be some serious gaps in skills and resistive mindsets, demonstrating a major barrier to innovation adoption inside firms. Also, the country’s lack of digital infrastructure is shown as a demotivating factor leading to the unsuccessfulness of twin transition in the country. Sri Lanka is still starting to improve in digital technologies like QR codes and card payments at a National infrastructural level, which puts a great emphasis on the current infrastructure level in the country.

“Leadership definitely is open-minded as long as whatever advancements or changes we make can benefit the firm as well as the customer.”

The above quote from a Yamaha participant shows great leadership visionary at the top management level, describing how much the leadership is open minded to adhere with a transformative agenda for the future benefit of their organization. But even with great vision from the leadership, the concern lies within the fact that these envisioned advancements and technologies that are so common in the first-world economy, become scarce to the developing economies due to the laidback policies of the governments. Another reason for this could be the financial struggles of Global South that delays the development of their general infrastructure in a resource-constrained setting.

4.2 Eurokitchens Trading & Contracting (EKTC)

Subject medium enterprise consists of leadership that showcases a strong moral responsibility towards sustainability due to its links with the HORECA sector. However, EKTC shows a lower readiness to the sustainability transformation due to high initial costs and lack of customer

demand for sustainable initiatives inside the current economy. EKTC utilize various digital tools like ERP and project management software and the leadership emphasizes the need for a national level policy and incentivization to promote the sustainability initiatives inside the country.

4.2.1 (RQ1) Strategic Relevance of Twin Transition

Although EKTC shows good digital readiness they still show lack of motivation towards green transitioning. They account sustainability as a moral imperative rather than a necessity for market and economic development. EKTC shows stronger commitment towards future sustainability development due to its HORECA sector customer base which is directly dealing with the international tourism industry of the country.

"It's more of a social responsibility than anything else in terms of bringing in sustainability. It's about, do you do things good today, for the future benefit of humankind? And I think it's more of a moral issue than anything else."

"If readiness is 10, we are probably at 2 at the moment."

These quotes from the informants of EKTC shows their current readiness and provides an overall example on the readiness level of Sri Lankan medium scale firms in twin transitioning agenda. Although they showcase high moral potential to achieve twin transition in the future, lack of motivation in the current timespan is highly noticeable. But overall, EKTC seems to understand the strategic importance of twin transitioning thanks to its unique sector of business although with lower readiness towards transformation.

4.2.2 (RQ2) Synergies Between Digital and Green Logistics

The case EKTC displays synergy between digital and green logistics arms mainly through the use of digital platforms like Accsoft ERP, ClickUp and Project management software to minimize the inefficiencies, emissions and material usage in their operations. It is also an indirect way of supporting the sustainability as EKTC does not showcase strong KPI-driven sustainability agenda.

"When we plan smarter using digital tools, we naturally save resources. It's like two sides of the same coin."

The above quote from an EKTC participant provides an example of the overall perspective of interviewed participants regarding the complementarity of digital and green logistics practices. Just like EKTC, all the other interviewees also accepted that digital and green logistics complement each other, displaying a great potential for twin transition synergy in future of the Sri Lankan economy. Thus, with a more moral approach to sustainability, backed

by the international HORECA sector customer base, EKTC represents a twin transition synergy which is unbalanced and biased towards digitality just like Yamaha.

4.2.3 (RQ3) Barriers and Enablers of Twin Transition

The main barriers that EKTC faces towards twin transition could be summarized as the lack of customer and regulatory pressures and high costs of initiation. Also, the interviewees pointed out the lack of demand from local customer base and lack of regulatory push as a huge barrier towards this transformation while leadership vision acts as their main enabler to overcome the same.

"The challenge really comes down to cost… how do we ensure that we recover the investment?"

"Advanced logistics technology is hard to invest in due to budget constraints."

"We are either hiring or training, but exposure is a challenge."

The above quotes from EKTC participants demonstrate that even with proper training, there would still be serious gaps with skills, lack of exposure and resistive mindsets, playing as a subtle barrier in the adoption of innovation inside the firms. It also presents the ROI (return on investment) pressure, that occurs through the high cost associated with the implementation of new technologies and practices. This implies that the EKTC's moral approach to sustainability is often persuaded by the financial constraints and hence, a contrast is created with their corporate strategy against their own leadership vision in transformation.

"We've implemented a training program in onboarding to keep them updated on technologies."

"It is up to us to drive, but the best practices we believe are, predominantly led by me. And the board supports that to a great extent."

"…especially from multinational clients. Some will not even consider us unless we show ISO standards in our product or services "

The above quotes from the EKTC participants showcases great leadership visionary from its top management, describing how much the leadership is open minded to adhere with transformative agenda for the future benefit of the organization. Especially given the training and onboarding methods used in the firm, it demonstrates a high opportunity for twin transition to progress a step further in the future. It also shows that multinational clients often push for sustainability than local clients and firms must put in special efforts for customer satisfaction of these special groups of customers by adhering with the required regulatory

standards and certifications. This can be interpreted as a special case of demand hyping the regulatory necessities for sustainability initiatives creating a win-win situation for both regulatory pressure vacuum and sustainability upbringing inside the Sri Lankan market.

"We've implemented a training program in onboarding to keep them updated on technologies."

"Once the team starts to understand the process, it became natural."

The above quotes from EKTC participants indicate how training and onboarding programmes lead to successful integration of new technologies within the organizations. It indicates an importance and divergence of training, from just being a new adaptation that the employees must blindly obey, to an opportunity that changes the resistive mindsets of employees and improve their skills to better adapt to the new transformative environments. Overall, although there are more barriers for twin transition than the enablers, case EKTC shows how barriers could be transformed into the enablers for the betterment of the logistics and supply chain industry.

4.3 MAC Holdings

Subject large enterprise demonstrates a good level of alignment with digital and green practices due to its link with the international trade partners. They also show strong technological adaptation through CargoWise ERP, MIS systems and digital payment platforms collaborating with local banking sector and government authorities. Green strategies are aligned and included in their broader corporate strategy but however, there exists certain limitations in executing these efforts due to the lack of skilled employees and lower local customer demand for green initiatives.

4.3.1 (RQ1) Strategic Relevance of Twin Transition

Out of the four cases, MAC represents good readiness for an upcoming twin transition secondary only to that of LAUGFS'. This readiness is driven mainly by the international trade compliance that the international firms must adhere with when dealing with oversea suppliers and trade clients.

"We would describe our readiness as being at an advanced transition phase."

These quotes from a MAC Participant shows the current readiness as an example of the level of majority of Sri Lankan freight forwarding firms and their potential to achieve a higher level of transformation in terms of twin transition in near future. Due to the high competitiveness and evolving nature in the freight forwarding industry, there is always high digital readiness shown in terms of innovative transformations. This can be interpreted as the Global influence

that the industries acquire when dealing in international trade. Sri Lanka, being at the centre of East-West trade route, is notably developed in its port operations, logistics and supply chain aspects and therefore, we could expect market leaders like MAC to take part in leading the transformation in the Sri Lankan freight forwarding field, as well in the country's overall economy.

4.3.2 (RQ2) Synergies Between Digital and Green Logistics

MAC's sustainability agenda is precisely integrated to its corporate strategy via its strong IT agenda. The main green practices include paperless workflows and waste reduction in terms of cost efficiency and though not prominently promoted, sustainability is also given a good level of importance from within the organization compared to its digital prominence.

"Digital logistics enables data-driven decisions that enhance efficiency and directly support greener and more sustainable operations."

"Tracking deliveries, distances, and fuel usage... helps us optimize our resources."

Talking about the integration with the export customs system, we are aligning with Sri Lanka Customs and the Port Community System (PCS) to ensure faster clearance, transparency, and smoother document exchange with ports and authorities like the Sri Lanka Ports Authority."

Above quotes from a MAC employee displays how MAC incorporates sustainability vision in their corporate strategy and derive data-driven decisions for innovative service designing for their special sector of international trade customers. In terms of MAC, we can say that the synergy of their green and digital arms is almost seamlessly aligned with appropriate leadership guidance towards transformation, and if given the required support from the government authorities, Sri Lanka could benefit with more fruitful trade results via the development of logistics and freight forwarding industry.

4.3.3 (RQ3) Barriers and Enablers of Twin Transition

The main barries of MAC for twin transitioning can be stated as the lack of regulatory and infrastructure support from the government and skill gaps in their workforce. Although MAC already has an established IT infrastructure of their own, they still find it hard to incorporate their technology with their international trade clients due to the restrictions and disabilities in the current governmental IT infrastructures.

"Government regulation needs to change. Logistics behind technological products face serious challenges due to old regulations."

"Limited access to renewable and green logistics. There's also inconsistent digital infrastructure..."

The above quotes from the MAC employees suggest that the government and the old regulatory network of the country play a huge role in hindering the advancements and innovation in the logistics field of the country. The researcher suggests that if basic infrastructure could be more optimized, the freight forwarding field alone could lead the whole economy of the country towards a new direction, since, Sri Lanka as a crucial hub in global trade holds the most prominent strategic location in the East-West trade route which eases its reach to almost all the directions via sea and air. However, thankfully, MAC also experiences higher levels of customer pressure from international trade partners and leadership pressure to keep up with the sustainability standards in their own method, amidst the lack of infrastructural support. This interprets the power of private sector conglomerates in persuading the government of the country, to strive from 'developing' to more towards 'developed' state of economy.

"Digital devices often contain a lot of plastic... this creates a conflict with green principles."

"Small firms don't have that financing capacity."

"Actually, it's mostly the cost the firm currently looks at."

These quotes from MAC participants represent high cost associated with the implementation of new technologies and practices which is still a considerable barrier even to large firms like MAC who are leaders in freight forwarding industry of the country. Contradictory to all the benefits discussed, one MAC participants also pointed that the digital equipment uses a lot of unsustainable particles which is the only uncomplimentary between digital and green aspects found out during the study.

"...there is a growing market demand, especially from international clients, who expect more transparent supply chain practices. This encourages companies like ours to adopt digital systems for documentation, tracking, and reporting because they require transparency in shipments and payments."

Even though there seems to be a lot of barriers in terms of cost and regulation fragmentation inside the country, it is evident that the growing international customer demand, partnerships and international trade compliance pressures keep up the momentum of MAC towards a transformative future which is a good sign of development for the country. From the above findings, we can interpret that the twin transition of MAC is currently at a stable position

trying to be better at every organizational aspect they could develop, for the advantage of their own future.

4.4 LAUGFS Holdings

Short for 'Lanka Auto Gas and Fuelling Systems', LAUGFS is categorised as a very large enterprise in Sri Lanka and showcases the highest readiness among the firms for twin logistics transition. They have initiated digital tools like ERP, GPS tracking and route planning software and engages in sustainability measurements related to their operations mainly by using emission tracking, consolidating and digital invoicing. LAUGFS demonstrate a strong C-level support and internal governance for upbringing novel integrations within their organization.

4.4.1 (RQ1) Strategic Relevance of Twin Transition:

LAUGFS shows a great alignment and strategic approach towards twin transitioning via their strong digital arm accompanied by an ESG strategy. Out of the four firms, LAUGFS gets the most benefit out of this strategic alignment combined with their great leadership vision and sustainability standards. Although, being a huge conglomerate, this synergy could be varied across various subsidiaries, but the main business locations of LAUGFS adhere to these aspects in a well-occupied manner.

"They absolutely complement each other… most green solutions need digital support to track and monitor."

"We track fuel emissions, energy use, and plastic waste as part of our ESG strategy."

The above quotes from LAUGFS participants show how they proactively use emission, energy and waste tracking in their operations, keeping up their strategic alignment with the twin transition. They also provide an example to the country on the importance of incorporating an ESG strategy for the efficiency and optimization of their own operations as well as for the betterment of the environment. So, from the angle of strategic relevance, LAUGFS sits at a top position among the four firms which are struggling to some levels in keeping up with the synergy of twin transition within their corporate strategy.

4.4.2 (RQ2) Synergies Between Digital and Green Logistics

As found out above, LAUGFS display a perfect synergy between its digital and green arms throughout its corporate strategy alignment and outlook. Therefor it creates an easy pathway for them to keep track of their sustainability achievements and make way for new strategic innovations inside the organization for years to come.

"When we installed route optimization software with GPS tracking, fuel consumption dropped and delivery times improved. I think that was a huge win in both green and digital goals."

"I think digital technology helps us measure and improve sustainability efforts. For example, our route optimization tool shows us how much fuel we are saving and analytics help us cut down our carbon output."

These quotes from LAUGFS participants suggest that there are a lot of operational benefits that are acquired through twin transition synergy and LAUGFS is proactively chasing the balance between digital and green benefits through minimizing their environmental impact in terms of operational and cost efficiency. This synergy level of LAUGFS can be interpreted as the combination of both high level of vision and high level of readiness for change management in LAUGFS, and the researcher points out that the exceptional inter-departmental collaboration and high hierarchical system of the organization also contributes to the development of twin transition synergy alongside the ESG agenda inside LAUGFS to a greater extent.

4.4.3 (RQ3) Barriers and Enablers of Twin Transition

Even though it categorizes as one of the main conglomerates in Sri Lanka, LAUGFS do not face much consumer pressure as MAC or EKTC regarding the sustainability as per the interviews done with their employees. LAUGFS has also adhered with sustainability initiatives like eliminating the production of packaging under 100 millilitres and therefore their products and services are already up to the current sustainability standards of the country, gaining lesser customer demand for green initiatives.

"Limited access to renewable and green logistics. There's also inconsistent digital infrastructure..."

"Government regulation needs to change. Logistics behind technological products face serious challenges due to old regulations."

"From a government level, I don't think there are any incentives... I don't think even as a country, we are ready."

"Government needs to incentivize organizations... eliminate the additional cost you need to pass on to meet green initiatives."

Instead, the main barriers that they face consists of limited access to renewable and green logistics, lack of infrastructure and government regulation to promote sustainability and

digitalization, and the old regulations that pose much threat to the upbringing of future logistics practices. Also, they mention the lack of incentivization, and the additional costs make sustainability a luxury, making it unaffordable to the general public, demotivating their buy-in further.

“Customers, especially corporate ones, also demand transparency and sustainability.”

"Yes, so we have our corporate team which is driving the entire ESG (Environmental, Social, and Governance) agenda where sustainability is also part of it.

The above quotes from LAUGFS participants show evidence that multinational and corporate clients often push for sustainability in their procurement choices. Although conglomerates like LAUGFS do maintain the required regulatory standard where it is mandatory, very rarely, they may have to consider the customer satisfaction of these kinds of customer groups whereas the regular customer or the regulatory framework doesn’t request such kind of standard at the moment. This shows the impact of consumer demand, in promoting sustainability initiatives creating an indirect regulatory pressure vacuum inside the market. Also, the ESG agenda of LAUGFS play a huge role in enabling the transformation process by acting as a guiding factor for LAUGFS to push through digital and green inefficiencies, in order to achieve a well-balanced twin transition for the future benefit.

4.5 Cross-Case Patterns and Contrasts

In this cross-case analysis, we identify how the four firms perceive the integration of twin logistics transition inside their organizations uniquely. The cross-case analysis was done using the key themes to expose their overall position across the topic of twin transition synergy. To get an idea about the types of the firms that are being analysed, below table is created to show the financial background of the firms, using the information available on their official websites and internet, and collected through the interviews.

Table 3 Summary of the Organizations

Firm	Industry	Size	Customer Base	Estimated Annual Revenue	Industry Reach
Yamaha Music Centre	Musical Instruments & Education	Small–Medium	Niche (musicians, schools)	< USD 5 million	National (Retail/ Education)

Eurokitchens Pvt Ltd	Commercial Kitchen Equipment & Contracting	Medium	B2C & B2B (HORECA sector clients)	USD 5–10 million	National (High-End)
MAC Holdings Pvt Ltd	Logistics, Travel, Aviation, Marine	Large	B2B (Logistics and Tourism sector clients)	USD 20–50 million	Regional & Global
LAUGFS Holdings Ltd	Conglomerate (Energy, Retail, Services)	Very Large	FMCG market & industrial mass market	> USD 200 million	International

According to above table, the four firms belong to the small, medium, large and very large categories according to their business models. Yamaha operates in the import and distribution of musical instrument and education industries, EKTC operates in the import and distribution of commercial kitchen equipment and industry while MAC operates in the freight forwarding and logistics industry and LAUGFS operate in mainly logistics and FMCG industries. In these diverse backgrounds, let's compare how these four firms perceive the twin logistics transition under the focus of Technology-Organization-Environment (TOE) framework, by Tornatzky & Fleischer (1990).

4.5.1 Answering to the Research Questions

First, let's analyse the answers in accordance with the three research questions at hand, the strategic relevance of twin logistics transition, operational synergies between digital and green logistics, barriers and enablers of twin logistics transition. The answering to the subject research questions would bring out the foundation for the discussion chapter in which the researcher will develop a novel framework through the identified gaps and contrasts in the subject findings.

Strategic Relevance of Twin Transition (RQ1)

All the respondents acknowledged that integration of digital and green logistics is an increasingly relevant priority which is especially urgent in the present times. However, they perceived that digitalization had more benefit, as they get immediate benefit to the cost incurred through digitalization, unlike sustainability, which has less or no return in the Sri Lankan market. They perceive that though costly, digital transformation is immediately actionable and green transformation is both costly and lagging in terms of complexity and policy support.

Figure 2 Word Cloud

The above word-cloud represent the overall picture of digital and green logistics in Sri Lanka with the major institutions linked with logistics industry such as the government and customs. Major barriers are shown with the emphasis on words such as costs, regulations, infrastructure and hope for future improvements are illustrated by the words such as benefits, improve, support and goals. Altogether, the key findings hint at a high strategic relevance of the subject topic in terms of the Sri Lankan logistics field.

The below table represents how much justification can be drawn to the strategic relevance of twin logistics transition in Sri Lanka from the point of view of all the participants. While many feel that regulatory framework of the country needs to be stronger to create a competition among the firms for sustainability, they also state that the lack of customer demand and cost factor stands as a huge barrier in the twin logistics implementation.

Table 4 Justification for Twin Integration

Driver	Digital	Green	Quotes
Regulation	✓	✓	*"So right now, I know the government is putting up for the digital side of it, but not for the other sides yet. So, until we have an overall policy coming and governing, all of this is going to be hard." – EKTC Participant 1*
Competitiveness	✓	✓	*"If we start first, yes, we will get the most recognition in the industry." – MAC Participant 1*

			"If you don't do that change in the next three years, businesses will be irrelevant, especially in the digital front." – LAUGFS Participant 1
Market and Customer Pressure	✓	✓	*"...customers don't request printed receipts. For any documents or invoices, they ask us to email them. That's an indirect way they're helping to fulfill this green concept." – MAC Participant 3*
Technological Advancements	✓	✓	*"We use digital tools to optimize. That means fewer emissions... technology supports sustainability initiatives." – LAUGFS Participant 1*
Cost Efficiency and Risk Management	✓	✓	*"When we installed route optimization software with GPS tracking, fuel consumption dropped and delivery times improved. I think that was a huge win in both green and digital goals." – LAUGFS Participant 2*
Strategic Alignment with Long-Term Goals	✓	✓	*"Yes, so we have our corporate team which is driving the entire ESG (Environmental, Social, and Governance) agenda where sustainability is also part of it. So they are involved in driving this agenda for us." – LAUGFS Participant 1*
Access to Funding and Partnerships	✓	✓	*"We don't have formal partnerships, but we collaborate with some authorized suppliers and logistic vendors who follow eco-friendly practices." – YAMAHA Participant 3*
Reputation and Stakeholder Trust	✓	✓	*"I strongly believe that digital and green logistics complement each other, because moving to electronic invoices, digital payment approvals, and online documentation with banks and clients, so we have significantly reduced paper usage." – MAC Participant 3*
Data-Driven Decision Making	✓	✓	*"Digital logistics enables data-driven decisions that enhance efficiency and directly support greener and more sustainable operations." – MAC Participant 2*

From the above table we can derive that the participant exhibits great insight on the importance of twin transition in the Sri Lankan economy. Not only they acknowledge the importance, but they also show immense readiness for an upcoming transformation that involves both digital and green outcomes. Therefore, overall, there cannot be seen any difference between the firms in perceiving the importance of twin logistics transition in Sri Lanka.

Since there is no difference by the firm level, below table is created to check whether the perceived urgency for twin transition is differed by different management levels in the firms. The perspectives were grouped in the levels of top management, logistics managers, IT managers and finance managers and their most prominent quotes are used as examples to check if there exist any patterns.

Table 5 Perceived Urgency for Twin Transition

Participant's Designation	Perceived Urgency
Group Managing Director	*"it's more of a social responsibility than anything else in terms of bringing in sustainability. It's about, do you do things good today, for the future benefit of humankind? And I think it's more of a moral issue than anything else" – EKTC participant 1*
General Manager / Director	*"Customers need these 'now' and don't understand the backend regulations required. From their point of view, it's fair because these old regulations hinder us from providing better timelines and deliveries." – YAMAHA participant 1*
Group IT Manager	*"Because still, we are adapting in that area. Most of the organizations have not yet moved forward with green concepts. So in that sense, if we start first, yes, we will get the most recognition in the industry." – MAC participant 1*
Supply Chain Director	*"These types of platforms and insights have helped us serve customers better and reduce the dissatisfaction that comes from delays or a lack of communication around realistic delivery times" - LAUGFS participant 1*
Finance Manager	*"Because, for example, if they continue to use the unsustainable packaging, with low cost they will make profit in the short term. But in the future, they will be rejected from the customers. So, in the future, when the good firm comes into the competition with a good product, environmentally friendly packaging, then they will lose the competition." – EKTC participant 3*
Deputy Manager - Finance	*"Actually, not the certificates. But customers don't request printed receipts. For any documents or invoices, they ask us to email them. That's an indirect way they're helping to fulfill this green concept. Even if they aren't asking for certifications, they are indirectly expecting us to be green." – MAC participant 3*
Supply Chain Manager	*"Green logistics helps strengthen our brand as well among the competitors, if you look at (our clients) international hotel chains, they are heavily concerned about how their suppliers and they are more concerned about the green concepts." – EKTC participant 2*
Logistics Manager	*"digitizing our dispatch planning saved our warehouse teams several hours a week, which they could then use for quality checks or maintenance tasks. Clients are also happier because we communicated more accurately on delivery and their timeliness, enhancing their trust in Yamaha service standards." – YAMAHA Participant 2*

According to the table above all the major departments of organizations such as Top management, Finance, Logistics and IT, acknowledge the urgent requirement of twin transition adoption. They perceive twin transition as a competitive tool against their competitors and think whoever moves first will have an upper hand over the followers of twin

transition in the economy. They even assume the time wasted on slower traditional practices as a hindrance to allocating quality service to their customers as a twin transition benefit. However, a clear difference was identified between the insights of each management level, and the following diagram is created to showcase the gaps identified in perceived importance of each element, focused by separate management levels.

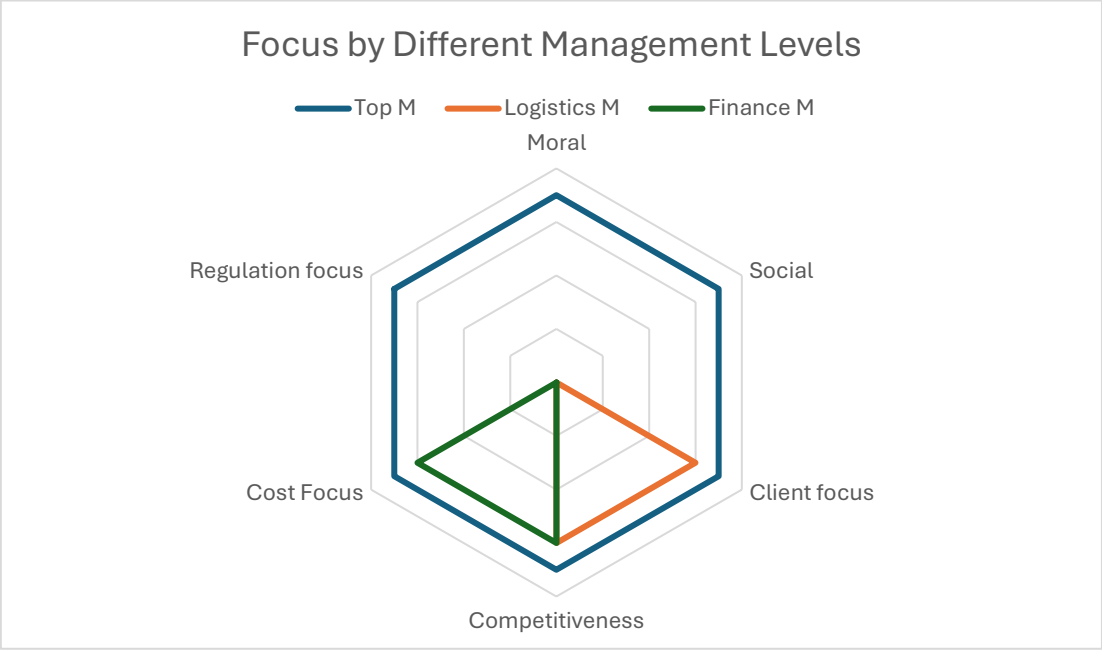

Figure 3 Focus by Different Management Levels

After analysing the responses from each designation, it was evident that the top management of the four firms radiate a more holistic, social and morally responsible approach towards the twin transition in Sri Lanka with a customer oriented, competitive and regulative angle. However, Logistics mangers tend to deviate more on the topic in a client specific and competitive manner, while Finance managers are more about being competitive in the market and being cost efficient. Also, the moral approach of EKTC is more prominent than in the other firms as it deals with the HORECA (Hotel/Restaurant/Catering) sector of the country which associates with tourism and hospitality, one of the highest income generating sectors of the country. Overall, according to above observations, all the organizations show good understanding on the strategic relevance of twin logistics transition in the country.

Synergistic Impact on Sustainable Operations (RQ2)

The interviews consistently revealed the synergistic effect of digital tools and sustainable outcomes in a compelling manner. From paperless offices, basic route optimization systems to robotics, AI and automation, interviewees expressed their perspectives of the current system and a perceived future of transformation. Below table is created to represent a summary of the complimentary nature of digital tools towards generating green benefit that were found out through the interviews.

Table 6 Complementarity of Green and Digital tools

Digital Tool	**Green Outcome**	**Quote**
Route Optimization	Fuel and emission reduction	*"We plan in advance… fewer emergency shipments… helps us reduce fuel and emissions."*
Digital Invoicing	Reduced paper use	*"We've significantly reduced paper usage."*
Cloud-based systems	Efficient shipment tracking, hence optimized usage of fuel and resources	*"Tracking deliveries, distances, and fuel usage… helps us optimize our resources."*
Barcode & Sensors	Waste and labour reduction	*"We can remotely diagnose errors… it reduces unnecessary travel and fuel waste."*
Consolidation tools	Lower freight shipments, hence lower emissions	*"We try to club as many orders… reduces repeated shipments and emissions."*
CRM/ERP	Operational efficiency, hence lower wastage	*"All our systems, client requests… are mapped through ERP and CRM."*
AI & automation	Faster communication and less labour	*"Using AI to respond via WhatsApp and website… gives real-time data to customers."*

As per the insights drawn from above summary, the complementarity between digital and green logistics becomes even more confirmed. Tools like route optimization reduce and monitor fuel consumption and emissions while cloud-based systems, ERP and CRM contribute to the enhancement of operational efficiencies. Digital tools like digital invoicing, barcoding and censoring allow firms to produce less waste and minimize errors in packaging and distributing. Also, the AI, automation and various kinds of consolidation tools allow the processes to be smartly operated without high energy consumption and low cost ensuring greener outcomes. Now let's evaluate the wordings from the study to see if there's any

significant patterns of co-occurrence that further demonstrates the complementarity of the digital and green synergy.

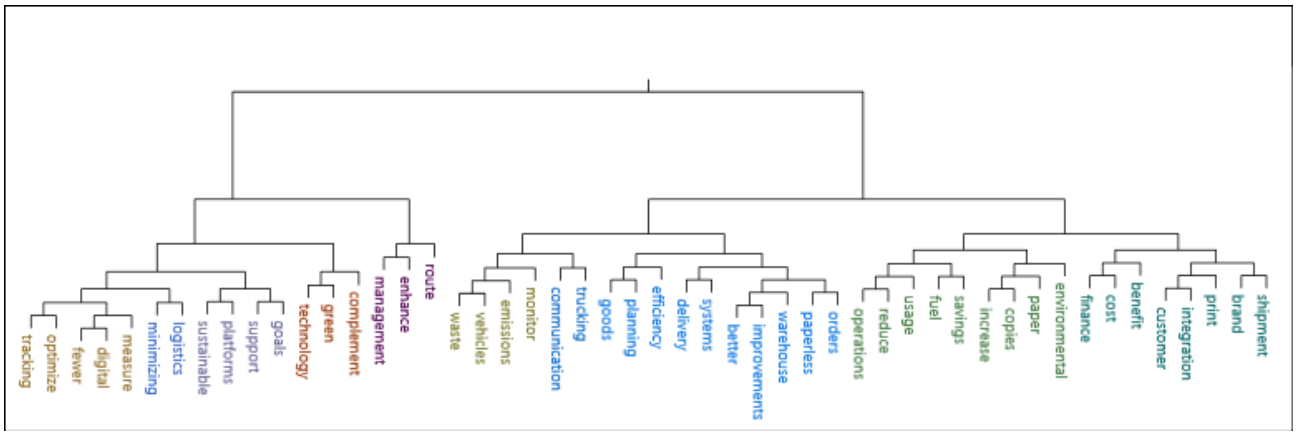

Figure 4 Cluster Dendrogram for Twin Transition Synergies

The cluster dendrogram represent the co-occurrence of keywords coded under the theme twin transition synergies. In the rightmost cluster in green, we see the keywords, 'customer, integration, cost, finance and benefit', implying the benefit of the twin logistics integration and the cost and finance elements associated with it. In light green colour we see the keywords, 'environment, fuel, reduce and savings', implying the benefits of wastage reduction and enhanced green benefits derived for the firm. Overall, this cluster demonstrates the green outcomes that could be expected from integrating twin logistics within organizations.

In the middle cluster in blue colour, we see the keywords, 'orders, paperless, improvement, systems, efficiency, trucking, delivery, communication and warehouse' displaying the digital aspects affecting sustainable outcomes in terms of organizational operations and in yellow green we see the keywords, 'monitor, emissions, vehicles and waste' supporting the green theme and its outcomes. Overall, this cluster indicates the relationship between digitalization of organizational operations, workflows and green outcomes obtained from it.

In first part of left cluster in purple colour, we see the keywords, 'route, enhance and management', the keywords which are relating to digital enablement and operational efficiency. The keywords in brown, 'compliment, green and technology' suggests the complementarity of implementation of twin logistics and further supports the theme of the diagram, synergy of twin logistics integration. Therefore, overall, this cluster suggests that the

digital technologies lead for greener and operationally efficient logistics and seamless synergy of twin transition as a result.

In the second part of the left cluster, in light brown we see the keywords 'measure, digital, optimize and tracking', showcasing the digitalization of workflows, further optimizing the twin transition synergy. The keywords, 'logistics and minimizing' in light blue and keywords 'goals, support, platforms and sustainable' in ash colour further give out the synergistic vibe of the digital platforms and systems, in minimizing the logistical mishaps and promoting the twin transition synergies.

This dendrogram suggests how the digital tools like, tracking platforms, monitoring systems and planning software are frequently placed besides wordings indicating fuel savings, delivery time reduction and efficiency improvements. Also, wordings like 'paper, plastic, fuel, carbon and reuse' shows how sustainability is often defined through means of waste reduction in the Sri Lankan context. The cluster of wordings 'invoices, documentation and workflow' suggests how important is the digitalization of administrative processes is to achieve environmental benefits through sustainability measures like reduced paper use. Terms like 'leadership, corporate and policies' show how important is the internal governance for implementing transformation inside the corporate environments and overall, this dendrogram visually suggest how all these elements of clusters are mutually aligned with each other in an economy instead of being exclusive with each other.

Challenges and Opportunities in Implementation (RQ3)

By far this has become the most referenced theme of the study as it reflected many barriers to implementation of twin transition and many possible opportunities for the country in future, only if the challenges get addressed correctly and immediately. The highest barriers identified are the lack of National policy, lack of government support, lack of infrastructure, high cost of initial investments, technological and green illiteracy and resistance to change from both the government and private sector employees. The greatest enablers identified are the leadership from private sector business leadership, banking sector and technological advancement lead by the government over the recent years that indirectly affected the sustainability inside the country through the means of reducing costs. Another observation is that the sustainability has a huge challenge unlike technology, which is currently gaining most prominent attention in the Sri Lankan economic context.

To roll out this phenomenon in a quick example, we can say that most of the firms will not be interested in recycling of electronic waste, if it costs them extra (for technology and the process) just because it is environmentally friendly. But if they could recycle the waste back

into their supply chain and reduce cost for new material (through the technology) then they will go for the transformation and adoption of the new technology, indirectly supporting the green outcomes. But more than the sustainability effect, the firms would be more focused on the cost benefit gained through the technological investment that they risk.

Barriers

The table below summarizes the frequency of quotes that were relevant inside each given criteria of barriers and thus showcases what are the most common barriers that the logistics field in Sri Lanka usually face. We can already identify the cost, infrastructure, lack of government and regulatory support and employee skill gaps and resistance being the most talked-about barriers in the logistics field and many interviewees have highlighted the fact that even the available amount of infrastructure is distributed in a very unbalanced manner creating a high rural-urban difference in the country.

Table 7 Barriers of Twin Logistics Implementation

Barrier	**Frequency**	**Example Quote**
Customer Demand	8	*"Consumers are not willing to pay for that." – LAUGFS Participant 1*
Digital Barriers	14	*"Sri Lanka's digital infrastructure is still not at its best. Internet speeds and connectivity are nowhere compared to European countries." – YAMAHA Participant 1*
Employee Resistance	20	*"Some firms don't like to change their procedures. They request printed invoices or checks." – MAC Participant 3*
Employee Skills Gap	21	*"Skill shortages, less trainings on new tech investments were major issues." – LAUGFS Participant 3*
Infrastructure	35	*"Limited access to renewable and green logistics. There's also inconsistent digital infrastructure…" – YAMAHA Participant 3*
Lack of Government Support	35	*"From a government level, I don't think there are any incentives… I don't think even as a country, we are ready." – EKTC Participant 1*
Logistic Barriers	9	*"Logistics costs coming into play… product cost now somewhere around 10% or 7%." – YAMAHA Participant 1*
Regulation Impact	17	*"Government regulation needs to change. Logistics behind technological products face serious challenges due to old regulations." – YAMAHA Participant 1*

Twin Transition Barriers	8	*"Right now, we have a long way to go (in terms of twin logistics transition)." – EKTC Participant 1*
Cost	32	*"We prioritize usually when it either saves us money or avoids shipping delays... High-cost tools with slow returns are harder to justify..." YAMAHA Participant 2*

As per the table infrastructure, lack of government support, employee skill gap and employee resistance pose the most challenge for Sri Lankan organizations in leading towards the twin logistics. Going forward, these factors need to be assessed carefully in order to minimize the threats and maximize the adoption of twin transition across Sri Lanka. The cost factor also comes as one of the biggest barriers in twin logistics transition and below cluster was created to summarize the effect of cost verses each of the digital, green and twin implementations for by coding similarity to better understanding on the effect of cost barrier in the economy.

It is also understood that the cost has a bigger impact on the green transition as it has referenced by many interviewees as a major obstacle against sustainability motivation and as a whole against the twin logistics transition. The below cluster map is done to further analyse the coding similarity between different barriers and their relationships.

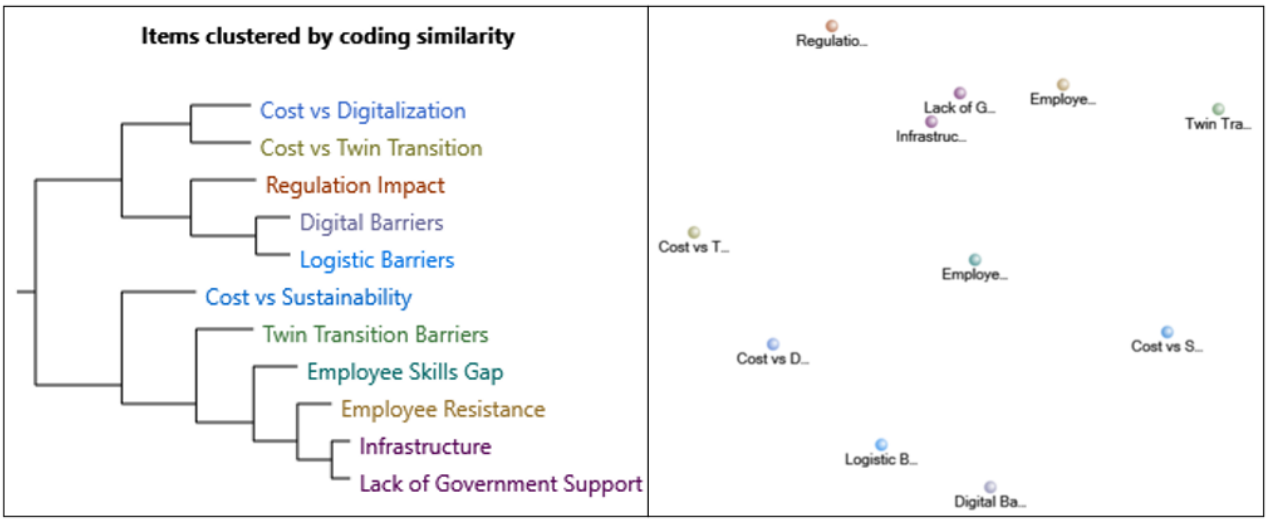

Figure 5 Items Clustered by Coding Similarity

The cluster map shows two defined branches grouping costs, regulation and digital/logistics barriers into one group and sustainability related costs, twin transition barriers and people/infrastructure barriers into the second group. The first cluster suggests that

interviewees often mention budget concerns together with the implementation of digital and green initiatives. Regulatory barriers join the cluster next followed by the digital and logistics barriers indicating their impact with the cost. It also suggests that the technological and operational/logistical barriers frequently co-occur with the cost and regulation barriers. The second cluster shows the connection between the codes, twin transition barriers and cost vs sustainability, highlighting the financial limitations in terms of implementing sustainability initiatives. It is noted that the twin transition is generally seen as a costly procedure by the interviewees which is common to both the digital and green aspects.

The third cluster shows the connection between the wordings, employee skill gaps, employee resistance, infrastructure and lack of government support. It suggests that there is considerable human capital challenge in terms of skills and readiness to change, and the government policy and infrastructure gaps are also evident when talking about the barriers to twin implementation. The same information on the dendrogram can be further illustrated by the visual cluster diagram next to it, for the better understanding of the reader. Overall, there is evidently a lot of barriers for twin transition in Sri Lankan developing economy, and the barriers showcase more weight towards the green transition than to the digital transition according to the research findings.

Enablers

The below table summarizes the enablers of twin logistics transition and their specific frequencies to highlight which enablers has the most impact on twin transition synergy in Sri Lanka. Partnerships, training and onboarding has the maximum number of references indicating its prominence in creating a favourable environment for the upbringing of twin logistics transition in Sri Lanka.

Table 8 Enablers of Twin Logistics Implementation

Enabler	**Frequency**	**Code**
Global Examples	7	*"If we compare with global organizations like DHL and many other worldwide firms, they are using more technology than in the Sri Lankan context." – MAC Participant 1*
Government Support and Incentives	16	*"Government needs to incentivize organizations… eliminate the additional cost you need to pass on to meet green initiatives." – LAUGFS Participant 1*

Partnerships	33	*"We work with third-party logistics service providers who follow eco-friendly practices." – LAUGFS Participant 1*
Recognition	7	*"There are a few entities that do recognize for developing sustainable goals." – EKTC Participant 1*
Supplier Evaluation	8	*"We use platforms to evaluate shipping lines… look at their carbon footprint and sustainability efforts." – LAUGFS Participant 1*
Training and Onboarding	33	*"By starting small, giving training to employees… we expanded gradually without disrupting daily operations." – YAMAHA Participant 2*

The table shows that unlike the barriers; there's quite a small number of enablers for the twin transition in Sri Lankan. Though chances are small it still suggests that partnerships and proper training and onboarding plays a huge role in enabling the twin logistics transition whereas the need for government incentives to support this change is highly discussed by the interviewees under the code government support and incentives. Overall, this section identifies the importance of internal-external environmental alignment as a huge supporter for the twin transition in relation to the logistics field in Sri Lankan economy.

4.5.2 Patterns Among Top Management

Although it was evident that all the 4 leaders who were at top executive and operational management level were having positive perspectives on digital and green logistics integration, some patterns were identified revealing overall position of Sri Lanka in terms of the mindsets of business leaderships, for the upcoming transformation in the economy.

Digital Vs. Green Focus

It was interesting that all the four leaders perceived both digital and green transitions as essential but honestly stated that they give priority to the digital transformation. They considered green logistics and sustainability aspects as something costly, and not yet seek by the local consumer, hence, unworthy to pursue in large scale due to its complexity, cost and lower demand.

"We are probably a 2 out of 10 in readiness. Especially on the green front, it'll take another 10 years." – EKTC Participant 1

"Digitalization is more of a necessity. Sustainability comes after." – YAMAHA Participant 1

"Green logistics is talked about but adoption is slow because infrastructure is lacking." – MAC Participant 1

"Digital optimization directly reduces emissions. But we don't see customer pressure for green logistics yet." – LAUGFS Participant 1

It's evident that although they see the potential for twin transition very much relatable for future benefit of Sri Lanka, the lack of green demand and infrastructure for sustainability is hindering them from going forward towards the next step. As a summary, the main patterns observed are that all the firms accepted that digital adoption goes hand-in-hand with training effectiveness. Three firms, MAC, LAUGFS and EKTC give priority to the internal training agenda and therefore they have obtained reliable results in overcoming the shortages of skills in their staff. Also, it is noteworthy that all the four firms have initiated at least one training or onboarding program demonstrating their strategic thought process aligning with the transformation. Two firms, EKTC and Yamaha, state that they have considerable operational inefficiencies due to infrastructure constraints and being small-medium enterprises, we can say that the inefficiencies of the governments hugely affect the development of SME's in the country more than the conglomerates.

Support for Transformation Vs. Readiness for Transformation

Although all the leaders show support for the transformation, it was found out that there is a significant difference in organizational readiness when it comes to an upcoming major change in the economy. The table below was created to summarize the readiness levels of the firms including the prominent quotes to elaborate each firm's weaknesses and strengths according to their readiness for transformation.

Table 9 Readiness of Organizations for Transformation

Firm	Readiness	Quote	Readiness
EKTC	Low	*"If readiness is 10, we are probably at 2 at the moment."*	Lowest readiness among the four firms, digital adoption is limited to core business functions and green logistics is not yet a priority. Limited by SME barriers
YAMAHA	Low-Moderate	*"We don't have a green goal right now. We are following what Yamaha Japan is doing globally, but in Sri Lanka, it is still not*	Moderate to low readiness, focuses primarily on digital transformation, not yet green-focused. Limited by SME barriers and strategic scope.

		something that we can plan or measure at this point."	
MAC	Moderate	*"Still, we are adapting in that area. Most of the organizations have not yet moved forward with green concepts. So, in that sense, if we start first, yes, we will get the most recognition in the industry."*	Second highest readiness in overall readiness, faces customer pressure due to being in the competitive freight forwarding sector, competitive pressure drives green and digital adoption.
LAUGFS	High	*"We continuously look for digital tools… optimization plays a big role. We use technology to increase loadability and utilization, which makes our vehicles run less… this obviously consumes less fuel and produces fewer emissions."*	Shows the highest overall readiness for twin logistics transition, strong performance across transformation agendas, benefits from its conglomerate structure and strong leadership focus on digital and ESG agendas.

It was evident that EKTC and Yamaha showcases lowest readiness for transformation since they acknowledged various factors like lack of consumer demand and regulatory pressure makes them not to pursue sustainability in large scale and MAC and LAUGFS showcased highest readiness as they admitted that they continuously look for ways to improve their mechanisms through the support of their organizational strategy. Overall, we can conclude that small and medium size enterprises have lesser readiness even though they have a good visionary, because of the resource-constraints that they regularly face; and large enterprises face these same obstacles in a lesser degree making them ready to acquire the next step in innovation and transformation within their organizational context.

Optimization, Cost Saving and Efficiency

All the leaders undoubtedly stated the value of digital optimization in reducing the unnecessary costs and improving the overall firm performance. But it was evident that these aspects affect largely to the small and medium enterprises than the larger enterprises due to their prominent financial strength.

"We track kilometers per ton, and optimize routes using tech. That's how we reduce fuel use." – LAUGFS Participant 1

"Customer complaints are solved through GPS tracking. Without digital visibility, it's impossible." – YAMAHA Participant 1

It is evident that through digitalization, for example through optimization of fuel usage through route planning software, both cost efficiency and customer satisfaction has been garnered by the firms, subsequently improving the operational efficiency of the practices and gaining green benefit as a byproduct. Although these benefits are acquired by all the firms to different extents, the most fruitful results are acquired by large firms like MAC and LAUGFS due to their large business models. Therefore, cost benefit is deemed to be the biggest benefit that all kinds of small, medium and large firms acquire, through twin transition followed by operational efficiency and customer satisfaction coming into second and third positions.

4.5.3 Contrasts in Strategic Positioning

Although all the organizational leaders show interest in integrating twin logistics into their processes, some of the gaps have been evident in their readiness in adopting the transformation due to various barriers. Below table is created as a summarized version of readiness verses gaps as per the interview responses of the participants to provide a clear understanding to the reader.

Table 10 Readiness Vs the Gap in Vision

Firm	Strategic Vision Level	Vision
YAMAHA (Small Medium Enterprise)	Balanced vision and readiness	Focus on the primary stage of transformation (customer demand, efficiency and paperless processes)
EKTC (Medium Enterprise)	High vision, low readiness	In early stage of AI discussions, moderate sustainability adoption
MAC (Regional & Global)	Committed vision and moderate readiness	Focused on interdepartmental digital coordination, good phase of green adoption
LAUGFS (International)	Practical and data-driven vision	Operational KPIs on both digital and ESG level, evidence of digitally driven sustainability

According to the above table LAUGFS and MAC have been able to position themselves as leaders in twin transitions in relation to their vision and strategic positioning while EKTC and Yamaha showcase the need for more aligned visionary and strategical position in order to achieve twin transition synergy in the coming future. In conclusion, though all the top management employees of the firms exhibit thorough knowledge and vision towards a twin transition enabled future, their readiness levels are somehow limited by the many obstacles

created as a result of the prevailing economic status of the country. But the firms which are in a good strategic position in the current market exhibit a high chance of acquiring the envisioned future with regard to their strategic composure.

4.5.4 Cross-Case Summary

As discussed in above topics, there is a contrast between the readiness of each organization to perceive the digital and green synergy from twin logistics integration. Even though all the organizations demonstrate a stronger bias towards digitalization, green practices are bought less productively and often as a byproduct of digitalization. The synergy between both digital and green aspects are often showcased through technological advancements like AI, automation and various software and platforms subsequently eradicating route and emission inefficiencies and therefore producing green outcomes.

Below is the summary of the findings from the cross-case comparison between each top management employee on the readiness, digital logistics, green logistics, twin implementation and key enablers and barriers of the twin transformation inside their own organizations. For this cross-case summary all the cases from participants labeled '1' out of each firm (top management) were selected and thoroughly analyzed.

Table 11 Cross-Case Comparison Summary

Firm	Title	Readiness	Digital Integration	Green Integration	Twin Transition	Key Enablers	Primary Barriers
EKTC (Medium Enterprise)	Group Managing Director	Low-Moderate	In planning stage for AI automation tools. Use ERP and dashboards for visibility	Not prioritized due to the high cost of initiation and less compliance pressure	Mostly conceptual	Leadership and vision on AI	Lack of regulatory push on a national level, cost and employee resistance
YAMAHA (Small-Medium Enterprise)	General Manager / Director	Moderate	ERP, Paperless procedures and GPS tracking	No sustainability initiative, only as a byproduct of digitalization	Only digital focused	Digital focused customer service strategy	Data privacy concerns, cost and weak digital infrastructure
MAC (Regional & Global)	Group IT Manager	Moderate-High	ERP integration with API based integration	Track the eco-friendliness and integrate green practices	Twin coordination functional at early stage	Cross department systems thinking, strong IT focus along with	Lack of support from government institutions in digital infrastructure

			across platforms	with IT to some extent		industry partnerships with banking sector	and outdated policies
LAUGFS (International)	Supply Chain Director	High	ERP, digital and ESG KPIs for efficiency	Receive green benefits as a byproduct of fuel and route optimization	Twin coordination at operational synergy level	Performance-driven and KPI based culture	No consumer pressure for green products or practices

From the management perspective, the top management showcased a wider knowledge on long-term sustainability and moral and social responsibility; and therefore their key insights were taken into consideration when summarizing the findings across the four organizations. The middle managers demonstrated a considerable responsibility towards the same but focused more on cost, efficiency and customer satisfaction more than on the bigger picture of long term transformative and innovative sustainability and digitalization.

The cream of the futuristic visions that the participants have shared at the follow-up interviews were a Nationwide smart logistics ecosystem, ESG embedded public-private partnerships and centralized green logistics application with real-time carbon tracking and rewarding systems backed by the government regulations of Sri Lanka. These visions showcase a strong mindset among collaborative private sector enterprises in achieving a technology-driven, eco-conscious logistics infrastructure for the country in the coming future.

In summary, it is evident that digital logistics act as a key enabler of green outcomes and hence enhances green logistics. Also, digital and green synergy is currently under-leveraged and informal inside Sri Lanka and leadership and strategic alignment in the private sector organizations play a crucial and pivotal role in enabling the twin transition in the country. Also, the firms lack required customer demand and regulatory support from the government at the moment, and if fulfilled these two criteria can act as a giant force towards twin logistics enabled future of logistics.

Perceived Readiness for Twin Transition

The radar graph below is constructed to provide a summary of the findings in analyzing the overall readiness of the firms in achieving twin transformation in the future. Markes were given out of two for each of the criteria (Organizational Support, External Support, Current Level of Readiness, Future Readiness and Transformative Mindset) to get an overall mark out of ten for the four firms respectively.

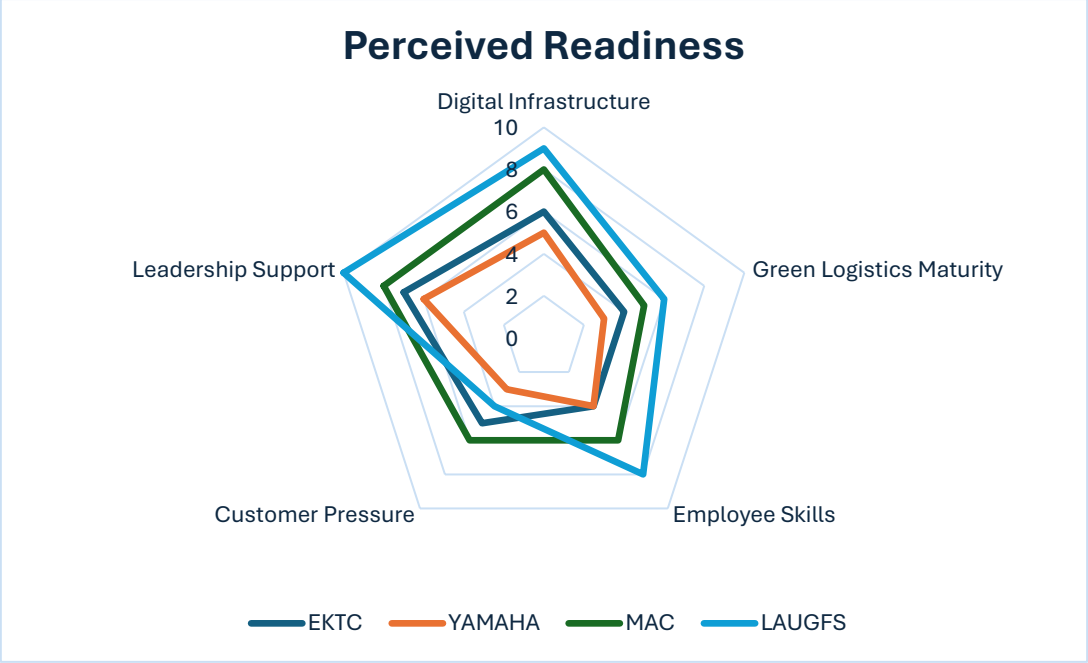

Figure 6 Perceived Readiness of the Firms

From the marks given in the findings, we can create this radar map showing how much the readiness of these four firms is in terms of adopting the novel digital and green transformation on a scale of 1-10. It is evident that LAUGFS, as a conglomerate, showcases much more readiness followed by MAC which surpasses LAUGFS only in terms of customer pressure, due to being in the highly competitive freight forwarding industry. Yamaha and EKTC being small and small-medium enterprises, showcase less readiness to the twin logistics transition as they only focus on the digital aspects in the core of their businesses at the moment.

In conclusion, the researcher was able to find several key motivators and demotivators that affect the twin logistics transition in Sri Lanka and found out that the size and strength of the business organization also affects the readiness of the firms towards a transformative future. Also, the researcher found out that though it is important, the vision and leadership alone, cannot decide the readiness level of firms in developing economies due to the highly volatile and resource-constraint nature of the economies in Global South.

5. DISCUSSION

The aim of this chapter is to critically analyse and interpret the empirical findings that were presented under chapter 4 and to evaluate the analysed data under the Technology-Organization-Environment (TOE) framework by Tornatzky & Fleischer (1990). By doing so, the researcher aims to answer the research questions and develop a theoretical understanding of the importance of twin transition, or the digital and green logistics integration in the Sri Lankan economy. This allows the reader to see how twin logistics transition can be successfully operationalised in the logistic field in Global South more holistically. The discussion will combine the empirical findings across the four cases and analyse them into broader academic context, by sewing the novel insights found into the TOE framework. Therefore, the discussion will introduce a new 'twin transition synergy framework' that will enhance the TOE framework into a new paradigm that is unique to the developing economic context of Global South. The derivation of the arms of this new framework will be further discussed at the latter part of the chapter, using the answers to the three research questions separately. Now let's see how we can propose a framework to interpret the findings of this study accordingly.

5.1 Twin Transition Synergy Framework

Although the TOE framework by Tornatzky & Fleischer (1990), supports the Technological, Organizational and Environmental aspects regarding innovations, the elements such as internal-external environmental bridging, regulatory and consumer demand vacuum, transformative and change readiness attitudes do not reciprocate within the subject framework. The researcher suggests that if above three layers of barriers and opportunities discussed further under the topic 5.4 (Strategic alignment between external and internal environments, cultural mindset and regulatory & customer pressure) team up with the 'Technology, innovation and decision making' output of the TOE framework by Tornatzky & Fleischer (1990), a synergy could be obtained in digital and green logistics integration, which is backed by not only the cultural mindsets, but also the external stakeholder pressures. The main arm of this synergy will be the 'technology, innovation and decision making' that is derived from TOE framework, teamed up with the strategic alignment between organizational and external ecosystems, showing that technology plays a vital role in enhancing the green outcomes in the twin logistics integration.

Therefore, let's add the strategic alignment layer, regulatory and customer pressures layer and cultural mindset layer to create a novel framework and evaluate the research objectives of this thesis in a new angle.

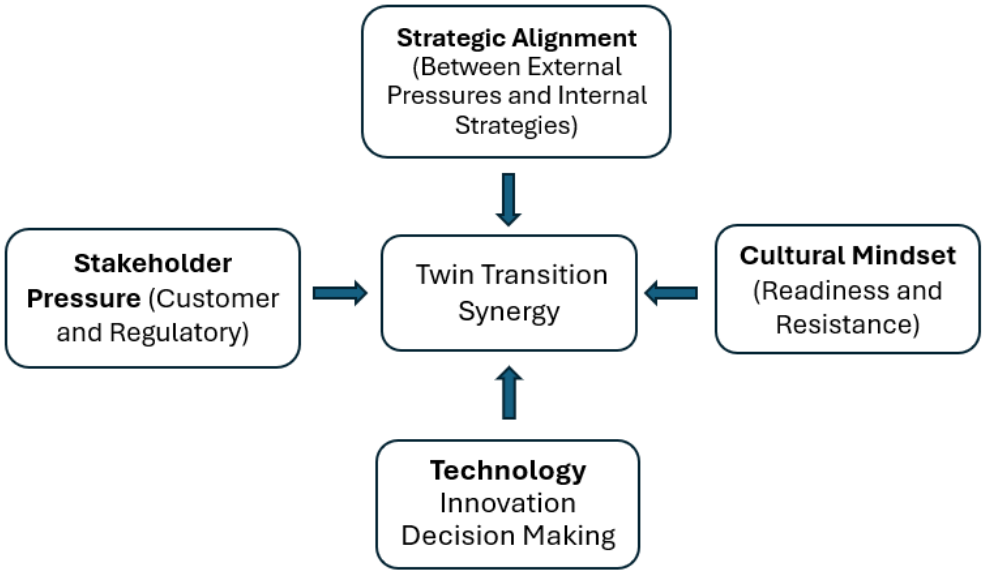

Figure 7 Twin Transition Synergy Framework

According to the framework derived above, the main themes can be explained as below in accordance with answering the research questions.

5.5.1 Digital as an Enabler for Sustainability (Innovation & Decision Making)

According to the findings it is evident that the digital tools like ERP and route optimization tools poses out indirect green outcomes aligning with the literature by Chauhan et al., 2022 and Moshood et al., 2021. From this study the researcher found out that green logistics practices are not intentionally strategized but a coincidental outcome from the digital logistics practices in Sri Lanka. Therefore, it is noteworthy to mention that initiating digital-prioritized, green-by-design logistical practices suits best in developing economies like in Sri Lanka to strategically promote sustainability inside the economy, than blindly forcing regulations on firms to make them adhere with green practices, which seems unreasonable with the ongoing financial struggles of the country.

5.5.2 Strategic Misalignment (Internal Strategies & External Pressures)

Although the top management is focusing on the holistic view of green logistics practices, the middle management looks at is from a cost and competitive angle. That means if a green practice is on the verge of higher cost and lower competitiveness among the customers, the middle managers did not want to spare it a higher concern, but the top management was concerned regarding the same from an ethical angle. This aligns with the literature by Bag et

al., 2020 but differentiates with addition of intra-organizational divergence as a new insight, which is especially relevant in developing economies where sustainability aspects are rather a complement than consumer driven. Starting from internal, it is evident that the misalignment spreads with the external environment as well, where there exist some green certifications hosted by government authorities, yet unreachable and unappealing to the firm level. Also, there were some instances that the authorities allow online transactions via certain banks instead of allowing access via full banking sector, leading to discouragement from firms to change their trusted banking partners that they usually work with. Also, there were instances where government was too late to introduce certain basic digitalization tools like card payments or QR scanning for important public infrastructure like highways.

5.5.3 Cultural Mindset and Institutional Barriers (Readiness & Resistance)

There are certain internal institutional gaps such as the lack of training, improper hiring mechanisms and policy and regulation gaps that pave way for development of cultural resistance inside organizations. This could also be due to the National cultural values like respecting the seniority by age rather than by skills which hinders growth of skill-based promotion culture inside organizations, hence leading to resistive mindsets which are prone to change. This lies in contrast with the Western culture where policy is of utmost importance according to the studies by Rehman et al., 2023. According to this study, it shows that with lack of policy and change-ready mindsets, the firms will lead towards a stagnant state internally.

5.5.4 Stakeholder Pressure (Customer & Regulatory)

Although the study constantly confirms that lack of external pressures such as low customer demand and regulatory push, direct the economy towards abandonment of green practices, as the saying goes that every dark cloud has a silver line, the study also uncovers the futuristic vision of the strategic leaderships within these organizations. Though constrained by many obstacles and barriers physically, mentally and financially, these leaderships demonstrate the urge for a nationwide digitalized system, bound with smart and green logistical aspects despite the low regulatory and consumer pressures in the current market. This vison suggests that the leadership efforts and mindsets might precede in front of the institutional reforms in developing markets which is a reversed pattern from which we could see in the developed markets.

5.5.5 Theoretical Propositions for Future Research from Twin Transition Synergy Framework

The above novel twin transition synergy framework extends the Technology-Organization-Environment framework by Tornatzky & Fleischer (1990) and includes novel aspects which are unique to the developing economies. The TOE framework was not able to capture the dynamic nature of cultural aspects, strategical alignment and stakeholder and regulatory pressures that were related to the Sri Lankan economy although it was effective in identifying the overall technological, organizational and environmental aspects that affected the adoption of innovation generally. Therefore, for the development of new framework, the researcher identified the new paradigms that either contributes or hinders twin transition synergy in the Global South, namely internal-external strategic alignment, stakeholder pressure, cultural mindset and technology as an enabler for green. Although traditional models usually have several elements that appear in isolation, this new framework's elements are bound to work in unison to point out the synergistic impact of twin logistics transition. It mainly brings out the weak organizational and regulatory enforcement, resource constraints, low consumer buy-in and resistive mindsets that are backed by literature yet tailored to the Sri Lankan economic context in a unique way. Below are a few propositions that could be derived from the study for the future use in academia.

The first proposition is that the relationship between the technological innovations and sustainability outcomes are positively moderated by the strategic alignments between the intra-organizational and inter-organizational capabilities (Bag et al., 2020). The second proposition that can be derived is that the cultural resistance, skill gaps and digital and green illiteracy negatively affects the effectiveness of digital capabilities in attaining the green goals (Rehman et al., 2023). The third proposition is that the internal strategical alignment could be used as a strong mediator for gaining synergistic outcomes from the stakeholder pressures of both customers as well as from the regulatory environment. The fourth proposition is that, in resource-constrained environments although the technological arm is strong, the green outcomes maybe much less if the digital systems are not designed sustainably and leadership vision acts as a crucial moderator in hyping up the digital and green logistics adoption. And the final proposition is that the lack of stakeholder and regulatory pressures lead to suppressing of the green motives, making organizational vision and leadership a mediator for promoting the customer buy-in of sustainability, and sustainability would remain a byproduct of digitalization if not proper regulatory frameworks are introduced to the economy. In case of a quantitative study, the above propositions could serve as hypotheses for future testing and revalidated thereof.

In summary, the TOE framework by Tornatzky & Fleischer (1990), was not capable of highlighting the newfound aspects of stakeholder pressure vacuums, cultural dynamics and strategic alignment that was revealed from the study. Therefore, the researcher had to develop a novel twin transition synergy framework which is uniquely relevant to the economies in Global South. However, the TOE framework was used to perform the initial analysis and come up with the key assumptions that were used to guide the overall study and as a result the newfound framework consists of both the novel findings and TOE framework aspects simultaneously. Now let's evaluate how the three research questions were answered extending the theoretical and empirical knowledge and helped the subject study to derive the analytical insights that were used to create the above explained twin transition synergy framework.

5.2 Strategic Relevance of Twin Transition (RQ1)

RQ1. Why is the integration of digital and green logistics practices relevant for firms aiming for sustainability in Sri Lanka?

According to the findings, twin transition in Sri Lanka in relation to the logistics sector holds a great strategic relevance, driven by the external pressures, regulations, competition and reputational concerns. Even though it is not majorly driven by the external market or the regulatory forces of the country right now, all the firms interviewed agreed that via fulfilling the external pressure vacuums in the prevailing market Sri Lankan economy would be able to enhance sustainability at least as a byproduct of digitalization, and hence the twin transition synergy as a result.

Although the TOE framework can capture some of these aspects related to the external environment it is not able to realize how these pressures influence the internal-external alignment and the strategic prioritization of the twin transition synergy in the country. An example for this is that all the four companies demonstrated the preference to be recognized as a socially responsible, innovative entities by pursuing sustainable initiatives rather than just being adhered to it as a regulatory compliance. This phenomenon coincides with the institutional theory by DiMaggio & Powell (1983), confirming that the firms tend to follow leading actors in order to gain validity and legitimacy.

Also, it is evident that the C-level management interviewed, demonstrated a long-term sustainable, strategic thinking displaying their potential as change leaders while the lower/middle management showed lesser concern over the long-term benefits but was concerned more about the short-term cost and operational benefits. This notable contrast found between the top management and the lower management's strategic vision suggests a misalignment between the perspectives within different levels inside the organizations, known by the term intra-organizational divergence (Jarzabkowski, 2008). This is an important

finding of the study that suggests the twin transition needs to be realized within the organizational context, before trying to get aligned with the vast societal and business ecosystem context.

5.3 Synergies Between Digital and Green Logistics (RQ2)

RQ2. How can the integration between digital and green logistics practices enhance sustainable logistics operations in Sri Lankan firms?

As per the findings, the digital and green logistics transitions are not entirely distinct dimension in the Sri Lankan economy but rather synergistic although it is unnoticed most of the time. This synergistic impact of twin logistics is in a relationship of digital complementing green outcomes, and this synergy can be stated as unstructured and uneven. This is due to the under-leveraged and unintentional birth of sustainability rather than as in a strategical formation. Also, the digital tools are primarily focused by the firms due to their cost efficiency and operational benefits which outflowed the dual benefits of optimized energy usage and lesser wastage. Even the firms like Yamaha and EKTC which didn't showcase governed ESG policies or green practices, still managed to obtain the synergistic benefits out of digital tools which they only implemented primarily for cost and operational efficiency.

In summary, in all four firms the synergy was evident with the use of different digital tools. Route optimization tools with optimized fuel consumption, barcode scanning software with reduced warehouse wastage, as well as consolidation dashboards and shipment planning ERP with reduced delivery trips and therefore reduced emissions. But though these synergies are observed they are not measured or mandated and often overlooked by the firms and not formalized into their strategies and KPIs due to lack of external pressures. Because of that, it had created a void or a misalignment with the internal-external actors of the business environments as showcased in Figure 7 (Twin Transition Synergy Framework). Therefore, by doing this study the researcher identified the informal synergy of twin logistics in the Sri Lankan economy and suggest that the government should take initiatives to institutionalize the green efforts through strategic alignment of sustainable transition along with the digital transition to create the required regulatory pressure in the economy to drive towards an overall sustainability.

5.4 How to Cope with Challenges and Utilize Opportunities (RQ3)

RQ3. How to cope with the challenges and how to utilize opportunities, that the firms face when implementing digital and green logistics to attain sustainable operations?

There are four main barriers that have been identified by the researcher that leads to the unstructured synergy in twin integration. But when dealt with correctly, these challenges tend

to create great opportunities for the symmetrical transition of twin logistics in the Sri Lankan economy. Let's evaluate these four factors and see why they were chosen to be included in the novel twin transition synergy framework by the researcher.

5.4.1 Technological Enablers and Barriers

Across the cases it was implied that the difference in digital maturity plays a great part in enabling the twin transition to proceed on to next level. Cases like Yamaha and EKTC showcased a technological stagnant phase with their perception and skill gaps even with the availability of necessary technological tools proving the concept by Oliveira & Martins (2011), that the smaller firms often struggle with lack of confidence in their potential to integrate highly advanced technologies. On the other hand, the cases MAC and LAUGFS demonstrated a good technological adoption with an outlook towards AI and automation with high level of confidence towards a future of digitalization within their firms. Therefore, it is evident that 'Technology' is indeed an enabler for green transition, and it does not hinder the sustainability path of the firms in any way.

5.4.1 Strategic Alignment of Internal and External Environments

This layer showcases the gap between inter-organizational and intra-organizational factors that demotivates the twin transition. The government's lethargic actions towards sustainability and firms' less interests in adhering with them, on top of no regulatory background makes the twin transition even more difficult for the firms to achieve. Also, the gap between organizational top management's ESG alignment contrasting with the middle management's cost, efficiency and competition focus and the identified gap of sustainability motivation between the top and lower management levels in terms of moral responsibility and operational efficiency, plays a huge role in the misalignment of twin transition in Sri Lanka.

As mentioned above, the misalignment between both intra-organizational and inter-organizational environments is evident throughout the twin logistics transition in Sri Lanka leading to an imbalance in the twin logistics adoption. This asymmetric strategic alignment often shows higher weight on digitality and lesser weight on sustainability, which is only avoidable by shaping the customer expectations and leadership visions on sustainability in the firm level.

5.4.2 Cultural Mindset

This layer identifies the organizational resistance, illiteracy, skill shortages and moral responsibility, factors which are of utmost importance to the SMEs like Yamaha and EKTC, as inhibitors of the readiness towards transformation. It also identifies national culture and societal norms to be a blockage to the novel ideas and sustainability mindset development.

Firms which promote culture of innovation and continuous learning like MAC and LAUGFS showcased high adaptability towards transformation, whereas cases like EKTC and Yamaha often with uncertainty and fear of layoff, created a critical barrier for employees to think out of the box and made them digitally ambisinistrous and naturally resistive to change (Müller et al., 2024).

The above said barrier doesn't sufficiently get discussed inside the organizational context of TOE framework by Tornatzky and Fleischer (1990), in terms of cultural mindsets and skill gaps and therefor in subject thesis, the researcher suggests this finding should be treated as a distinct paradigm. Even though posed as a challenge, it was also found that if these gaps can be filled using internal training and onboarding programs as done in LAUGFS and MAC, they can act as drivers which can turn the tide, in building the employee motivation and improve digital readiness, leading towards a sustainable economy.

5.4.3 Regulatory and Customer Pressure

This layer identifies the low regulatory and customer pressure as a demotivator for the transformation towards twin logistics. The study showcased high pressure on sustainability from international customers rather than from the general local customer. Yamaha as a subsidiary of its oversea principal, had the same pressure to adhere with the sustainability principles but still, amidst the lack of pressure from its local market customers they were not concerned hugely by the oversea pressures. This showcased how the unregulated external environments could lead for unsustainable logistics practices that ignores the twin logistics' synergy in developing economies.

The other key observation from the analysis is the regulatory pressure vacuum inside the business ecosystems. This can be interpreted as a misalignment between the internal and external environments that inauthentically drive the direction of twin transition synergies in the Sri Lankan economy. Most organizations will adopt sustainability certifications only if there's a regulatory requirement and if otherwise, they will not be tempted to acquire the same for the sake of the environment or the sustainability of economy.

This could also be used as an opportunity for the government to bring out a novel regulatory framework promoting, incentivizing and tax-cutting green products and efforts, as suggested by the Finance managers of EKTC and MAC, to fill both the regulatory pressure vacuum and motivate consumers' buy-in on sustainability aspects into their day-to-day shopping behaviours.

6. CONCLUSIONS

The integration of digital transition and sustainability transition in relation to logistics, which is referred to as twin transition in logistics, presents a transformative opportunity for firms seeking to enhance efficiency, sustainability and competitiveness in terms of their day-to-day operations. This study explores the synergies between these two paradigms by leveraging insights from established theories in supply chain management and empirical data collected through a qualitative research method.

This chapter aims to provide a summary of the study, fulfilling the research objectives in terms of the information found through the analysis of key findings obtained from data collected. It gives a holistic view of the study while ensuring the coherence with the Technology-Organization-Environment (TOE) framework by Tornatzky & Fleischer (1990) and outlines the theoretical and practical contributions of the study with the invention of the novel twin transition synergy framework. It also highlights the limitation and future research directions that could be derived for the betterment of future of academia.

6.1 Theoretical Engagement

The TOE framework by Tornatzky and Fleischer, 1990, is an effective framework that has been developed to identify the barriers and enablers that the firms face when adopting novel innovations. But as this theory is used slightly differently in this thesis, which is to identify the strategic relevance, synergistic effect and barriers and enablers of twin logistics transition, the researcher had to innovate a more dynamic and synergistic model out of the existing TOE framework in order to answer the research questions more accurately.

Under the original TOE framework, the researcher has identified the evidence for technological context in par with the organization's digital capabilities and infrastructure, for organizational context in par with the organizational leadership, transformational readiness and human skills and mindsets and, environmental context in association with the market and customer demand, partnerships, competition and regulatory environment in the current market of the country. The study has also shown that digital technologies offer a versatile pathway for the green outcomes in a context that the green benefits are not strategically prioritised but obtained only as a byproduct. Also, the elements like, moral and mindset-related approach and governance-related approach which doesn't reciprocate with the traditional TOE framework urges the need for the expansion of subject framework in order to better illustrate the objectives of this thesis.

Therefore, the main theoretical contribution of this study if the extension of TOE framework by Tornatzky & Fleischer (1990) in relation to the logistics field to showcase the factors

affecting twin transition synergy in the developing economy context of the Global South. The proposed model captures the internal-external strategic alignment, stakeholder pressure and cultural mindset elements acting central in the sustainable economy transition in the logistics field of Sri Lanka. It also fills a gap in academia in terms of the logistics and sustainability transitions in the context of underrepresented economies in Global South.

Theoretical Interpretations of the TOE Framework (Tornatzky & Fleischer, 1990)

Now let's evaluate the theoretical interpretation that the study could showcase under the main guiding theory of TOE framework by Tornatzky & Fleischer (1990). As per the theory suggests under organizational context of the TOE framework, the study shows that the training investment is a huge enabler for digital adoption and the quality of the implementation is affected by the leadership buy-in. Therefore training, leadership and change management play a key role in twin logistics adoption. The digital systems and tools intersect with the technological context of the TOE framework where AI and ERP has been the main focus of the firms. The study intersects the environmental context with the green initiatives such as paperless and low waste policies that are implemented in the firms whereas in the organizational context, the green policies and practices are found to be shaped mainly by the cost and customer pressures.

Emerging Propositions through TOE Lens (Tornatzky & Fleischer, 1990)

Below are the emerging propositions that were evident through the analysis of findings via TOE framework as a concise summary. Organizations with structured onboarding processes, with digital tendency showcase higher readiness to digitalization. Leadership involvement mediates the training and adoption barriers of technology and its effectiveness internally. Regional areas and lower-resources firms need infrastructure facilities more than they need training and training without infrastructure is less effective. This gap hinders the digital-green synergy in those firms and areas. Customer drive on sustainability is a major motivator than the regulatory pressure. In fact, less regulatory pressure and low customer expectation leads to less readiness in Sri Lankan firms towards the twin logistics transformation.

Summary of Findings

The newfound 'twin transition synergy' framework extends the TOE framework by Tornatzky & Fleischer (1990), by combining the technological and innovative arm of the TOE framework with strategic alignment of internal-external environments, cultural mindsets and readiness, and external regulatory and consumer pressures. It confirms that the digital transformation and innovations as a crucial precursor in green maturity in a developing and resource-constrained economy. The new framework combines with the TOE framework, making it

unique and exclusive for analysing the intensity of twin transition synergy, valid for economies in Global South.

The study has exclusively found that green logistical practices remain under-utilized and prioritized in Sri Lanka under the demotivation of consumer and regulatory pressure vacuum. The main driver for green logistics practices in the country right now is the digital practices that unintentionally support green outcomes in certain ways. If consumer and regulatory pressure vacuum could be fulfilled, it might lead to the change of cultural mindsets and consequently, to change the misalignments between the internal and external environments in the organizational context of Sri Lanka. With the leverage of strong technological focus in the country, then only Sri Lanka will lead to full scale twin logistics transition synergy that could benefit the economy in the country in coming 5-10 years.

6.2 Practical Implications of the Framework

Although the above framework suggests that the digitally prioritised, green designed practices would be most suitable for developing economies, it will pose practical challenges to finance such initiatives with the current economic conditions. Also, the digital and green capacity of the country should be built more strongly to achieve the required level of synergy in the twin logistics integration by upscaling digital literacy and ESG leadership within organizations. The government also has a huge role in adhering immediately with these reforms and to introduce some kind of motivation to the general public through regulatory frameworks, incentives, tax-cuts or cashbacks to help the firms accelerate the integration and take to the next steps in transformation of economy. Though it might seem costly and unworthy at the moment with low demand, a nationwide platform for green certifications and sustainability monitoring is a must to initiate now itself, to garner long-term outcomes and to regulate the current detrimental practices in market.

The study suggests several implications to be minded by the policymakers and partitioners such as the importance of leveraging on digital tools with operational gains and then gradually expanding into the sustainability aspects, making the transition efforts much more bearable especially in financially constraint economies. It should be done methodically while giving the required trainings and motivations alongside monitoring and reviewing progress. The policymakers should also consider incentivising and tax-cutting on green initiatives in order to motivate the consumers and provide more digital infrastructure and ESG compliance benefits as a regulatory push. Various sectors like financial, government and tech can be encouraged to build up networks supporting the twin transition smoother and more supported through joint platforms, capacity-building trainings and knowledge-sharing conferences to promote sustainable logistics practices for the future.

6.3 Answer to the Research Problem & Questions

The research was mapped out around the underexplored topic of twin transition synergies in the developing economic contexts in order to provide a comprehensive understanding of how these dug out synergies could be integrated formally and effectively to other developing economies in a practical manner. While the existing literature provides a good foundation for this topic separately for each digital and green aspect, the researcher finds the explorations of synergies is a bit fragmented and lacking, and not very generalizable with the developing economic conditions. Therefore, by performing this study the researcher reconfirmed the integration of twin logistics practices benefits the developing economies with both environmental and operational efficiency gains which are of utmost importance when transitioning towards a sustainable economy.

The findings of the research were that digital tools serve as an enabler for green outcomes in developing economies and almost always as an unintentional benefit than strategically planned. The firms face a lot of barriers in terms of organizational cultures, resistive mindsets which lack skills, under-trained or just being resistive to change by nature, but also exhibits thorough leadership commitment and visions that could outperform the said barriers if given the favourable conditions. Also, the study finds that the regulatory vacuum, lack of government support and incentives as well as the lack of consumer demand further downgrades the requirement of green logistics. On the other hand, it upgrades the strategical misalignment of the firms with its external environment and even with its own internal environment downplaying the twin transition capabilities of organizations by a great degree. Now let's evaluate further how each of the three research questions were answered by the overall finding of this study.

1. Why is the integration of digital and green logistics practices relevant for firms aiming for sustainability in Sri Lanka?

In answer to the first research question the study found out that all the firms perceive digital logistics as a highly strategic tool with great cost and efficiency gains whereas green logistics is perceived as secondary byproduct often driven with moral and social responsibility and important only if the consumer or the regulation demands it. Although the strategic relevance is clearly seen it is unstructured and asymmetric with an upper hand to the digital logistics. Firms like LAUGFS and MAC, with international exposure and C-level sustainability visions clearly leads the transformation whereas SMEs like EKTC and Yamaha lags behind due to cost, infrastructure, low customer demand and visionary constraints.

2. How can the integration between digital and green logistics practices enhance sustainable logistics operations in Sri Lankan firms?

As stated above, the prominent but unstructured and asymmetric twin transition synergy is also not monitored or backed by the organizations with required level of effort. It is evident that the ERP systems, IoT, WMS, MIS, route optimization and shipment planning software, as well as AI and automation visions, give out the benefits of reduced waste, emissions and energy for the firms. But yet, the explicit strategies, governance and KPI driven monitoring for maximization of the synergistic benefits are not yet touched by the Sri Lankan firms in terms of optimizing the twin transition synergies at a sufficient level.

3. How to cope with the challenges and how to utilize opportunities, that the firms face when implementing digital and green logistics to attain sustainable operations?

In answering the final question, the study found that the main barriers for twin transition to be digital illiteracy, lack of training, insufficient regulatory push and consumer demand as well as infrastructure gaps of main scale. But also, the same challenges were found to be turned around when prioritization is given to proper training and onboarding under great leaderships, leading to skill development and resistive mindset change, with the help of sufficient regulatory push and consumer demand alongside the partnerships with banking, government and tech sector collaborations. The twin transition synergy framework, which was proposed by the researcher, emphasizes these factors while showcasing the importance of strategically aligning the internal readiness with external support inside business ecosystems precisely.

6.4 Limitations

In the modern world, understanding the twin transition synergies in relation to logistics is crucial as firms often face regulatory, market and stakeholder pressures to adopt sustainable and technology-driven logistics solutions. This research provided actionable insights for businesses, policymakers, and researchers on how to effectively integrate digital and green logistics for a more resilient and error-proof supply chain in the context of developing economies of Global South. Below are the main limitations and future research directions that was derived from the study in a concise manner.

The study showcased findings from only four firms relating to logistics in Sri Lanka and limited number of interviews and follow-up interviews, leaving more room for better findings in the future with large-scale surveyed validations. Therefore, the future researchers could perform quantitative validation for the proposed twin transition synergy framework and find out any missing factors thereof. They could also perform long-term case studies tracking the impact of twin transition over certain periods of time and inspect whether the framework is still valid for other sectors like, manufacturing, retail or public sector transport and logistics in Sri Lanka. Therefore, the reader should be cautious when applying these interpretations in

different economic settings and keep in mind that it lies closely with the unique conditions of economies in the Global South.

6.5 Future Research Directions

Although with the above contributions of the novel framework, it is noteworthy that the findings might not be comparative with economies of strong governance and those with other aspects unique to themselves. Also, the researcher could have identified even more insights if this topic was further investigated over a longer period of time specially on the informal networks and inter-organizational partnerships and collaborations that wasn't focused on subject research in depth. The researcher sees the opportunity for this framework to be validated across continents and to see how the findings vary with Global South and to investigate to which degree the consumer demand and external pressures shape the twin logistics transition synergy in Global North. Also, the researcher became curious on the motivational levels of the digital-green integration between the private sector logistics of the country against the public sector and thinks further studies could help improve these gaps to some extent in the future.

Overall, this research has birthed a comprehensive, novel model under the guidance of TOE framework by Tornatzky & Fleischer (1990), which could be used to evaluate the current situations of twin logistics transition in developing economies. By bridging the gaps between internal and external and inter-organizational environments, cultural readiness and mindsets, regulatory and consumer demand vacuums, these economies will stand a chance to attain the twin logistics transition synergy in the near future under the leverage of digitalization.

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Appendix 1. Email to Contact Informants

Dear Sir/Madam,

Thank you once again for agreeing to participate in my thesis interview. As part of my master's thesis at Hanken School of Economics, I'm exploring how logistics and supply chain-focused firms in Sri Lanka are integrating digital and green logistics, commonly referred to as 'twin logistics', to support sustainable and circular economic development. The study aims to understand the synergies, challenges, and enabling factors behind this integration from an organizational, technological and environmental perspective.

Your insights as an industry expert will contribute significantly to building practical and academic understanding in this area. To help you prepare, I've attached the interview guide below. The interview will follow a semi-structured format, allowing room for open discussion. And some questions that I have included may be revised or added according to final revisions of the questionnaire. Please feel free to reflect on your experiences and share any examples that you believe are relevant.

Please note that all information shared during the interview was collected, handled, and stored in accordance with the ethical guidelines of Hanken School of Economics. A formal consent form will be sent to you in due time prior to the interview to ensure your understanding and to obtain the necessary permissions for your participation. Looking forward to our conversation!

Appendix 2. Consent Form

Informed consent to participate in the research

[Integrating Twin Logistics for a Sustainable Economy: Exploring the Synergies of Digital and Green Logistics in Sri Lanka]

I have been requested to participate in the research identified above. I have received sufficient information about the research and processing of my personal data in the Privacy notice in writing (in print or electronic form) and have had the opportunity to ask questions and have my questions answered.

I understand that the participation in the research is voluntary. I am aware that I have the right to refuse to participate and the right to withdraw from the research permanently or for a temporary period at any time and without giving a reason. Withdrawal from the research will not result in any negative consequences to me. The information collected from or about me up to the point of my withdrawal may still be used in the research.

I agree that the interview with me will be voice recorded, for the research's purpose. The recordings will be processed in such a way that I cannot be identified in them.

I understand that the personal data collected during the research will remain confidential and protected in accordance with relevant data protection legislations and research integrity. The information I have provided during the research can be used as anonymized statements in the publications. My identity as an individual research participant will not be disclosed in a scientific publication or any other research results to be published.

I agree that I can be contacted at a later stage for further study or follow-up study.

I hereby give my voluntary consent to participate in this research.

_____

Name of the Interviewee

(Consent can also be given electronically, for example, by email.)

_____

Place and date

_____

[R.M.N.S. Rathnayake, +358 417407009]

Hanken School of Economics

Appendix 3. Interview Guide

3.1 Main Interview Topics and Questions

Demographic Data

1. What is your designation?
   - Could you briefly describe your main responsibilities?
   - How long have you been in this position?

2. How much experience do you have in/related to logistics field?
   - How has your role evolved over the years?
   - What major changes have you observed in the logistics field?

A. Technological Context

3. What are the digital technologies that are currently used in your logistics operations?
   - Which of these technologies do you find most critical?
   - Have you implemented any new technologies recently?

4. How do those technologies contribute to sustainability and green logistics goals?
   - Can you share a specific example where digital tech helped reduce waste?
   - How do you track environmental improvements?

5. What challenges have you faced when implementing these digital logistics tools?
   - How have you overcome some of these challenges?
   - Do you receive any external support to handle these issues?

B. Organizational Context

6. Do you have any sustainability and green goals related to your logistics operations?
   - Who sets these goals in your organization?
   - Are there any KPIs used to measure them?

7. Do you have any technological goals related to logistics operations?
   - How do you prioritize technological investments?
   - Are these goals aligned with your overall strategy?

8. How would you describe your organization’s readiness in adopting green and digital logistics practices?

- What would improve your organization's readiness?
- Is there a specific department leading the transformation?

9. What kind of support do you get from the organization for implementing green/digital initiatives?
   - What kind of training would be most helpful?
   - Is there recognition for sustainability achievements?

10. Are there internal barriers to sustainability/digital transformation?
    - How do you address these internal barriers?
    - Are there forums or meetings to discuss these changes?

C. Environmental Context

11. How do regulations, standards or customer expectations affect your strategy?
    - Which regulations have had the most impact?
    - Are your customers asking for green certifications?

12. Do you have partnerships to promote sustainable logistics?
    - How are these partnerships formed?
    - Have they been beneficial?

13. How do markets and infrastructure affect twin logistics transitions?
    - Are there regional differences in logistics readiness?
    - What improvements would help most?

D. Synergies and Strategic Outlook

14. Do you think digital and green logistics complement or disparage each other?
    - Can you give an example from your operation?
    - Which integration was most successful?

15. How do they complement each other in your other operations?
    - Have you seen measurable results from this synergy?
    - What other areas could benefit from integration?

16. What are the key benefits and outcomes expected from integration?
    - Which benefit is most important to your business?
    - Have any unexpected benefits emerged?

17. What are the key challenges and threats from integration?
    - How do you plan to mitigate these threats?
    - Are there ongoing discussions to address these challenges?

18. How are future opportunities and threats for twin logistics in Sri Lanka?
    - What trends do you think will shape the future?
    - How should firms prepare for them?

19. Any Final Thoughts?

3.2 Follow-Up Interview Topics and Questions

Purpose: To explore practical and forward-thinking ideas in digital and green logistics, based on insights from earlier interviews. This guide focuses on realistic improvements, future opportunities, and overcoming common barriers.

A. Green Logistics

1. Do you think small sustainability actions like reducing paper wastage or food waste could truly create much change in future?
2. Have you seen simple, low-cost changes (like in packaging or choosing suppliers) that could really help the environment but are often ignored due to its cost?

B. Digital Logistics

3. How do you envision tools like ERP or SAP could evolve in the future to support both cost efficiency and sustainability?
4. Which digital tool or method do you think could make a big difference if implemented in large scale, and why hasn't it caught on yet in Sri Lanka?

C. Synergy & Twin Transition

5. Imagine if green and digital logistics were fully integrated in Sri Lanka, what would that look like to you?
6. Is there a future idea combining tech and sustainability (like Pickme app showing emissions instead of just price), that you'd love to test or see implemented in future?

D. Organizational & TOE Factors

7. If you're responsible for implementing a digital/green logistics policy in your firm, how would you personally convince both managers and staff to support it?
8. What bold idea should Sri Lanka try soon, even if it seems too advanced or costly right now, so that we won't fall behind others in terms of tech or sustainability in future?