Conceptual Framework of Circular Economy Adoption for Green Logistics and Sustainable Supply Chain

Thanh Van Luu, Ph.D.

Doctoral Thesis Summary

Tomas Bata University in Zlín

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Faculty of Management and Economics

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Conceptual Framework of Circular Economy Adoption for Green Logistics and Sustainable Supply Chain

Koncepční rámec cirkulární ekonomiky pro zelenou logistiku a udržitelný dodavatelský řetězec

Author: **Thanh Van Luu, Ph.D.**

Degree Program P0413D050013 Economics and Management

Supervisor: doc. Ing. Roman Bobák, Ph.D.

Consultant: prof. Ing. Felicita Chromjaková, PhD.

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ABSTRACT

There are many studies on circular economy adoption for logistics and supply chains that ensure economic, environmental, and social sustainability. The big gap is a lack of understanding about a conceptual framework development, validation, and optimization for the circular economy adoption for green logistics and sustainable supply chain under a high-technology context.

The main objective of the study is to investigate a conceptual framework of Circular Economy Adoption for Green Logistics and Sustainable supply chains and its hypotheses to fulfil the above-mentioned gap, as well as concerning its practical aspects. Data were collected from the authors' network of universities, companies, and government sectors. Partial Least Squares Structural Equation Modelling is used to validate the proposed framework and its hypotheses. Other optimization approaches such as Combinatorial Optimization and Muti-Criteria Decision Making are employed for optimizing the real case operations in light of green and sustainable thinking and practices.

The key findings of the research are:

a) the confirmation of a dominant direct relationship of high-tech application with the circular economy adoption for green logistics and sustainable supply chain that benefits Vietnam stakeholders to motivate strategic changes.

b) reflection on the status quo of strategic awareness and operations in Vietnam, such as the promulgation and implementation of policies in government sectors, as well as the development of modern logistics and supply chain programs in universities.

c) The real-world cases inform distribution supply chain network design and operations decisions, encompassing facility layout and location requirements for costs optimization (SME company), warehouse layout improvements for efficient picking and sustainability (ATP case), and enhancing business process management within the context of knowledge-based and circular economies to improve business performance in light of sustainable competitiveness (MVN Group). Green and sustainable practices are intrinsic corporate values in fostering a premium circular economy for contemporary enterprises.

The scope of the study is focused on logistics and supply chains; however, variables for other industries and areas such as manufacturing and agriculture as well as countries require further investigation.

ABSTRAKT

Existuje mnoho studií uplatnitelnosti cirkulární ekonomiky v logistice a řízení dodavatelských řetězců, které zajišťují ekonomickou, environmentální a sociální udržitelnost. Velkou mezerou je nedostatečné porozumění ohledně vývoje, ověřování a optimalizace koncepčního rámce pro přijetí oběhového hospodářství pro zelenou logistiku a udržitelný dodavatelský řetězec v kontextu špičkových technologií.

Hlavním cílem studie je prozkoumat koncepční rámec přijetí oběhového hospodářství pro zelenou logistiku a udržitelné dodavatelské řetězce a jeho hypotézy k naplnění výše uvedené mezery, jakož i jeho praktické aspekty. Sběr dat vychází z autorovy sítě univerzit, společností a institucí vládního sektoru. Pro validaci vymezeného koncepčního rámce a definovaných hypotéz je využita metoda nejmenších čtverců a modelování strukturních rovnic. S ohledem na zelené a udržitelné uvažování a praktiky jsou v práci použité i další optimalizační metody kombinační optimalizace a multikriteriálního rozhodování deklarované na reálných případových studiích.

Klíčovými výstupy realizovaného výzkumu jsou:

a) potvrzení dominantních přímých vazeb high-tech aplikací adaptace cirkulární ekonomiky a udržitelných dodavatelských řetězců pro zelenou logistiku a udržitelný dodavatelský řetězec, které motivují vietnamské stakeholdery ke strategickým změnám.

b) reflexe status-quo o strategickém povědomí a aktivitách ve Vietnamu zaměřených na vyhlášení a implementaci politik ve vládním sektoru a také rozvoj moderních studijních programů logistiky a udržitelného dodavatelského řetězce na univerzitách.

c) případové studie ze světa poukazují na příklady návrhů distribučního dodavatelského řetězce a operativních rozhodnutí, zahrnujících požadavky na rozmístění příležitostí a jejich uspořádání s ohledem na optimalizaci nákladů (SMEs), efektivní vychystávání ze skladů s ohledem na udržitelnost (ATP příklad) a zlepšení řízení obchodních procesů v kontextu znalostně orientované cirkulární ekonomiky v návaznosti na zvýšení výkonnosti a udržitelné konkurenceschopnosti (MVN Group). Zelené a udržitelné praktiky jsou klíčovými firemními hodnotami v podpoře prémiového oběhového hospodářství v stávajících firmách.

Rozsah této studie je zaměřen na logistiku a řízení dodavatelských řetězců, nicméně proměnné pro jiné oblasti a odvětví, např. zemědělství, výroba vyžadují další výzkum.

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1 INTRODUCTION

1.1 Motivation

This section was detailed in the research papers Luu et al (2023), and Luu (2022, 2021a, 2021b). Global logistics is propelled by three driven forces: Economic trends, Technological advancements, and Policy challenges. Hence, this thesis argues that logistics and supply chain is a high-tech industry with three distinct attributes: economics-technology-policy framework, as well as focuses on two independent constructs of its configuration, and collaboration in supply chain networks.

The motivation for this work is based on the existence of an increasing interest in a circular economy (CE) business model on green logistics and sustainable supply chain (GLS) areas that can be applied to Vietnam logistics industry.

1.2 Research statement & gap

The IPBES (Fischer, et al., 2018) reported that "*The health of ecosystems on which we and all other species depend is deteriorating more rapidly than ever. We are eroding the very foundations of our economies, livelihoods, food security, health, and quality of life worldwide*". The circular economy concept is one of the most appropriate approaches to achieving sustainability in the future (Hazen et al., 2020). Humans tried to plan their resources as time, effort, costs, etc., for any necessary activities (Luu, 2022).

The majority of academics have investigated either CEs or high-tech applications (ID4.0) separately (Birkel & Müller, 2021; Morseletto, 2020; Kirchherr, Reike, and Hekkert, 2017), while others examined connections between them in terms of a specific industries and businesses (Agrawal et al., 2022; Rajput & Singh, 2022; Kumar, Rehman Khan et al., 2022; Singh, and Kumar, 2021; Bag and Pretorius, 2020). For example, Shayganmehr et al. (2021) explored the impact of ID4.0 and CEs on sustainable production. Massaro et al. (2021) studied how ID4.0 enables CEs and affects businesses. Rajput & Singh (2019) identified key facilitators linking CE, ID4.0, and supply chains. Kumar et al. (2021) analyzed inhibitors in SC operations due to ID4.0 and CE. Dev et al. (2020) focused on operational excellence in reverse logistics with CE and ID4.0. Agrawal et al. (2022) and Rosa et al. (2020) propose integration of ID4.0 and CEs through literature review (Luu, et al., 2023; Luu, 2021a, 2021b). Obviously, previous studies have focused on production and manufacturing fields; or enablers and barriers analysis; or systematic literature reviews; or theoretical framework development and methodological validation without considering practical concerns, it is difficult for companies to adopt them into their operations. A notable gap exists in comprehending a conceptual framework for the adoption of a circular economy in green logistics and sustainable supply chains within a high-technology context. This study is one of the first attempts to further the development, validation, and optimization of a conceptual framework for CE adoption in GLS transitions and practices.

1.3 Research questions and objectives

1.3.1. Research questions

The research questions are specifically developed below.

RQ1. Do high-tech applications impact CE adoption and GLS?

RQ2. Do government policies influence CE adoption?

RQ3. Do SC collaboration and configurations play a role in a GLS network?

RQ4. How is a CE model adopted for GLS?

1.3.2 Research objectives

Coming from the main aim of the dissertation and to answer the research questions, the thesis forms the following objectives:

RO1. To explore Industry 4.0 technologies, directly and indirectly, impact CE adoption and GLS, respectively.

RO2. To examine the influence of government policies on CE adoption.

RO3. To capture the effects of supply chain collaboration and configurations on GLS network.

RO4. To use PLS-SEM and others for the proposed model validation and optimization.

1.4 Research Design

The study is designed as a mixed approach consisting of three phases (Figure 1). Details of the research methodology are summarized in Table 1, as follows.

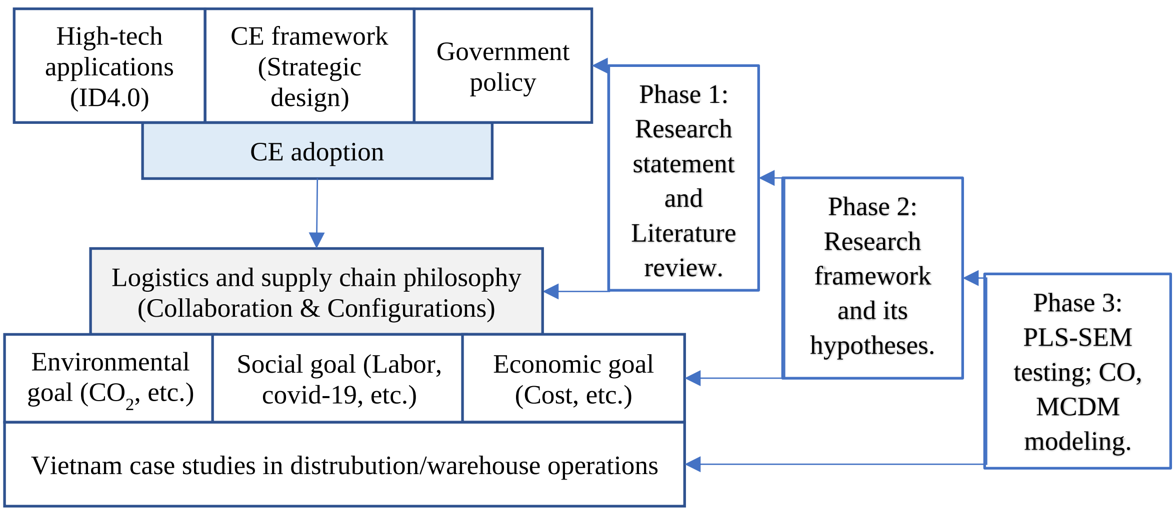

Figure 1: Research conceptual design
Source: own research

Table 1: Research methodology summary

Research approaches	Mixed methods	
	Qualitative study	**Quantitative study**
Methods	- Thematic Analysis	- Survey/Case studies
Research techniques	- Interviews - Documentary review	- Questionnaires & PLS-SEM Model. - MCDM/MILP & CO of TSP/CDA
Object of analysis	- Professors/ lecturers/ civil servants/ managers.	- Employees/students. - Companies in Vietnam industry.
Research data	- 18 key involved persons	- 210 responders (primary data). - 3 companies (secondary data).
Data analysis	- The interviews were recorded and stored in MS Word & Excel.	- SmartPLS/ADANCO software. - IBM ILOG CPLEX software. - LINGO solver.
Research studies	**1. Study 1:** Framework, hypotheses & measurement development. **2. Study 2:** Verification of the 7 constructs & 32 variables.	**3. Study 3:** Framework validation and hypotheses testing. **4. Study 4:** Critical analysis on KCE model of the MVN. **5. Study 5:** MCDM solving for SCND in the SME. **6. Study 6:** CO solving for OPW in the ATP.
Research objectives/results	Satisfied all RQs/ROs of 1, 2, 3, and 4.	

Source: own research

1.5 Summary of three real-world case studies

The three companies in different Vietnam industries are known as SME, MVN, and ATP since its name and other information that would allow for the identification of companies have been made anonymous (Luu & Chromjaková, 2023a, 2023b; Luu, et al., 2023).

The MVN

MVN is the largest dairy company in Vietnam. The research aims to critically analyze the MVN outcomes realized in its business process management and the value chain in the knowledge-based and circular economics context constitutes a key element in ensuring sustainable competitiveness.

The SME

The SME operates in retail distribution. The SME is coping with distribution problems such as high costs of transportation, inventory, and rental; as well as considering more distribution depots and warehouses.

The ATP

ATP, the biggest network provider in Vietnam. The main problems of this case are ineffective warehouse leads to weak performance in order picking operations.

2 LITERATURE REVIEW - CONCEPTS, DEFINITIONS, AND MATERIALS

2.1 Theoretical background

As defined in Figure 2, this thesis employs two primary theoretical perspectives: Policy Feedback theory (Pierson, 1993) and Resource-Based View (RBV) theory (Barney, 1991). The RBV elucidates how organizations attain a competitive advantage through strategic internal resources such as CEs and ID4.0 capabilities. Conversely, external pressure such as government policy (GOP) yields resources and incentives for organizational actors, operating in diverse ways that significantly impact government, enterprises, and communities (Luu, et al., 2023; Harland et al., 2019).

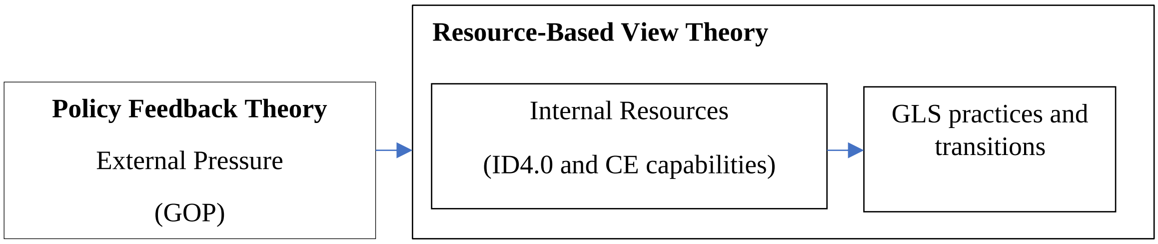

Figure 2: Theoretical framework
Source: adapted from Pierson (1993) and Barney (1991)

2.2 Related material

2.2.1 Industrial engineering & management

Industrial engineering and management are key facilitators of global supply chain and production, which is highly associated with a nation’s economic, industrial, and agricultural development (Luu, 2022). Supply chain management has become one of the primary key success factors in dealing with the increasing complexity of the current business environment (Alkahtani et al., 2018). Those trends aim to create a greener living and reduce the environmental footprint to sustain not only manufacturing but also the global supply chain.

2.2.2 Logistics and supply chain background

Logistics and supply chain management is now one of the key success elements in dealing with the growing complexity of the present business environment in today's global economies merged with ID4.0 (Agrawal et al., 2022; Karaman et al., 2020; Khan & Zhang, 2021). The demand for varied and specialized industrial manufacturing, the accessibility of dispersed global resources, the increased consumer market, and sustainable criteria are all factors in the global logistics and supply chain (Luu, et al., 2023; Luu, 2022).

2.2.3 Distribution supply chain network, and warehouse management

Retailers play a pivotal role in determining the flow and pace of a distribution network, making them indispensable for community sustainability (Alikhani et al., 2019; Fernie and Sparks, 2014). Consequently, there is a growing need to comprehend the intricate process of designing a retail distribution supply chain network (Alikhani et al., 2021; Ning and You, 2018). Therefore, optimizing warehouses is essential for effective logistics and supply chains focusing on five key decision categories: warehouse size and layout design, equipment selection, operational strategy, storage assignment, and routing policies.

2.2.4 Supply chain collaboration and configuration

The research argues that logistics and supply chain is a high-tech industry that influences the adoption of the circular economy, and examines more two independent variables such as supply chain configuration and collaboration within the supply chain network (Luu, 2022; Hussain & Malik, 2020). Govindan & Hasanagic (2018) coined the term ‘industrial chains’ to emphasize the need for collaboration between several supply chains within a wider supply chain network that typically spans many industries (Luu, et al., 2023). The inherent flexibility of existing supply chain structures to introduce and extend the reverse product flow to the larger supply chain network is a key component of supply chain design that allows the transition to GLS (Tura et al., 2019; De Angelis et al., 2018).

2.2.5 Industry 4.0 and circular economy background

The CE idea attracted a lot of attention in the 1960s (Luu, 2022). Since, numerous studies have attempted to define the concept of circular economy (Figge et al., 2023; Kirchherr et al., 2017). This is a trillion-dollar opportunity with great potential for innovation, job creation, and economic growth (WEF, Ellen McArthur Foundation, and McKinsey & Company, 2014). One of the key elements of the development of a CE is the ID4.0 program. It develops an effective and integrated strategic approach that will foster sustainable operations through the utilization of improved knowledge of ID4.0 and CE treated as technological and social advancements.

2.2.6 Knowledge management, and knowledge economy

Knowledge management defined as the intentional and methodical coordination of an organization to generate value through reuse and innovation. Four factors referred to as ‘knowledge enablers’ included *a*) peoples, *b*) processes, *c*) technologies, and *d*) governance (Dalkir, 2017). Several knowledge economy definitions have been proposed and fine-tuned over the years by international organizations (APEC, 2000; World Bank, 1999). Typically, the Organization for

Economic Cooperation and Development (OECD, 2001) stated that it succinctly as an economy based directly on the creation, distribution, and application of knowledge and information.

2.2.7 Sustainability, KE, and CE for GLS

Sustainability has relationship with CE based on the dependence between economic, social, and environmental goals but may undertake by different approaches and methodologies (Luu, 2022; Geissdoerfer et al., 2017).

There are many studies on CE, ID4.0, KE for green logistics and sustainable supply chains (Luu, et al., 2023; Luu, 2022; Patwa et al., 2021; Morseletto, 2020). Moreover, Geissdoerfer et al (2017) provided conceptual clarity by distinguishing the terms and synthesizing the different types of relationships between CE and sustainability. Govindan and Hasanagic (2018) analyzed the drivers, barriers, and practices that influence the implementation of the CE in the context of supply chains. Hazen et al (2020) discussed how supply chain processes can support the successful implementation of CE. Yadav et al (2020) developed a framework to overcome sustainable SCM challenges through ID4.0 and CE-based solution measures. Bag and Pretorius (2020) proposed a research framework by integrating three contemporary concepts of ID4.0, sustainable manufacturing, and CE in the context of supply chain management. Besides, Hussain and Malik (2020) identified the organizational enablers of circular supply chains and its process facilitators of collaboration and configurations, and their relationships with the environmental performance of supply chains. Furthermore, Song et al (2022) found that technological innovation, a crucial notion of knowledge, is a buffer between high-tech applications and green and sustainable transformation. Summarizing the above analysis, it seeks KE prerequisites that enhance the transformative potential of CE adoption in mindset and practices for sustainable development (Zwiers et al., 2020).

2.2.8 Government policy, CE business model and framework

In terms of government policy, adoption of CE is heavily influenced by policies and legislations as noted by Luu et al (2023), Kazancoglu et al (2021), Patwa et al (2021). According to Govindan & Hasanagic (2018), stakeholders' awareness of political policies plays a significant role in driving CE adoption in supply chains. Kazancoglu et al (2021) identified various obstacles to implementation, including legal gaps in CE frameworks, inadequate regulation of circular economy suppliers, and a lack of governmental support for environmentally friendly initiatives (Luu, et al., 2023). Therefore, GOP plays a crucial role in facilitating the transition to a circular economy. In terms of CE framework, many prior studies investigated on that based on the number of strategies used (Luu, 2021a; Patwa et al., 2021; Morseletto, 2020; Jabbour et al., 2019). Such as 3R (i.e., reduce, reuse, and recycle), 4R, 5R, 6R, 10R, ReSOLVE, and especially a modified 3R1O (Vinamilk, 2020), etc. For instance, Morseletto (2020) investigated what targets may facilitate the transition toward a CE, based on the 10R framework, specifically including recover, recycle, repurpose, remanufacture, refurbish, repair, reuse, reduce, rethink, and refuse strategies. In terms of business model, typologies of circular business models (Lüdeke-Freund et al., 2019; Nußholz, 2017; Urbinati et al., 2017; Lewandowski, 2016; Rizos et al., 2016) are examples of conceptual advancements. Centobelli et al (2020) and Ferasso et al (2020) investigated in literature on circular economy and business models are related in the current business and management.

2.3 Related methods – models and algorithms

Mathematical modeling approaches that are usually considered in supply chain problems include linear programming, mixed-integer/ integer linear programming, nonlinear programming, multi-objective programming, fuzzy mathematical programming, stochastic programming, heuristic/metaheuristic algorithms, and hybrid models in several key research areas as supply chain network design, strategic alliance, logistics management, warehouse management, supply chain contracts, production planning and scheduling. Since combinatorial and multi-objective optimization were introduced, both mathematical programming and heuristic approach were proposed to deal with this kind of problem. Alperen Bal & Badurdeen (2020) presented an MCDM framework for the facility location problem integrating the proposed CE business models. Recently years, Khan et al (2021) investigated the present and emerging trends in the field of sustainable supply chain management that are dominated by MCDM-based research methods (Luu, 2022). According to the NP-hard, an efficient algorithm was suggested based on the genetic meta-heuristic algorithm. Concerning high-tech applications, Kouhizadeh et al (2020) examined how blockchain technology is likely to transform and advance CE realization, while Saberi et al (2019) argued that blockchain technology and smart contracts are critically examined with potential application to supply chain management (Luu, 2022).

3 RESEARCH APPROACHES

3.1 STUDY 1 – Research framework, and hypotheses development

As per the light of real-world cases and previous studies in the Literature Review, the conceptual research framework in Figure 3 is developed, the research focuses on 7 constructs of high-tech applications (ID4.0), government policy, SC collaboration, SC configuration, GLS, CE framework, and CE adoption. This qualitative study aims to use grounded documentary to investigate these 7 constructs and 32 associated indicators for conceptual framework and hypotheses development and its measurement. Based on the conclusions on the relevant hypotheses and associated variables, research questionnaires were drafted, and formulated the scientific conclusions.

Conceptual research framework

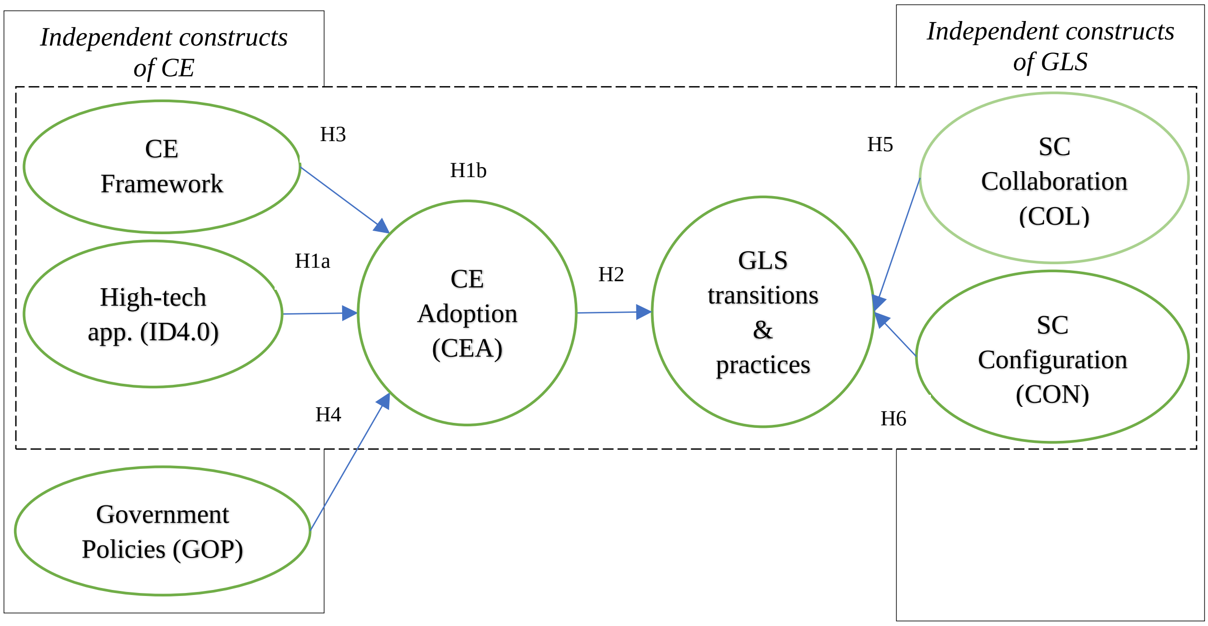

Figure 3: Conceptual framework
Source: own research

Summary of hypotheses

Table 2: Summary of proposed hypotheses

Hypotheses		
H1	*a. Direct effect*	*ID4.0 positively impacts CEA.*
	b. Indirect effect	*CEA mediates the relationship between ID4.0 and GLS.*
H2	*Direct effects*	*CEA positively affects GLS.*
H3		*CEF positively impacts the CEA.*
H4		*GOP positively affects the CEA.*
H5		*SC collaboration (COL) positive impact on GLS networks.*
H6		*SC configuration (CON) positively impact on GLS networks.*

Source: own research

Measurement development

Table 3: Variable measurement

Constructs	Variables Measurement	Source
1. Supply chain Collaboration (COL) measures the role of collaboration within the supply chain network in the adoption of CE.	(COL1) GLS are enabled by collaboration with supply chain partners within and beyond the immediate industrial boundaries. (COL2) GLS is enabled by a supply chain-wide responsibility. (COL3) GLS is enabled by enhanced information sharing and technological support.	Luu, et al., 2023; Hussain & Malik, 2020; Govindan&Hasanagic 2018; De Angelis et al. 2018; Tura et al. 2019; Bressanelli et al. 2018
2. Supply chain Configuration (CON) measures the role of supply chain configuration in the SC networks in the adoption of CE.	(CON1) GLS are enabled by the application of similar operational and logistical practices. (CON2) GLS are enabled by supply chain restructuring to include processes for end-of-life returns. (CON3) GLS is enabled by a greater supply chain structural flexibility that breaks geographical barriers.	Luu, et al., 2023; Hussain & Malik, 2020; Ritzen and Sandstrom 2017; Bressanelli et al. 2018; De Angelis et al. 2018;
3. Green Logistics and Sustainable Supply Chain (GLS) measure representing the effect of the adoption of circular economy on the operations of GLS	(GLS1) The operations of the GLS in compliance with the applicable environmental laws and regulations. (GLS2) The operations of the GLS in reducing energy consumption. (GLS3) The operations of the GLS in reducing the usage of hazardous/ toxic material. (GLS4) The operations of the GLS in enhancing green information technology and communication. (GLS5) The operations of the GLS in enhancing green transportation. (GLS6) The operations of the GLS in enhancing green manufacturing. (GLS7) The operations of the GLS in enhancing green storage and packaging. (GLS8) The operations of the GLS in enhancing green procurement.	Luu, et al., 2023; Hussain & Malik, 2020; Torasa & Mekhum, 2020; Mardani et al., 2020

	(GLS9) The operations of the GLS in enhancing the reverse logistics and renewable material.	
4. Circular Economy Adoption (CEA) measures the understanding and attitude of organizational actors towards CE for GLS transitions.	(CEA1) Understanding of circular economy insights. (CEA2) Sustainability awareness. (CEA3) Awareness of CE's potential for economic performance such as revenue gains and cost saving. (CEA4) Awareness of CE's potential for environmental performance such as reduction of CO2 emission and hazardous materials. (CEA5) Awareness of CE's potential for social performance such as reduction in the unemployment rate and covid-19.	Luu, et al., 2023; Hussain & Malik, 2020; Hazen et al., 2020; Geissdoerfer et al., 2017; Govindan & Hasanagic, 2018; Feizollahi et al., 2021
5. Circular Economy Frameworks (CEF) measure the understanding and practices of CE strategic designs.	(CEF1) Design for 'systems change' when considering any circular design strategy such as the framework of various Rs strategies. (CEF2) Design follows the basic principles. (CEF3) Design by systematic thinking for optimization. (CEF4) Design with different participants in the value chain. (CEF5) Design with 'hands-on' experiences.	Luu, et al., 2023; Macarthur, 2020; Moreno et al., 2016; Lewandowski, 2016; Kirchherr et al., 2017; Patwa et al., 2021; Morseletto, 2020
6. High-tech application measures the awareness and level of industry 4.0 technologies (ID4.0) in the organization.	(ID401) High-tech application is one of the fundamental values in the organization. (ID402) Level of modern systems applied in the operations. (ID403) Level of model and algorithms applied in the systems.	Jabbour et al., 2019; Dubey et al., 2019; Manavalan and Jayakrishna, 2019; Saberi et al., 2019; Bag and Pretorius, 2020; Del Giudice et al., 2020
7. Government policies (GOP).	(GOP1) Appropriate level of legislation, regulation, and standards development.	Luu, et al., 2023; Kazancoglu et al., 2021;

	(GOP2) Government policies promote capacity building for GLS. (GOP3) Plan of education and training to support and facilitate thinking. (GOP4) Urban planning: construction of synchronous infrastructure.	Patwa et al., 2021

Source: own processing

3.2 STUDY 2 – The proposed model verification

According to Saunders et al (2009), researchers should conduct semi-structured and in-depth interviews to compare data from published studies with principles guiding the research herein and real-world circumstances (Luu, et al., 2023). By understanding the adoption CE in GLS, it becomes possible to assess appropriate variables and constructs in the conceptual model as well as finalize questionnaires for data collection in a subsequent quantitative study. The study goal is to verify the assumptions of CE and green logistics on 7 constructs and 32 variables that are relevant to the model proposal to finalize questionnaires for data collection in a subsequent quantitative study.

Table 4 illustrates that a minimum of 78% of the interviewees concurred with the constructs and their associated variables greater than the threshold of 75%. With agreement rates ranging from 78% to 100%, all of them are guaranteed.

Table 4: Interview results on agreeing responses

Const.	**Indicator**	**Agreeing responses**				**Total (%)**
		Professor (5)	**Lecturer (4)**	**Manager (5)**	**Servant (4)**	
1. ID40	1. ID401	5	4	5	3	94%
	2. ID402	5	4	5	4	100%
	3. ID403	5	4	5	3	94%
2. CEA	4. CEA1	4	4	5	3	89%
	5. CEA2	5	4	5	4	100%
	6. CEA3	4	4	4	3	83%
	7. CEA4	5	4	4	4	94%
	8. CEA5	5	4	5	4	100%
3. CEF	9. CEF1	5	4	5	4	100%
	10. CEF2	5	4	4	3	89%

	11. CEF3	4	3	4	3	78%
	12. CEF4	5	3	5	4	94%
	13. CEF5	5	4	5	4	100%
4. GOP	14. GOP1	5	3	4	4	89%
	15. GOP2	5	4	5	3	94%
	16. GOP3	5	3	5	4	94%
	17. GOP4	4	4	4	3	83%
5. GLS	18. GLS1	5	4	4	3	89%
	19. GLS2	5	3	5	4	94%
	20. GLS3	5	4	3	3	83%
	21. GLS4	5	3	5	3	89%
	22. GLS5	5	4	5	4	100%
	23. GLS6	5	4	4	4	94%
	24. GLS7	4	4	5	4	94%
	25. GLS8	5	3	4	4	89%
	26. GLS9	5	4	5	4	100%
6. COL	27. COL1	5	4	5	4	100%
	28. COL2	5	4	5	4	100%
	29. COL3	5	4	5	3	94%
7. CON	30. CON1	5	4	5	4	100%
	31. CON2	5	4	5	3	94%
	32. CON3	5	4	4	4	94%

Source: own research

3.3 STUDY 3 – Framework validation and hypotheses testing

3.3.1 Results for the measurement model

This study was detailed in the research paper Luu et al (2023). According to Table 5, the outer loading values of 32 observed variables are in the range of 0.8147 (CEA3) to 0.9407 (GOP3), exceeding the threshold of 0.7 indicates thus that the reliability of the indicators is satisfied (Hair et al., 2017; 2014). All values of the construct reliabilities measured by Dijkstra-Henseler's rho (ρA), Jöreskog's rho (ρc), and Cronbach's alpha (α) are greater than the 0.7 thresholds. Therefore, all model items are related to their respective constructs in a meaningful and satisfactory manner (Hair et al., 2019; Henseler, et al., 2009). The AVE of all constructs is higher than the threshold of 0.5, this level or higher indicates that the construct explains an average of 50% or more of the variance of its indicators, so the convergent validities of the model are guaranteed (Hair et al., 2019; 2017).

Table 5: Summary of the measurement model

Factors	Indicators	Outer loading	Construct Reliability			Convergent Validity
			Dijkstra-Henseler's rho (ρA)	Jöreskog's rho (ρc)	Cronbach's alpha	AVE
COL	COL1	0.9183	0.9101	0.9415	0.9069	0.8428
	COL2	0.9183				
	COL3	0.9175				
CON	CON1	0.9057	0.8775	0.9209	0.8715	0.7952
	CON2	0.8822				
	CON3	0.8872				
GLS	GLS1	0.8761	0.9683	0.9722	0.9678	0.7952
	GLS2	0.9043				
	GLS3	0.8621				
	GLS4	0.8933				
	GLS5	0.9057				
	GLS6	0.8919				
	GLS7	0.8814				
	GLS8	0.8982				
	GLS9	0.9117				
CEA	CEA1	0.8233	0.9164	0.9374	0.9160	0.7502
	CEA2	0.9088				
	CEA3	0.8147				
	CEA4	0.8699				
	CEA5	0.9093				
CEF	CEF1	0.9182	0.9587	0.9580	0.9457	0.8204
	CEF2	0.8913				
	CEF3	0.8974				
	CEF4	0.9065				
	CEF5	0.9151				
ID4.0	ID4.01	0.8982	0.8882	0.9289	0.8854	0.8134
	ID4.02	0.9077				
	ID4.03	0.8997				
GOP	GOP1	0.9232	0.9453	0.9585	0.9423	0.8526
	GOP2	0.9335				
	GOP3	0.9407				
	GOP4	0.8954				

Source: own processing

Table 6: Discriminant validity

a. HTMT

Factors	COL	CON	GLS	CEA	CEF	ID4.0	GOP
COL							
CON	0.587						
GLS	0.539	0.554					
CEA	0.420	0.460	0.425				
CEF	0.358	0.360	0.294	0.433			
ID4.0	0.436	0.528	0.494	0.762	0.471		
GOP	0.416	0.400	0.420	0.534	0.429	0.715	

b. B_HTMT

Factors	COL	CON	GLS	CEA	CEF	ID4.0	GOP
COL							
CON	0.691						
GLS	0.637	0.651					
CEA	0.542	0.572	0.538				
CEF	0.470	0.477	0.413	0.533			
ID4.0	0.555	0.634	0.612	0.846	0.576		
GOP	0.539	0.523	0.537	0.635	0.535	0.804	

95% bootstrap quantiles

Source: own processing from ADANCO (Luu, et al., 2023)

Table 6*a* shows that HTMT values less than the threshold of 0.85 indicate that there is a valid discriminant between the constructs (Luu, et al., 2023; Hair et al., 2017). In addition to examining the size of the HTMT values, the research uses a bootstrapping procedure to determine whether the HTMT value is statistically significantly lower than 1, and it is done (see Table 6*b*).

3.3.2 Results for the structural model and hypotheses testing.

As in Table 7*a*, with the R^2 values of 0.36 and 0.49, the GLS and CEA constructs, respectively have medium effects based on the thresholds of Hair et al (2019, 2017).

Table 7: Effects and predictive relevance testing

a. Coefficients of R^2

Factors	Coefficient of determination (R^2)	Adjusted R^2
GLS	0.36	0.35
CEA	0.49	0.48

b. Construct cross-validated redundancy, Q^2

Factors	SSO	SSE	Q² (=1-SSE/SSO)
GLS	1890.000	1356.392	0.28
CEA	1050.000	671.988	0.36

Source: own processing from ADANCO and SmartPLS (Luu, et al., 2023)

Additionally, the endogenous constructs of GLS and CEA have Q^2 values of 0.28 and 0.36, respectively, greater than the threshold of 0.25 indicating the medium predictive relevance of the path model for these endogenous constructs (Table 7*b*) (Luu, et al., 2023). Table 8 shows that the SRMR of the research model is only 0.048 and 0.058 in the saturated and estimated models, respectively, indicating the goodness of model fit (Luu, et al., 2023; Hu & Bentler, 1998).

Table 8: SRMR

Saturated model	**Value**	**HI95**	**HI99**		**Estimated model**	**Value**	**HI95**	**HI99**
SRMR	0.048	0.043	0.047		SRMR	0.058	0.053	0.058

Source: own processing from ADANCO (Luu, et al., 2023)

As in Table 9, industry 4.0 with the *t*-values of 8.15 and 2.37 has a dominantly direct effect on circular economy adoption, as well as an indirect effect inference to green logistics and sustainable supply chain, respectively. (H1*a*, & *b* are accepted).

Table 9: The significance

Hypotheses		**Mean value**	**t-value**	**p-value (2-sided)**	**Decision**
H1a	ID4.0 ⇒ CEA	0.59	8.15	0.00	Accepted
H1b	ID4.0 ⇒ CEA ⇒ GLS	0.10	2.37	0.02	Accepted
H2	CEA ⇒ GLS	0.17	2.62	0.01	Accepted
H3	CEF ⇒ CEA	0.13	2.63	0.01	Accepted
H4	GOP ⇒ CEA	0.06	0.81	0.42	Not accepted
H5	COL ⇒ GLS	0.29	4.04	0.00	Accepted
H6	CON ⇒ GLS	0.29	4.10	0.00	Accepted

Source: own processing from ADANCO (Luu, et al., 2023)

Additionally, the adoption of the circular economy directly affects green logistics and sustainable supply chain transitions (H2 is accepted) (Luu, et al., 2023). The circular economy framework also affects circular economy adoption (H3 is accepted). The supply-chain collaboration and configuration have a positive effect on green logistics and sustainable supply-chain networks because the *t*-values are 4.04 and 4.10, respectively (H5 and H6 are accepted). Although government policy has no evidence to affect circular economy adoption (H4 is rejected) because its *t*-value is 0.81 lower than the threshold of 1.96. In summary, the above-analyzed results confirm ***the prominent impact of ID4.0 on CE adoption***. ***CE adoption inferred acts as a mediator between ID4.0 and GLS*** and ***has a positive effect on GLS***, as well as the ***CE framework's positive impact on CEA***. ***SC collaboration and configurations play positive roles in a GLS network***. The author comprehends this situation of ***government policy, which lacks empirical evidence to influence the adoption of the circular economy*** (Luu, et al., 2023). It reflects the status quo of Vietnam government policy; therefore, this finding helps the government sectors recognize and reorient their activities to better support businesses and society.

3.4 STUDY 4 – Critical analysis under knowledge-based circular economics (KCE) model

3.4.1 Hybrid framework of KCE in the MVN

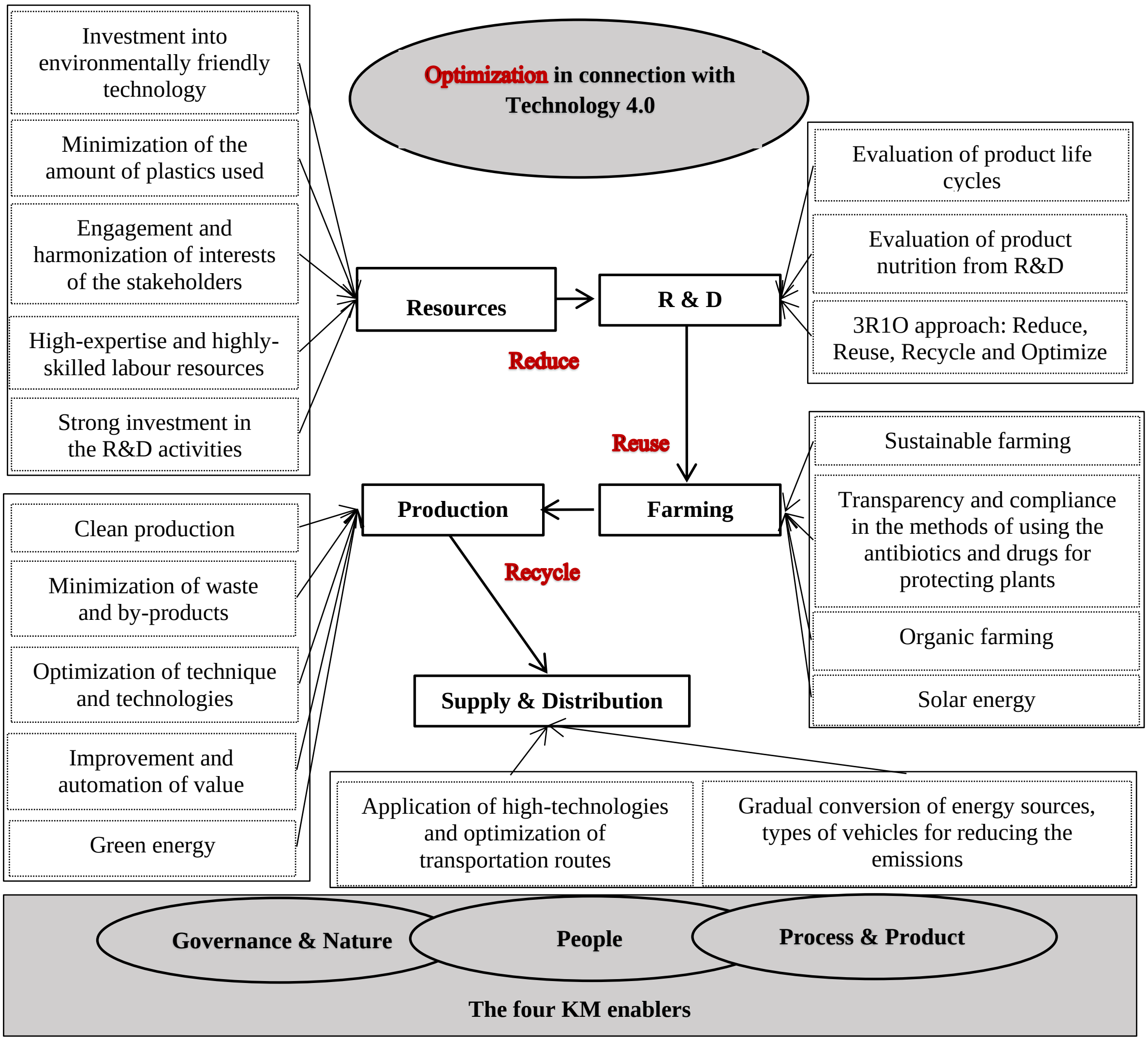

Figure 4: The KCE model for the MVN value chain
Source: own processing based on Sustainable Development Reports (2020, 2019)

This study was detailed in the research paper Luu & Chromjaková (2023b). Figure 4 describes the value chain of the MVN under the impacts of four KE indicators of people, process, technology, and governance with the CE framework of 3R1O to examine their impact on sustainable competitiveness.

The purpose of this study is to make a critical analysis of the real-world case, the MVN company, to investigate the impacts exerted on sustainable competitiveness by the knowledge-based circular economics adoption for a business performance management.

3.4.2 Critical analysis for the MVN performance

From a business perspective, the author is very impressed with the benefits of economics, society, and environment that the knowledge-based circular economics model brings to the MVN over years (see Table 10). For example, the receipt of 93 solution initiatives, with a breakout rate of 258% compared to 2019, as well as an increased percentage of 117% in savings.

Table 10: Highlights of the MVN performance

No.	Values	Highlights	2019	2020	Units	%
1	Financial matters	Charter capital	17,417	20,900	VND billion	20
2		Total revenue	56,400	59,723	VND billion	06
3		Profit after taxes	10,554	11,236	VND billion	06
4	Society	Contribute to state budget	4,840	5,273	VND billion	09
5		Saving	3.0	6.5	VND billion	117
6		Number of successful initiatives	26	93	No. of initiatives	258
7	Environment	Reduction in electricity	1,122,807	1,445,592	kWh	29
8		Reduction in CO2 emission	NA	17.3	million kg	
9		Reduction in plastic use	230,865	214,885	Kg	-7

Source: own processing based on the Sustainable Development Reports

This study is also an attempt to answer a part of the *RQ*4 of the "how" question, by examining a practical CE adoption for business operations under KE context. The findings of the MVN performance illustrate the impact of the circular economy adoption in the knowledge economy context to boost sustainable competitiveness to contribute to the growth of the company and country in general. In summary, KCE plays an essential role in the creation of sustainable and competitive value reflected in organizational performance that strengthens business process management. This is since, for modern companies, the issue of sustainable competitiveness is a fundamental corporate value for a premium circular economy.

3.5 STUDY 5 – An optimization model for a distribution supply chain network design (SCND)

3.5.1 Research design for SCND in the SME company

The study investigates the impact of ID4.0, especially the ID403 variable of model and algorithm (MCDM approach) to strengthen the retail distribution network of the real SME case and act as an examination of supply chain configuration and collaboration in a supply chain network in general.

The study uses the MCDM of MILP model by minimizing **total logistics costs** (i.e., transportation, inventory and renting costs). The model has 15 constraints including 1 customer demand constraint, 5 capacity constraints, 5 renting constraints, 2 inventory constraints and 2 safety stock constraints. The model is coded and solved by the CPLEX solver with the secondary data collected from the Accounting Department (Luu & Chromjaková, 2023a; Ning & You, 2018).

3.5.2 Research results

This study was detailed in the research paper Luu & Chromjaková (2023a). The author develops 3 scenarios of supply chain networks with specific assumptions below (Table 11). The scenarios are evaluated by their total costs with the optimal choice is the scenario 3.

Table 11:Testing scenarios

Scenarios	Description	Total costs (VND)
1. The current network	2 factories, 3 depots, 20 warehouses, and 209 customers	35,540,500,000
2. The old network	2 factories, 0 depots, 20 warehouses, and 209 customers	26,645,159,250
3. A modified network	2 factories, 0 depots, ≤ 20 warehouses, and 209 customers	22,250,892,500

Source: own processing (Luu & Chromjaková, 2023a)

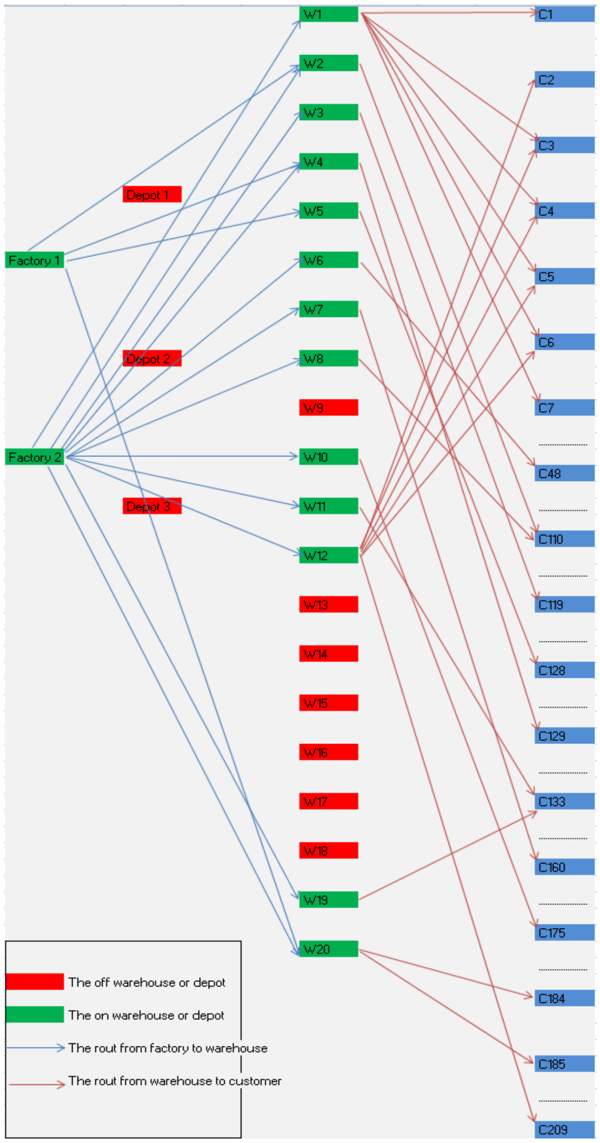

Figure 5:A modified supply chain network model
Source: own processing based on CPLEX results

The results of the study suggest that the SME should decide to close 3 depots and 7 warehouses, especially, since decisions are not only considering the number of closed warehouses but also their location such as warehouse 9 and warehouses 13 to 18 (Figure 5) (Luu & Chromjaková, 2023a).

This study is one of the quantitative attempts that address the last aspect of the fourth research question to satisfy the fourth research objective, particularly employing an MCDM approach (aligned in the ID403 variable: model and algorithms) for optimizing solutions in a distribution supply chain network.

3.6 STUDY 6 – An optimization approach for an order picking warehouse (OPW)

3.6.1 Research design for OPW in the ATP company

This study was detailed in the research paper Luu et al (2023). This study serves as the final slice of the thesis using optimization models (CO approach) to examines the impact of ID4.0, especially the ID403 variable of model and algorithm into the ATP warehouse operations.

The study aims to re-layout the allocations of goods in a more scientific way regarding picking path optimization. CO approach of the Travelling Salesman Problem (TSP) and Class-based Dedicated Assignment (CDA) are used within LINGO solver to optimize the distance that pickers must travel to collect an uncertain number of products over proposed warehouse layouts. Data is collected, calculated, and confirmed from the Operations and Finance reports.

3.6.2 Research results

a. Warehouse Layout Design Generating by CDA.

The study proposes and evaluates 3 alternatives to the warehouse layout described in Table 12, in which Map 0 is the current warehouse.

Table 12: Layout alternative

Alternative	Description
Map 0	The 1-door current warehouse layout (see Appendix 4*a*)
Map 1	A modified 1-door current warehouse layout
Map 2	A 2-door warehouse layout

Source: own processing

For example, Figure 6 describes the layout of Map 2 is assigned by CDA algorithm.

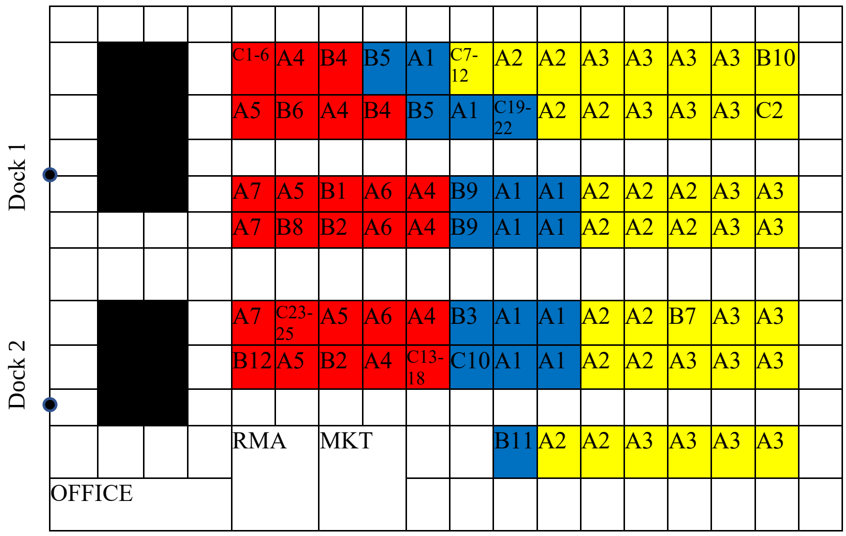

Figure 6: Map 2 assigned.
Source: own processing

b. Picking Path Optimization by TSP Model and Algorithm

Purchase orders are randomly picked for determining the picking path over three maps solved in LINGO with TSP heuristic algorithm to produce a feasible or optimal picking path. For example, an order of 7 SKUs (A1, B1, A4, B10, A2, A3, and C2) is used 10 times in the model, and the LINGO outcomes in average distance travel are 87m, 70m, and 60m over Map 0, Map 1, and Map 2, respectively (Table 13).

Table 13: Order picking performance in 3 Maps

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Average distance**	**Total distance**
Distance per order (m)	Map 0	100	90	66	72	116	94	96	64	79	88	87	865
	Map 1	80	76	60	66	28	82	66	72	80	92	70	702
	Map 2	48	68	48	40	50	88	64	64	60	68	60	598
Map 1 improvement		20%	16%	09%	08%	76%	13%	31%	-13%	- 01%	- 05%		
Map 2 improvement		52%	24%	27%	44%	57%	06%	33%	00%	24%	23%		

Source: own processing

As a result, Map 2 has been chosen with the final percentage utilization and optimization of approximately 31% and 15% compared to Map 0 and Map 1, respectively (Table 14).

Table 14: Pair comparison of maps

Pair Comparison		**Map 0**	**Map 1**	**Map 2**
		87	*70*	*60*
Map 2	*60*	31%	15%	-
Map 1	*70*	19%	-	
Map 0	*87*	-		

Source: own processing

In summary, this study is the final quantitative attempt of the thesis to satisfy the fourth research question and associated objective of the proposed model optimization using the CO approach of the CDA and TSP to suggest a class of decisions in warehouse layouts to optimize the picking paths. This study, once again, highlights the outstanding impact of high-technology applications (Hypothesis 1*a* & *b*) on a company in which warehouse layout is a crucial function of supply chain operations that was outlined in the proposed research framework and design, specifically in the ID403 variable of model and algorithms.

4 DISCUSSION AND CONTRIBUTIONS

4.1 Discussion

Economic trends encompass a wide range adoption of circular economies (CEA) or green economies and sharing economies in a knowledge-based economy context that exerts significant influence on GLS. Understanding these trends is crucial for logistics stakeholders to optimize their operations and adapt to changing market dynamics.

Technological advancements usher in a new era of efficiency, effectiveness, and connectivity within GLS transitions and practices. Such as ID4.0 technologies are defined in the thesis as the number of high-tech applications (ID401), the number of digitalized processes (ID402), and the applied mathematical model and its algorithm (ID403) that enable visibility, transformation, and redesign networks, minimize logistics costs, optimize distance traveled and times, etc., to enhance the overall resilience of logistics and supply chain networks and sustainable competitiveness of an organization or country.

Policy challenges encompass a spectrum of regulatory, government legal, geopolitical issues (GOP), and design strategies (CE Framework) that logistics professionals must handle. Staying abreast of evolving regulations and developing strategies to mitigate their impact is crucial for sustainable and compliant logistics operations.

4.2 Theoretical implications

The research examined two theoretical lenses of Resource-Based View and Policy Feedback Theories (Luu, et al., 2023). Circular economics, green logistics & sustainable supply chain are the main areas of knowledge. Literacy on high-tech applications such as the adoption of blockchain, and AI technologies in Vietnam SMEs is scarce (Luu, 2022). The study contributes to developing the conceptual framework of the CE model on green logistics and sustainable supply chain transitions and practices as well as in the knowledge economy context (Luu, et al., 2023; Luu & Chromjaková, 2023a, 2023b; Luu, 2022).

4.3 Practical implications

The study provides practical implications to answer each of the corresponding research questions as below.

RQ1 "Do high-tech applications impact CE adoption and GLS?"

The research discloses the robust influence of ID4.0 underscores the significance of high-tech applications within companies, driving strategic changes and decisions to optimize GLS operations and foster sustainable development (Luu, et al., 2023; Luu, 2021a, 2021b). This also enhances Vietnam's competitiveness within ASEAN such as Thailand and helps reduce the gap with more developed countries.

RQ2 "How government policies influence CE adoption?"

The study reveals that the relationship between government policy and CE adoption reflects the current strategic awareness and operations in Vietnam, as well as the formulation and implementation of policies. This finding offers valuable insights for government stakeholders to enhance their legal services (Luu, et al., 2023).

RQ3 "Do supply chain collaboration and configurations play a role in a GLS network?"

This research elucidates their role and impact. These insights aid in optimizing supply chain structures, fostering collaboration, and enhancing overall network performance, contributing to more efficient and sustainable GLS practices.

RQ4 "How does a CE model adoption for GLS?"

Finally, this thesis investigates a model of CE adoption for GLS both validation and optimization under a high-technology context. It provides guidance and applicable insights for the Board of Management to embrace CE practices in their operations including facility requirements, logistics cost optimization (e.g., SME), warehouse layout improvements for efficient pick paths and sustainability (e.g., ATP), and enhancements in business process management within a knowledge-based circular economics context for sustainable competitiveness (e.g., MVN).

5 CONCLUSIONS

5.1 Conclusion of the thesis

According to the existing literature, although the theme of CE and GLS and its adoption have attracted scholars, this thesis is motivated by emerged research gaps, as follows:

a) Contributions of CE integrated with high-tech applications for GLS transitions and practices to corporation performance, in sides of framework development, validation, and optimization, have been still missing.

b) There has been a lack of studies aimed at investigating GLS practices-oriented along with green and sustainable mindsets in Vietnam.

In order to conduct this study, the author refers to mixed research approaches. These approaches are an appropriate way to understand the complexity of the research statement (Creswell & Creswell, 2017). The study is designed to cooperate with the qualitative and quantitative data collection and analysis procedures which are employed sequentially in six single and interrelated studies to develop, validate, and optimize a model of CE adoption for GLS under a high-technology context.

In summary, the results point out that green and sustainable mindsets and practices are the main factor that stimulates the adoption of circular economics for GLS transitions and practices under the impact of high-tech applications in a knowledge economy context.

5.2 Limitation and further research

The limits of this study provide novel prospects for the conduct of further research in the relevant area.

Firstly, this research primarily focused on the Vietnamese industry. In future investigations, it is imperative to expand the scope by incorporating other countries into the analysis. This comparative approach will facilitate an examination of divergent experiences in adopting CE principles within GLS transitions and operations.

Secondly, within the broader context of green and sustainability concerns, there exists an opportunity for further inquiry into alternative sectors, such as agriculture, where Vietnam holds a pivotal role as a major global supplier of rice. This sector could serve as a noteworthy subject for future studies, exploring the integration of CE principles and sustainable practices.

Thirdly, the scales, algorithms, and programming languages employed in this study are primarily drawn from existing software with established validation in small and medium sizes. It is recommended that forthcoming research endeavors aim to develop and assess novel measurement scales, advanced algorithms like metaheuristics, and modern programming languages such as Python. These innovations will enhance the capacity for evaluating and optimizing GLS operations.

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AUTHOR’S CURRICULUM VITAE

Personal information

- Full name: Luu Van Thanh. Nationality: Vietnamese. Email: luu@utb.cz
- Address: MSI, Nam T. G. Masaryka 1281, 76001 Zlin, Czech Republic

Work experience

- 2010 – to date: Lecturer at International University, VNU- HCMC.
- 2001-2010: Lecturer and director at AITVN, STU, TDTU, TNV, and BigC.
- 1996-2001: Supervisor and manager at KAO; S.C. Johnson & Son

Education

- 2020 – to date: Ph.D. student at Tomas Bata University, Czech Republic
- 2002 – 2003: Master’s degree at Katholieke Univeriteit Leuven, Belgium
- 2001-2002: Diploma program at Asian Institute of Technology, Thailand
- 1991-1996: University Degree at HCMC Polytechnic University, Vietnam

Research interests

- Circular Economy and Industry 4.0
- Green Logistics and Sustainable Supply Chain and Production
- Optimization and data analysis using statistical tools.

Research activities at Tomas Bata University in Zlin

- M-SI-1817-2324-172622. Tourism and Agriculture Sustainable Alliances - #TASA network, BOKU - University of Natural Resources and Life Sciences, Vienna, Department for Landscape, Spatial and Infrastructure Sciences, 10-11/2023.
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- Peer Review for the manuscript of “Environmentally sustainable supplier development and environmental sustainability practices’ adoption among suppliers”, *Business Strategy & Development*, Web of Science record, 2023-12-08.
- Peer Review for the manuscript of “Collaborative Technologies and Project Performance in Manufacturing in the Industry 4.0 Environment: Mediating Effect of Individual, Organizational, Sociotechnical Factors”, *Business Strategy & Development*, Web of Science record, 2023-08-29.
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Thanh Van Luu, Ph.D.

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