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RESEARCH ARTICLE

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A model of industry 4.0 and a circular economy for green logistics and a sustainable supply chain

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Abstract

The objective of this study was to investigate a hybrid framework for Industry 4.0 and a circular economy for logistics and supply chains with an environmentally-friendly and sustainable basis. Data were collected from universities, companies, and civil service departments. Partial Least Squares Structural Equation Modeling was applied to evaluate and validate hypotheses. Key findings comprise (a) confirmation of a predominant direct relationship between Industry 4.0 and adopting a circular economy for green logistics and a sustainable supply chain, which stimulates strategic change; and (b) deliberation about current strategic awareness and operations occurs, giving rise to the promulgation and implementation of state authority policies, and advancements in modern logistics and supply chain programs at universities. Since the analysis concentrated on logistical and supply chain matters, investigation of other variables would be required for other industrial activities such as manufacturing.

KEYWORDS
circular economy, industry 4.0, logistics, partial least squares structural equation modeling, supply chain, sustainability

1 | INTRODUCTION

Human activities are damaging the planet in various ways, and sea levels are rising. Increase in the population as well as numbers of livestock has resulted in greater waste and a worrying decline in biodiversity. Attempts have been made to tackle issues triggered by an escalation in demand for natural resources. Regulatory bodies are pushing global supply chains to become sustainable across all operational activities in an attempt to make them more environmentally-friendly and financially feasible, forcing the adoption of advanced technologies. A solution would be to combine Industry 4.0 (ID4.0) and a circular economy (CE) in order to flexibly utilize resources (Agrawal et al., 2022). Indeed, ID4.0 drives the digitization of operations, enabling digital communication throughout the value chain and then simplifying business processes. And, CE focuses on the design of production-consumption systems, enhancing resource efficiency (Kumar et al., 2021) and effectiveness by improving collaboration and configuration in a supply chain network (Hussain & Malik, 2020).

The majority of academics have investigated either CEs or ID4.0 separately (Birkel & Müller, 2021; Kirchherr et al., 2017; Morseletto, 2020), while others examined integration between them for progressing toward sustainable societies and industries (Agrawal et al., 2022; Ghadimi et al., 2019; Kumar et al., 2021; Shayganmehr et al., 2021). For sustainable production and manufacturing, Shayganmehr et al. (2021) are interested in the effects of ID4.0 and CEs. Massaro et al. (2021) sought to understand how ID4.0 facilitated CEs, alongside the associated

influences exerted on businesses. On the sides of enablers and barriers analysis, Rajput and Singh (2019) reported a CE, AI, service, and policy framework were key facilitators linking a CE and ID4.0 in a supply chain. Similarly, Kumar et al. (2021) analyzed inhibitors affecting SC operations by implementing ID4.0 and a CE, before which Dev et al. (2020) considered the matter of operational excellence for reverse logistics by combining a CE and ID4.0. Although Agrawal et al. (2022) and Rosa et al. (2020) contained proposals for integration on ID4.0 and CEs via systematic literature review only. Obviously, yet no-one has proposed an integrated framework of ID4.0 and a CE expressly for logistics and SC practices from a green and sustainable perspective.

This research is motivated that logistics and supply chain is a high-tech industry with two distinct attributes of advanced technology (ID4.0) and modern economics (CE) under government policy impacts, as well as focuses on two independent components of configuration and collaboration in supply chain networks, intending to devise an economic mechanism to achieve corresponding social and environmental goals. An integrated ID4.0 and CE-based supply chain would exhibit flexibility, sustainability, and interoperability (Rajput & Singh, 2019) as well as improve smart logistics and resources efficiency (Agrawal et al., 2022). The authors believe this study is one of the first to further the development of an integrated framework for mutual ID4.0 and CE adoption (CEA) in connection with green logistics and sustainable supply chain practices (GLS). Partial least squares structural equation modeling (PLS-SEM) was applied to evaluate and validate the given model. Specifically, the following questions are addressed:

> RQ1. How does the interaction of ID4.0 and a CE affect logistics and supply chain operations?
>
> RQ2. Which crucial principles influence the framework devised for mutual ID4.0 and CE adoption in connection with GLS?

In an attempt to answer them, the following objectives were determined:

> RO1. Development of an integrated model of ID4.0 and CEA for ensuring GLS.
>
> RO2. Application of ADANCO and SmartPLS-SEM to analyze and validate the model.

Herein, Section 2 reviews theoretical development from previous studies on ID4.0, CEs, sustainability, and GLS operations, which informed the framework and associated hypotheses, while Section 3 covers methodology, and detailed statistical analysis. The results are examined in Section 4, with a discussion subsequently presented in Section 5. Conclusions on theoretical and practical implications, alongside information regarding future research, appear in Section 6.

2 | THEORETICAL DEVELOPMENT, RESEARCH FRAMEWORK, AND ASSOCIATED HYPOTHESES

2.1 | Theoretical framework development

Previous studies have tended to examine the impact of ID4.0 and CE on logistics and supply chain (Agrawal et al., 2022) and attempted to explain organizational decision making as independent motives for organizations and different roles of external pressures and internal resources as well as their capabilities (Dubey et al., 2019). However, in CE and ID4.0 context it is not well understood how external pressures can affect internal resource development, and in turn their adoption to enhance green logistics and sustainable supply chain transitions and practices. Hence, the authors use two overarching theoretical lenses based on the theories of Policy Feedback (Pierson, 1993), and resource-based view (RBV; Barney, 1991) to examine the relationship between external pressure such as government policy and internal resources of an organization as CE and ID4.0 capabilities. The RBV explains how an organization can achieve competitive advantage by creating bundles of strategic resources and organizational capabilities. Although government policies (GOP) generate resources and incentives for organizational actors (Harland et al., 2019). These mechanisms operate in a variety of ways but have significant effects on government, enterprises, and communities. Thus, anchored to such theories, the theoretical framework is indicated in Figure 1.

2.2 | Conceptual framework and hypotheses development

From the above arguments, a simple path model was employed that defined outer and inner models, exogenous and endogenous constructs, and reflective variables. Figure 2 is a conceptual framework that includes the internal capabilities of ID4.0, and CE as well as the external impact of GOP on GLS practices and transitions. In this scenario, the resource-based view motivates GLS transitions in a CE context to induce supply chain network configuration (CON) and collaboration (COL; Hussain & Malik, 2020), as well as a CE framework (CEF) in strategic design, respectively (Morseletto, 2020; Patwa et al., 2021).

2.2.1 | ID4.0 and CE

CEs and ID4.0 are emerging concepts of interest to academics and practitioners. For example, Preston (2012) claimed that contemporary CEs originated from industrial ecology, a concept devised in the 1970s. However, no study has thoroughly and systematically examined definitions (Kirchherr et al., 2017). Several definitions portray the CE as a versatile concept, with some including waste management and others aligning it with sustainable development (Kirchherr et al., 2023). Recently, Figge et al. (2023) defined that "The CE is a multi-level resource use system that stipulates the complete closure of all resource loops. Recycling and

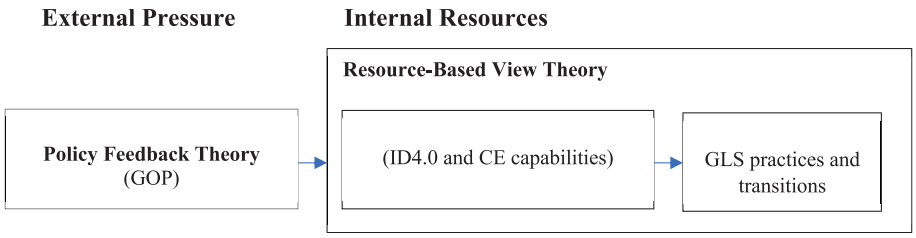

FIGURE 1 Theoretical framework. *Source*: Adapted from Pierson (1993) and Barney (1991).

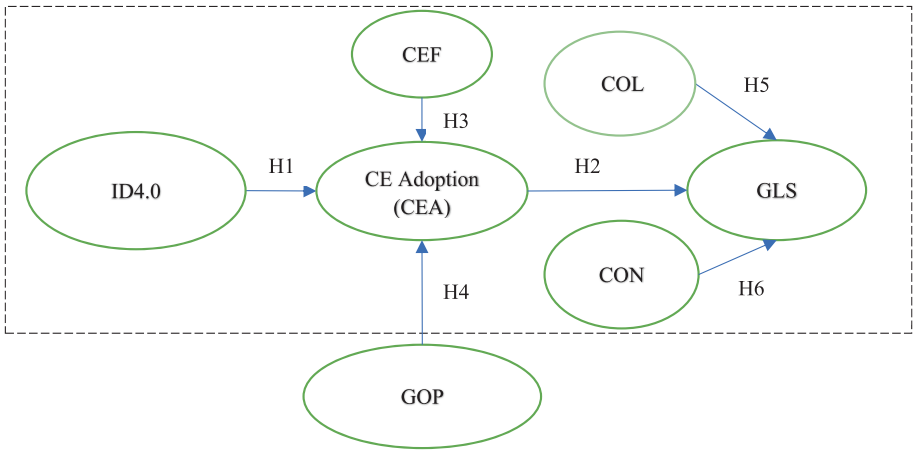

FIGURE 2 Research conceptual framework. *Source*: own processing.

other means that optimize the scale and direction of resource flows contribute to the CE as supporting practices and activities. In its conceptual perfect form, all resource loops will be fully closed. In its realistic imperfect form, some use of virgin resources is inevitable."

The ID 4.0 concept was introduced in 2011 by the German government as a high-tech strategy for 2020. It can be defined as "real-time, intelligent and digital networking of people, equipment, and objects for the management of business processes and value-creating networks" (Agrawal et al., 2022; Dombrowski et al., 2017). The ID4.0, the fourth industrial revolution, has become a metaphor for tremendous change in the manufacturing sector using Information and Communication Technologies (ICT), and relates to the application of innovative technologies, for example, smart objects, IoT, AI, and so forth, in commercial enterprises (Culot et al., 2020).

Although ID4.0 stems from technological advancements in production, CEs originate from social innovations in consumption. It was described as an industrial system with operational and strategic benefits at micro- and macro-economic levels, constituting a trillion-dollar opportunity with great potential for innovation, job creation, and economic growth (WEF, Elle MacArthur Foundation, and Mckinsey, & Co, 2014).

Industry 4.0 has altered modern society, influencing it through inextricable links that exist between social and technological advances. Performing CE practices with cutting-edge, digital technologies is a core contribution of ID4.0 (Shayganmehr et al., 2021). ID4.0 technologies afford numerous opportunities for businesses; it enhances their circular performance and is defined as a powerful strategic instrument for CE adoption that optimizes the utilization of resources (Rosa et al., 2020). The initiative of ID4.0 constitutes a major component of CEA, as confirmed by statistical analysis of the following hypothesis:

Hypothesis 1. ID4.0 exerts direct positive effects on CEA.

The ID4.0 construct is measured herein by three observed variables, as follows:

- ID401: *The number of high-tech applications* at the organization. Analysis of big data, IoT, AI, and blockchains are widely applied to boost business performance and sustainability (Dubey et al., 2019; Manavalan & Jayakrishna, 2019; Rajput & Singh, 2022; Saberi et al., 2019). For example, Del Giudice et al. (2020) discovered that a big-data-driven SC would moderate interconnections between CE-HR management and company performance.
- ID402: *The number of digital processes* applied in operations, such as MRPII/ERP, EOQ, and machine learning. For example, Sharma et al. (2020) reported on machine learning within an agricultural SC. Angolia and Pagliari (2018) wrote about using a commercial software application like SAP ERP for SC management.
- ID403: *The model and its algorithms—the number of relevant variables integrated into the given model*. Optimization models, heuristic algorithms, and other components enhance business performance within such an arrangement. Mathematical techniques, for example, linear, nonlinear, integer linear, and fuzzy programming, tackle complex, global, SC-management-related matters; indeed, MCDM was introduced for this express purpose (Khan et al., 2021). In this respect, heuristic algorithms represent good options for enterprises, for example, a genetic algorithm, ANN, or the fuzzy method (Feizollahi et al., 2021; Kazancoglu et al., 2021).

2.2.2 | CE and sustainability

The ideology behind CEs and sustainability is based on the 3Rs: reduce, reuse, and recycle. Various methodologies exist regarding interconnections between CEs and sustainability that aim to heighten the dependencies of economics, society, and the environment (Korhonen et al., 2018). Implementing a CE within an organization helps foster sustainability. The fundamental distinction between the two is that the latter emphasizes the integration of financial, social, and environmental objectives, treating them as equal factors, whereas a CE focuses more on economic concerns that benefit society and the environment, though it could be perceived as a more business-centric strategy (Geissdoerfer et al., 2017).

2.2.3 | CEA for GLS

Numerous studies have been published on CE adoption to logistics and SCs. Govindan and Hasanagic (2018) analyzed drivers, barriers, and practices that influenced CE implementation in the context of SCs. Hussain and Malik (2020) found that a proposed framework emphasized the joint effects of organizational actors and process facilitators, including SC collaboration and configuration which enabled circular SCs. Hazen et al. (2020) discussed how SC processes aided the successful implementation of CEs. Kumar et al. (2021) discerned that insufficient funding for ID4.0 initiatives and inefficient strategies for integrating ID4.0 with environmental measures formed two principal barriers to achieving sustainability objectives. Incorporating ID4.0 and CEA, logistics and SC management has proven decisive in successfully navigating the highly complex contemporary business environment. Global logistics and sustainable SC are essential in diverse and specialized sectors, where a balance has to be struck between the availability of resources worldwide, the growing consumer market, and the requirement to be green and sustainable. This has led to a rise in the extent of GLS practices that are developed in tandem with CEA. Hypothesis 2 below was derived from these findings:

Hypothesis 2. CEA directly affects GLS practice.

Research indicates that CEA reflects the understanding and attitude of management and staff at an organization to a CE during a transition to GLS, through the variables observed below:

- CEA1: *CE insights*. CE principles and insights embraced by both management and employees facilitate a shift to GLS (Hussain & Malik, 2020).
- CEA2: *Awareness of sustainability*. A shift to GLS is made possible when staff have a good understanding of what constitutes sustainability (Tura et al., 2019).
- CEA3: *Awareness of the economic possibilities of CE*. Staff's awareness of CE potential for revenue gains and cost savings enables a GLS transition (Bressanelli et al., 2019).
- CEA4: *Capacity of CE to improve environmental conditions*. A transition to GLS is facilitated if staff are aware of CE practices for CO_2 and greenhouse gas emissions reduction (Jadhav et al., 2019).
- CEA5: *Benefits of CE to society*. Employee awareness of CE potential for a reduction in unemployment or Covid-19 impact supports a GLS transition (Sarkis et al., 2020).

2.2.4 | CEF and GOP

The promotion of circular economies is essential. Besides high-tech impact, Luu (2021a) investigated the adoption of CE principles in the impacts of governmental policy (GOP), and CE framework (CEF). The study presented various CEFs categorized based on the number of R strategies involved. Kirchherr et al. (2017) found that a CE was typically considered a combination of the 3Rs, yet a systemic transformation was required. Morseletto (2020) stated, in the context of the 10Rs, that widespread strategies for recovery and recycling did not always lend themselves to CE support, with others promoting more potent CE instead. Various CEFs were studied to understand and practice a CE adoption. As a result, the following hypothesis is established:

Hypothesis 3. CEF positively affects CEA.

Research thoroughly investigates indicators of CEF-related factors, as follows:

- CEF1: *Design strategies*. Designs should encompass a "system change" if a circular design policy is being considered, for example, an "R" strategy (Kirchherr et al., 2017; Patwa et al., 2021).
- CEF2: *Design principles*. Basic principles shape the design: waste reduction, construction for reuse, sustainability through diversity, energy from renewable sources, and so forth (Ellen MacArthur Foundation, 2013).
- CEF3: *A systematic concept*. Comprehending interactions among components and understanding relationships between the whole and its parts are essential. A systematic approach prioritizes flow and connections over time, enabling effective handling of regenerative situations (Ellen MacArthur Foundation, 2013).
- CEF4: *Various participants*. Different participants should be considered in the value chain, in consideration of the needs and opinions of internal and external customers (Ellen MacArthur Foundation, 2013).
- CEF5: *Construction of design by experienced people* (Ellen MacArthur Foundation, 2013).

Additionally, CE adoption is greatly influenced by policies (Kazancoglu et al., 2021; Patwa et al., 2021). It is sometimes aided by enforcing regulations or promoting new approaches. Several countries have enacted legislation that encourages cleaner methods of production and consumption systems, serving as mandatory drivers in

developing nations. Govindan and Hasanagic (2018) found that awareness of policies by stakeholders highly encouraged CEA in SCs. Kazancoglu et al. (2021) discovered obstacles to implementation comprised of gaps in law on CEs, insufficient regulation of CE suppliers and obligations on their part, and a lack of governmental support for environmentally-friendly initiatives. Hence, the hypothesis is developed concerning the variables outlined below.

Hypothesis 4. GOP positively affects CEA.

- GOP1: *Legislation*, that is, appropriate regulations, and laws for GLS practices in a CE context. A strong regulatory framework and such strategies help create an ecosystem in which businesses cooperate, form partnerships, and promote sustainability (Harland et al., 2019).
- GOP2: *Capacity building*. Concerning CEs, GOPs reinforce the development of GLS capabilities. Governments initiate capacity-building programs that encourage communities to join forces and engage in activities to engender a sustainable society. Capacity building is required for proper educational outreach (Gupta & Koontz, 2019; Patwa et al., 2021).
- GOP3: *Educational strategy*, that is, education and training to develop thinking, and reinforce green and sustainable practices. Such endeavor relates to knowledge and informs attitudes toward sustainability and compliance with regulations (Patwa et al., 2021).
- GOP4: *Urban planning*, that is, a synchronous infrastructure for GLS in a CE context. Urban planning is critical to addressing the problems faced by emerging countries of rapid economic and demographic growth, and the desire to live sustainably (Ahluwalia, 2019).

2.2.5 | Collaboration and configuration in GLS

GLS-orientated operations constitute key factors for enhancing performance in green and sustainable development (Antheaume et al., 2018; Ghadimi et al., 2019; Tseng et al., 2019). Depending on the given economic potential and level of advancement in science and technology, each nation determines its strategy for such improvement. Selection is made of a model deemed suitable for superior market-related efficiency and effectiveness; one which expedites social and environmental sustainability. Govindan and Hasanagic (2018) coined the phrase "industrial chain" to emphasize the need for collaboration between SCs (COL) within a primary SC network that typically spans multiple business sectors. Although COL seeks out potential means for industrial symbiosis, most pre-existing SC configurations (CON) have to be modified to enable sharing with the overarching SC (Antheaume et al., 2018). The inherent flexibility of lesser SC structures already in place for introducing and extending reverse product flow into the primary SC network represents a core component of design that facilitates a transition to GLS. Investigation consequently encompassed another two independent GLS variables, specifically COL and CON (Hussain & Malik, 2020; Tseng et al., 2019). Hypotheses were constructed as follows:

Hypothesis 5. COL positive affects GLS.

Hypothesis 6. CON positively affects GLS.

To elucidate corresponding relationships in the framework, research was conducted on several variables of COL and CON, respectively.

- COL1: *Collaboration with SC partners*. Such cooperation inside and beyond industrial boundaries facilitates GLS (De Angelis et al., 2018; Govindan & Hasanagic, 2018).
- COL2: *SC responsibility*. GLS is made possible by an SC-wide responsibility for implementing CE guidelines (Herczeg et al., 2018; Hussain & Malik, 2020).
- COL3: *Data sharing*. GLS is enabled through superior data sharing and the presence of supportive technology (Bressanelli et al., 2019; Tura et al., 2019).
- CON1: *Similarity in operational practices*. A commonality in operational and logistic procedures in an SC aids the implementation of GLS (Hussain & Malik, 2020).
- CON2: *SC restructuring*. Restructuring SCs eases the transition to GLS, including managing end-of-life returns or waste generated during manufacture (Sultan & Mativenga, 2019; Tura et al., 2019).
- CON3: *SC structural flexibility*. Heightening the structural flexibility of an SC, eliminating "linear lock-in," and lifting geographical restrictions all contribute to accomplishing GLS (De Angelis et al., 2018).

Finally, the analysis covered nine variables for GLS operations influenced by CE practices.

- GLS1: *Compliance with environmental regulations*. GLS operations are conducted under applicable environmental laws and regulations, as a consequence of CE adoption (Hussain & Malik, 2020; Seroka-Stolka & Ociepa-Kubicka, 2019).
- GLS2: *Reduction in energy consumption*. GLS cuts energy consumption through the actions of CE practices (Hussain & Malik, 2020).
- GLS3: *Reduction in hazardous materials*. Efforts to achieve GLS by adopting CE strategies lead to a reduction in the use of hazardous materials (Hussain & Malik, 2020).
- GLS4: *Green IT*. GLS operations enhance green IT and communication, enabled by implemented CE practices (Luu, 2021b; Torasa & Mekhum, 2020).
- GLS5: *Green transportation*. GLS operations bolster green forms of transportation via adopted CE practices (Khan & Zhang, 2021; Seroka-Stolka & Ociepa-Kubicka, 2019).
- GLS6: *Green manufacturing*. GLS operations reinforce environmentally-friendly manufacturing techniques, through the adoption of CE methods (Luu, 2021b; Torasa & Mekhum, 2020).

- GLS7: *Green storage*. GLS operations underline efforts to use eco-friendly storage and packaging solutions through the adoption of CE practices (Khan & Zhang, 2021; Seroka-Stolka & Ociepa-Kubicka, 2019).
- GLS8: *Green procurement*. GLS operations aid green procurement, enabled by CE practices (Luu, 2021b; Mardani et al., 2020).
- GLS9: *Reverse logistics*. GLS operations improve reverse logistics, as facilitated by CE strategies (Khan & Zhang, 2021; Rajput & Singh, 2022).

As a result of Section 2, the details of 7 observed components and 32 associated variables are summarized in Table A1 (Appendix 0).

3 | METHODOLOGY

3.1 | Research conceptual design

This study comprises three phases (Figure 3) with data originating from qualitative and quantitative approaches.

The first constitutes a literature review of ID4.0, CEs, logistics, and SCs in the light of theoretical lenses of policy feedback and resource-based view theories; the second proposes an integrated framework of ID4.0 and CE for GLS, wherein associated hypotheses are developed; while the last informs about quantitative methods in the form of statistical software (e.g., ADANCO and SmartPLS-SEM) employed to evaluate and validate the proposed model, in addition to future directions.

PLS-SEM is deployed instead of other validation techniques, for example, covariance-based structural equation modeling (CB-SEM), and artificial neural networks (ANN). According to Dash and Paul (2021), CB-SEM and PLS-SEM provide very similar results. Although CB-SEM has high data demands, PLS-SEM performs well with small sample sizes and non-normal distributions (Goodhue et al., 2012; Hair et al., 2017). Whereas ANN is unable to test causal relationships, PLS-SEM affords an explanation of them among multiple variables without rigid preconditions and assumptions (Hair et al., 2017), making PLS-SEM the preferred inferential technique.

3.2 | Research design procedure

An illustration of the research procedure is given (Appendix B in Figure B1) including three stages of *sampling and sample size*, *assessment in measurement*, and *structural models*.

3.2.1 | Sampling and sample size

This study required a high volume of samples for reasons of associated distribution theory (Raykov & Widaman, 1995). Hair et al. (1998) state that three different sample sizes exist for SEM: small ≤100; medium = 100 ÷ 200; and large ≥200. In a later paper, Hair et al. (2017) suggest that the sample size for PLS-SEM could be derived by multiplying the given variable by 10 to achieve the greatest number of forwarding arrows unto itself. The authors herein decided to conduct 300 observations, resulting in data collection from a sufficient number of respondents (i.e., 210) to adhere to the criteria for a large-sized sample.

Interviews were carried out to compare data from published studies with principles guiding the research herein and real-world circumstances. Specific individuals were approached to ensure a high quality of research was conducted, including three professors specializing in industry and economics, three business executives, two civil servants, and five lecturers. Their contributions helped identify important matters that subsequently informed the finalized questionnaires, aiding clarification of links between the 7 constructs and 32 variables in the proposed framework.

Bilingual English-Vietnamese and English-Czech questionnaires (Appendix C) were used for all units of observation. Indicators were measured on a 5-point Likert scale. HoChiMinh City, the largest commercial hub attracting skilled laborers globally and in Vietnam, was chosen as the primary survey site. The survey focused on experienced persons (75% with ≥5 years of experience) in CEs, ID4.0, and logistics, holding positions such as professors/lecturers (30.5%), managers (25.2%), and CEOs (17.6%) across a balanced network of universities (36%), companies (33%), and public & other sectors (31%). Detailed sample distribution is provided in Table D1 (Appendix D).

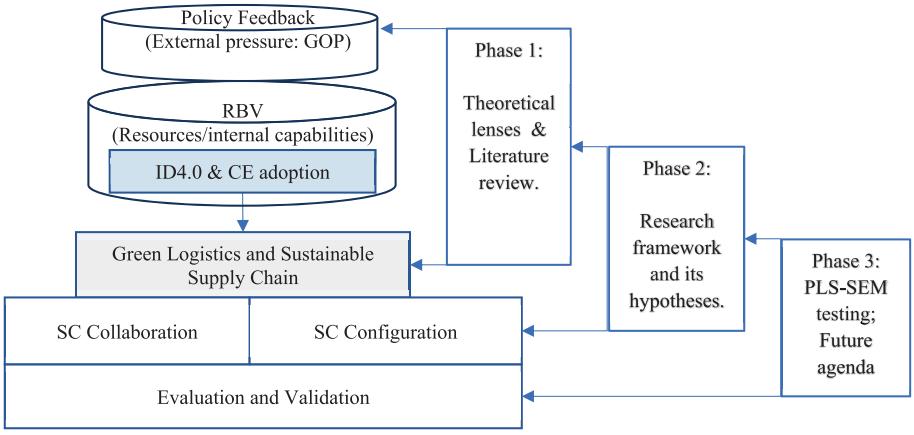

FIGURE 3 Conceptual design.
Source: Own processing.

The reflective measurement model is evaluated by the reliability of indicators and constructs, convergent validity, and discriminant validity. The thresholds of descriptive statistics are summarized in Table E1 (Appendix E).

Structural evaluation is to analyze the inner structural model to whether theoretical structural relationships between the constructs fit and were significant. The coefficients of Pearson's determination (R^2), cross-validated redundancy (Q^2), standardized root mean square residual (SRMR), *t*-value, and *p*-value were applied. Table E2 (Appendix E) describes their thresholds for descriptive statistics.

4 | RESULTS

Figure 4 illustrates the solved research framework exported from ADANCO software that uses for result analysis.

4.1 | Measurement model assessment

Based on recommendations by Hair et al. (2017) for PLS-SEM, the first stage of the *reflective measurement model* for outer evaluation involved examining outer loadings, construct reliability, and convergent validity by AVE.

As shown in Table 1, the loading values for the 32 observed variables lay in the range of 0.815 for CEA3 to 0.941 for GOP3, exceeding the threshold of 0.7, thus the reliability of the indicators was satisfied (Hair et al., 2014).

All the values for construct reliability were discerned by Dijkstra–Henseler's rho (ρA), Jöreskog rho (ρc), and Cronbach's alpha (α), so were greater than the 0.7 thresholds; hence the model factors related to their respective constructs in a meaningful manner. The AVE of the constructs was higher than the threshold of 0.5, indicating the values for convergent validity were accurate.

The last stage was given over to evaluating discriminant validity, an indicator of constructs independent of one another (Hair et al., 2014, 2017) The discriminant evaluation method recommended by the Heterotrait-Monotrait ratio (HTMT) of correlations, with values lower than 0.85 for conceptually distinct constructs and less than 0.90 for conceptually similar constructs. Table 2a shows that HTMT values of less than the threshold of 0.85 indicated a valid discriminant between the constructs.

In addition to examining the size of the HTMT value, the research involved the use of a bootstrapping procedure to determine whether the HTMT value was statistically significantly lower than 1, and this was evidenced (Table 2b).

4.2 | Structural assessment and hypothesis test

The investigation was made as to the inner *structural model* after ensuring discriminant validity. Pearson coefficients (R^2) were applied for initial analysis at this point; R^2 evaluated the portion of the variance of the endogenous constructs, as explained by the structural model, and indicated the quality of the adjusted model.

Table 3a shows that the GLS and CEA constructs exerted a medium to large effect because both values for R^2 of 0.364 and 0.490 exceeded the 0.26 threshold of Cohen (1988) and nearly the 0.5 threshold of (Hair et al., 2017, 2019). The blindfolding technique in SmartPLS3.0 was also employed to calculate cross-validated redundancy (Q^2); the values of 0.280 and 0.360 were greater than 0.25, indicating the medium predictive relevance of the path model for the endogenous constructs of GLS and CEA.

In order to discern the fit of the model, Henseler et al. (2014) assessed the efficacy of the standardized root mean square residual (SRMR) between the observed correlations and the model-implied correlations. In this respect, Table 3b shows that the SRMR of the research model was just 0.048 and 0.058 in the saturated and

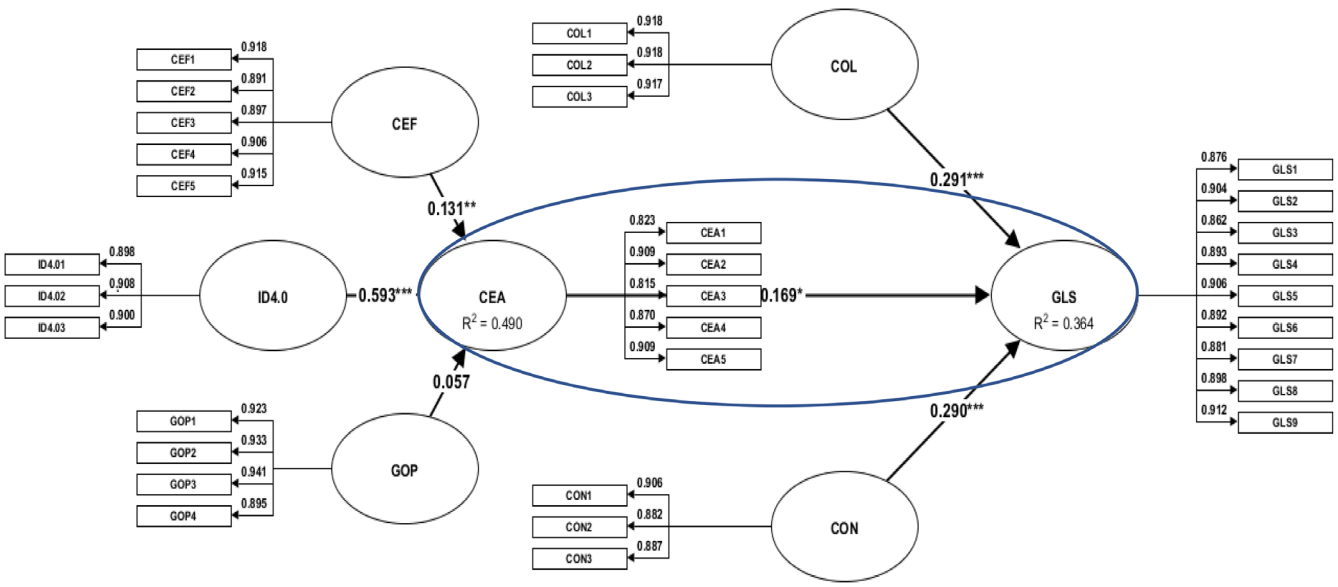

FIGURE 4 Solved research framework. *Source*: Own processing from ADANCO.

TABLE 1 Summary of the measurement model.

Construct	Variable	Outer loading	Construct reliability			Convergent validity	Outer weight	Construct priority	Variable priority
			Dijkstra-Henseler's rho (ρA)	Jöreskog's rho (ρc)	Cronbach's alpha (α)	AVE			
ID4.0	ID4.01	0.898	0.888	0.929	0.885	0.813	0.365	1	2
	ID4.02	0.908					0.393		1
	ID4.03	0.900					0.351		3
COL	COL1	0.918	0.910	0.941	0.907	0.843	0.370	2	2
	COL2	0.918					0.383		1
	COL3	0.917					0.337		3
CON	CON1	0.906	0.877	0.921	0.872	0.795	0.405	3	1
	CON2	0.882					0.376		2
	CON3	0.887					0.339		3
CEA	CEA1	0.823	0.916	0.937	0.916	0.750	0.229	4	3
	CEA2	0.909					0.230		2
	CEA3	0.815					0.227		4
	CEA4	0.870					0.241		1
	CEA5	0.909					0.229		3
CEF	CEF1	0.918	0.959	0.958	0.946	0.820	0.222	5	3
	CEF2	0.891					0.184		5
	CEF3	0.897					0.185		4
	CEF4	0.906					0.252		2
	CEF5	0.915					0.259		1
GOP	GOP1	0.923	0.945	0.959	0.942	0.853	0.285	6	2
	GOP2	0.933					0.247		4
	GOP3	0.941					0.286		1
	GOP4	0.895					0.266		3
GLS	GLS1	0.876	0.968	0.972	0.968	0.795	0.121	7	5
	GLS2	0.904					0.121		5
	GLS3	0.862					0.115		6
	GLS4	0.893					0.130		1
	GLS5	0.906					0.126		3
	GLS6	0.892					0.126		3
	GLS7	0.881					0.125		4
	GLS8	0.898					0.129		2
	GLS9	0.912					0.129		2

Source: Own processing from ADANCO.

estimated models, respectively (<0.08 threshold) indicating the fit of the model was good.

The structural equation model is used to evaluate construct relationships. When the *t*-value is greater than 1.96, the significant threshold is indicated as less than 5% (*p*-value <.05; Hair et al., 2014, 2017, 2019). In this context, ADANCO has the capacity to produce *t*-/*p*-values (Table 4). In which, ID4.0 with *t*-values of 8.15 and 2.37 exerted a direct, positive effect on CEA, as well as an indirect influence on GLS, respectively (H1—accepted). Similarly, CEA directly affected GLS, as evidenced by the *t*-value of 2.62 (H2—accepted). With a *t*-value of 2.63, CEF also positively changed CEA (H3—accepted). COL and CON benefited GLS, too, since their *t*-values equaled 4.04 and 4.10, respectively (H5, H6—accepted).

Unfortunately, no evidence was seen that GOP altered CEA (H4—rejected) because its *t*-value of 0.81 was lower than the threshold of 1.96.

5 | DISCUSSION

The results revealed that ID4.0 had a dominant effect on CEA for GLS, followed by SC configuration and collaboration, which strongly

TABLE 2 Discriminant validity.

(a) HTMT							
Construct	**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							
Construct	**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	

Source: Own processing from ADANCO.
Note: 95% bootstrap quantiles.

TABLE 3 Structural model testing.

(a) Coefficients of R^2 and Q^2					
	***R*-squared**		**Cross-validated redundancy**		
Construct	**Coefficient of determination (R^2)**	**Adjusted R^2**	**SSO**	**SSE**	**Q^2 (=1-SSE/SSO)**
GLS	0.364	0.355	1890.000	1356.392	0.280
CEA	0.490	0.483	1050.000	671.988	0.360
(b) Standardized root mean square residual (SRMR)					
	Value		**HI95**		**HI99**
Saturated Model	0.048		0.043		0.047
Estimated Model	0.058		0.053		0.057

Source: Own processing from ADANCO & SmartPLS.

TABLE 4 The construct relationships significance.

		Standard bootstrap results				
Hypothesis	**Effect**	**Mean value**	**Standard error**	***t*-Value**	***p*-Value (2-sided)**	**Decision**
H1	ID4.0 ⇒ CEA	0.59	0.07	8.15	0.00	Accepted
	ID4.0 ⇒ GLS	0.10	0.04	2.37	0.02	Accepted
H2	CEA ⇒ GLS	0.17	0.06	2.62	0.01	Accepted
H3	CEF ⇒ CEA	0.13	0.05	2.63	0.01	Accepted
H4	GOP ⇒ CEA	0.06	0.07	0.81	0.42	Not accepted
H5	COL ⇒ GLS	0.29	0.07	4.04	0.00	Accepted
H6	CON ⇒ GLS	0.29	0.07	4.10	0.00	Accepted

Source: Own processing from ADANCO.

affected GLS practices; finally, the CE framework contributed to CEA, which in turn positively influenced GLS operations. The above-specified constructs and their variables are prioritized according to weight in Table 1. In this context, the authors would recommend that SC partners pay more attention to ID4.0. They suggest that companies initially focus on deploying a modern system via digitized processes, such as MRPII or ERP (ID4.02), in their operations. This could be followed up by strongly investing in and enthusiastically adopting technological innovations, for example, AI applications, big data analysis, and a blockchain (ID4.01). Finally, it would prove necessary to train and recruit highly skilled staff to apply a new model and related algorithms (ID4.03), for example, MCDM, in systems to optimize trade from the perspective of green and sustainable development. Universities ought to contribute to this by putting on progressive courses in logistics and SCs that inform about the latest technologies and concepts, alongside ID4.0, CEA, and others.

As to why Hypothesis 4 was rejected, most of the respondents came from universities, government sectors, and enterprises in Vietnam, and were aware of the inadequacies of Vietnamese schemes. Although the government has strategies in place for the adoption of CEs and ID4.0 in commerce, executive bodies have neither issued laws in a timely fashion, nor provided directions to aid implementation, and some regulations even overlap, causing numerous difficulties for businesses. Hypothesis 4 reflects the status quo of Vietnamese policies and associated legislation. Ostensibly encompassing capability building, educational initiatives, and synchronous infrastructure for urban planning, present activities should be reassessed to support businesses and society more effectively.

6 | CONCLUSIONS

This study addresses the research gaps in the integration of CE with ID4.0 for GLS transitions and practices. The study proposes a conceptual framework and associated hypotheses. The data were collected through interviews and questionnaires with 210 valid respondents from universities, companies, and public sectors with expertise in logistics and supply chain fields.

The main findings indicate dominant impacts of ID4.0 on CEA and GLS, with CEA positively influencing GLS and CEF impacting CEA. Additionally, COL and CON have positive effects on GLS (Hypotheses 1–6 are accepted). However, there is no evidence supporting the impact of the GOP on CEA, as Hypothesis 4 is rejected.

6.1 | Theoretical implications

First, this study examines two key theoretical lenses of resources-based view and policy feedback theories in the context of GLS and contributes to the literature by highlighting the concepts of ID4.0, CE, and GLS transitions in light of a green and sustainable mindset. Second, the integration of CE and ID4.0 impacts on GLS in conceptual framework development and validation is investigated, which are filled the outlined research questions. The findings align with the research motivation and successfully address the two research objectives. Finally, the author believes this study is one of the first to further the development of a mutual connection between ID4.0 and CE adoption with GLS operations. Thus, future scholars should concentrate on obtaining a better understanding of how to utilize current green and sustainable mindsets and practices in the logistics and supply chain industry in order to fine-tune the results and the findings.

6.2 | Practical implications

The study provides practical solutions, benefiting companies, universities, and government sectors in implementing ID4.0 and CE adoption in GLS practices. It also contributes to training human resources for the logistics industry. The strong effects of ID4.0 underscore the significance of high-tech applications in driving strategic changes and optimizing GLS operations.

However, the weak relationship between government policy and CE adoption reflects existing challenges in strategic awareness and policy implementation. Addressing this weakness can improve legal services in government sectors and enable universities to develop modern logistics and supply chain programs to nurture skilled human resources.

6.3 | Limitations and future research

Since ID4.0, CE, and GLS remain the subject of research, certain limitations exist which need investigation. An example is how variables affect relationships and models for activities like manufacturing, agriculture, and services. Collecting data proved a challenge, hence experienced individuals were approached to ensure sufficient respondents. Although criteria were met for reliability testing, convergence validity, and discriminate validity, a common bias in data collection was evident (Jordan & Troth, 2020; Podsakoff et al., 2003). In response, it was discerned if recipients were competent to take part.

Further research should explore the application of other theories and algorithms, such as the natural resources-based view (NRBV) by Hart (1995), which extends the prior resource-based view (RBV) theory to support sustainable practices. Additionally, powerful algorithms like ANN, known for detecting non-linear relationships and exhibiting strong predictive performance, should be considered. To achieve this, a hybrid approach can be employed by integrating neural networks into the partial least squares (PLS) framework. This hybrid method has the potential to provide a precise assessment of the relative (both linear and non-linear) effects of each construct. Future research should investigate the proposed framework using the hybrid PLS-ANN method to attain an optimal evaluation of the impacts of each construct.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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APPENDIX A

TABLE A1 Constructs and variables measurement.

Constructs	Variables measured	Source
1. ID40	1. ID401: The number of high-tech applications	(Del Giudice et al., 2020)
	2. ID402: The number of digital processes	(Angolia & Pagliari, 2018)
	3. ID403: The model and its algorithms	(Kazancoglu et al., 2021)
2. CEA	4. CEA1: CE insights	(Hussain & Malik, 2020)
	5. CEA2: Awareness of sustainability	(Tura et al., 2019)
	6. CEA3: Awareness of the economic possibilities	(Bressanelli et al., 2019)
	7. CEA4: Potential environmental performance	(Jadhav et al., 2019)
	8. CEA5: Potential social performance	(Sarkis et al., 2020)
3. CEF	9. CEF1: Circular design strategies	(Kirchherr et al., 2017)
	10. CEF2: Design principles	(Patwa et al., 2021)
	11. CEF3: A systematic concept	(Ellen MacArthur Foundation, 2013)
	12. CEF4: Various participants	(Ellen MacArthur Foundation, 2013)
	13. CEF5: Construct of design by experienced people	(Ellen MacArthur Foundation, 2013)
4. GOP	14. GOP1: Legislation & regulations	(Harland et al., 2019)
	15. GOP2: Capacity building	(Gupta & Koontz, 2019)
	16. GOP3: Education and training	(Patwa et al., 2021)
	17. GOP4: Urban planning	(Ahluwalia, 2019)
5. COL	18. COL1: Collaboration with SC partners	(Hussain & Malik, 2020)
	19. COL2: SC-wide responsibility	(Herczeg et al., 2018)
	20. COL3: Data sharing	(Bressanelli et al., 2019)
6. CON	21. CON1: Similarity in operational practices	(Hussain & Malik, 2020)
	22. CON2: SC restructuring	(Sultan & Mativenga, 2019)
	23. CON3: SC structural flexibility	(De Angelis et al., 2018)
7. GLS	24. GLS1: Compliance with environmental law	(Hussain & Malik, 2020)
	25. GLS2: Reduction in energy consumption	(Hussain & Malik, 2020)
	26. GLS3: Reduction in hazardous materials	(Hussain & Malik, 2020)
	27. GLS4: Green IT	(Torasa & Mekhum, 2020)
	28. GLS5: Green transportation	(Khan & Zhang, 2021)
	29. GLS6: Green manufacturing	(Luu, 2021b)
	30. GLS7: Green storage	(Seroka-Stolka & Ociepa-Kubicka, 2019)
	31. GLS8: Green procurement	(Mardani et al., 2020)
	32. GLS9: Reverse logistics	(Rajput & Singh, 2022)

Source: Own processing.

APPENDIX B

RESEARCH PROCEDURE; *SOURCE*: OWN PROCESSING

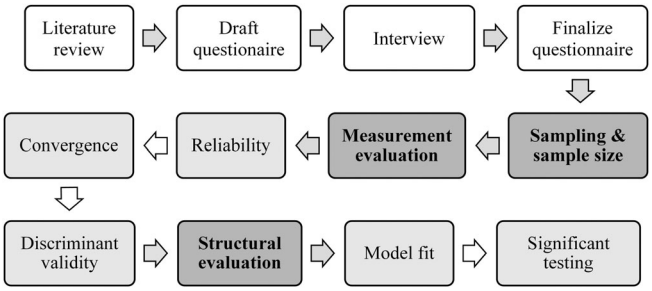

FIGURE B1 Research design procedure. A flow graph defines three main steps such as sample size, measurement test, and structural evaluation.

APPENDIX C

QUESTIONNAIRE (ENGLISH AND VIETNAMESE); *SOURCE*: OWN PROCESSING

My name is Luu Van Thanh, a Ph.D. student at Tomas Bata University in Zlin, the Czech Republic. I am investigating an integrated Industry 4.0 and Circular Economy model for Green Logistics and Sustainable Supply Chain. I am looking forward to receiving your comments on the model. I promise that the information you provide will be kept confidential and only used for the research process. I thank you very much for your answer.

Tôi là Lưu Văn Thành, là nghiên cúu sinh tiến sĩ tại Đại học Tomas Bata ở Cộng hòa Séc, hiện tôi đang nghiên cứu về áp dụng mô hình tích hợp kinh tế tuần hoàn và công nghệ 4.0 cho logistics xanh & chuỗi cung ứng bền vững. Tôi rất mong sẽ nhận được sự góp ý của Quý Anh/Chị cho mô hình mà tôi đang nghiên cứu. Tôi cam kết những thông tin Quý Anh/Chị cung cấp được bảo mật, chỉ phục vụ cho quá trình nghiên cứu. Tôi rất cảm ơn sự cộng tác của Anh/Chị.

I—Integrated Industry 4.0 (ID4.0) and Circular Economics (CE) Model and for Green Logistics and Sustainable Supply Chain (GLS).

Nội dung về mô hình tích hợp công nghệ 4.0 và kinh tế tuần hoàn cho logistics xanh và chuỗi cung ứng bền vững.

Circular economy and Industry 4.0 are emerging concepts. While ID4.0 resulted from technological innovation that focuses on production, a CE was formed from social innovation that focuses on consumption. There are cross-cutting and influencing business models and strategies. The concepts benefit each other (Cagáňová et al., 2020). ID4.0 technology is a foundation for CE strategies by addressing those technologies as a basis for sustainable management decision making.

There is a need for a better understanding of an integrated framework of ID4.0 and CE for green logistics and sustainable supply chain (GLS) that aims to improve three pillars of their sustainability performance, that is, economic, environmental, and social objectives.

The proposed framework for GLS is constructed of 7 factors (32 observed variables) with three main aspects of government, enterprise, and university. This research involves how CE and ID4.0 can influence and adopt for logistics and supply chain field to solve problems that arise in their operations along with the new trend of a green and sustainable mindset. In general, the circular economy can be considered as a tool to solve social-economic-environmental problems to achieve sustainable development goals in the context of environmental pollution and resource depletion.

Kinh tế tuần hoàn và Công nghệ 4.0 là những khái niệm mới nổi. Trong khi ID4.0 là kết quả của sự đổi mới công nghệ tập trung vào sản xuất, thì CE được hình thành từ sự đổi mới xã hội định hướng vào tiêu dùng. Chúng xuyên suốt, ảnh hưởng qua lại và mang lợi ích cho nhau. Công nghệ 4.0 là nền tảng cho các chiến lược kinh tế tuần hoàn làm cơ sở cho việc ra quyết định quản lý bền vững.

Nhu cầu cấp thiết phải hiểu rõ về khuôn khổ tích hợp của mô hình kinh tế tuần hoàn và công nghệ 4.0 cho lĩnh vực logistics xanh và quản lý chuỗi cung ứng bền vững (GLS) nhằm mục đích cải thiện hoạt động bền vững, tức là thỏa cả ba mục tiêu kinh tế, môi trường và xã hội.

Khung đề xuất cho GLS được xây dựng bằng 7 nhân tố (32 biến quan sát) ở ba khía cạnh khảo sát chính là nhà nước, doanh nghiệp và trường đại học. Nghiên cứu này khảo sát ảnh hưởng và ứng dụng của kinh tế tuần hoàn và công nghệ 4.0 trong lĩnh vực logistics và chuỗi cung ứng để giải quyết các vấn đề nảy sinh trong hoạt động của nó theo tư duy xanh và bền vững. Nhìn chung, kinh tế tuần hoàn có thể coi là công cụ giải quyết các vấn đề xã hội—kinh tế—môi trường nhằm đạt được các mục tiêu phát triển bền vững trong bối cảnh ô nhiễm môi trường và cạn kiệt tài nguyên.

1. Please give some information about your understanding of CE and ID4.0? Please tick (X) on the correct box.

Anh/Chị hãy cho biết một vài thông tin về CE và ID4.0. Xin hãy tích (X) vào ô mà Anh/Chị thấy đúng.

☐ Your organization has applied new business models and high-tech in its operations. (*Công ty Anh/Chị có áp dụng các mô hình kinh doanh mới và công nghệ cao trong hoạt động*).

☐ You have knowledge/information of CE & ID4.0 (*Anh/Chị có hiểu biết/thông tin về kinh tế tuần hoàn và công nghiệp 4.0*).

☐ You have been trained in CE for the last 5 years (*Anh/Chị được đào tạo về kiến thức về kinh tế tuần hoàn trong thời gian 5 năm gần đây*).

☐ You have been trained in the new technologies in ID4.0 for the last 5 years (*Anh/Chị được đào tạo về các công nghệ mới trong Công nghiệp 4.0 trong thời gian 5 năm gần đây*).

☐ You have studied, researched, and taught on the application of CE, ID4.0 and GLS (*Anh/Chị từng tìm hiểu, nghiên cứu và giảng dạy về việc áp dụng mô hình kinh tế tuần hoàn, công nghệ 4.0, cũng như lĩnh vực logistics và chuỗi cung ứng*).

If you do not have any understanding of CE and ID4.0, the survey ends here. If you choose any of the above options, please continue the survey. Thank you very much.

Nếu Anh/Chị không có bất kỳ sự hiểu biết gì về kinh tế tuần hoàn và công nghiệp 4.0 thì cuộc khảo sát đến đây kết thúc. Nếu Anh/Chị chọn bất kỳ tùy chọn nào ở trên thì xin mời tiếp tục cuộc khảo sát. Cảm ơn Anh/Chị rất nhiều.

2. The factors of CE and ID4.0 model for GLS.

Please rate the importance of the factors in the proposed CE and ID4.0 model for GLS that I have given by ticking (X) in the appropriate boxes with the following convention:

(1: least important; 2: less important; 3: moderately important; 4: more important; 5: most important)

You rate the factors based on your knowledge and experience to answer the question "What factors are important for the proposed CE & ID4.0 model?" This question is NOT about evaluating the implementation in your company.

Anh/Chị hãy đánh giá sự quan trọng của các yếu tố trong mô hình CE & ID4.0 cho logistics xanh và chuỗi cung ứng bền vững mà tôi đã đưa ra bằng cách đánh dấu (X) vào các ô thích hợp với qui ước sau:

(1: Rất ít quan trọng; 2: Ít quan trọng; 3: Quan trọng; 4: Rất quan trọng; 5: Hoàn toàn quan trọng)

Anh/Chị hãy đánh giá các yếu tố dựa trên kiến thức và kinh nghiệm của mình để trả lời câu hỏi "Yếu tố nào là quan trọng của mô hình CE và ID4.0 được đề xuất?". Câu hỏi này KHÔNG đánh giá việc thực hiện trong công ty của Anh/Chị.

	Factors and observed variables (Các yếu tố và biến quan sát)	1	2	3	4	5
I	**Supply Chain Collaboration_COL (*Hợp tác trong chuỗi cung ứng*)**					
I.1	In the CE & ID4.0 model, GLS is enabled by collaboration with supply chain partners within and beyond the immediate industrial boundaries. *Trong mô hình kinh tế tuần hoàn và công nghệ 4.0, logistics xanh và chuỗi cung ứng bền vững được kích hoạt bởi sự hợp tác với các đối tác chuỗi cung ứng từ nhiều ngành công nghiệp.*	1	2	3	4	5
I.2	In the CE & ID4.0 model, GLS is enabled by a supply chain wide responsibility for implementing CE principles. *Trong mô hình kinh tế tuần hoàn và công nghệ 4.0, logistics xanh và chuỗi cung ứng bền vững được kích hoạt bởi trách nhiệm được phân bổ trên toàn chuỗi cung ứng cho việc thực hiện các nguyên tắc kinh tế tuần hoàn.*	1	2	3	4	5
I.3	In the CE & ID4.0 model, GLS is enabled by enhanced information sharing and technical support within the value chain. *Trong mô hình kinh tế tuần hoàn và công nghệ 4.0, logistics xanh và chuỗi cung ứng bền vững được kích hoạt nhờ sự tăng cường chia s thông tin và hỗ trợ công nghệ trong chuỗi giá trị.*	1	2	3	4	5
II	**Supply Chain Configuration_CON (*Cấu trúc chuỗi cung ứng*)**					
II.1	In the CE and ID4.0 model, GLS is enabled by the application of similar operational and logistical practices across the supply chain network *Trong mô hình kinh tế tuần hoàn và công nghệ 4.0, logistics xanh và chuỗi cung ứng bền vững được kích hoạt bằng cách áp dụng các thông lệ vận hành và phân phối logistics tương tự trong mạng lưới chuỗi cung ứng.*	1	2	3	4	5
II.2	In the CE & ID4.0 model, GLS is enabled by supply chain restructuring to include processes for end-of-life returns, managing the by-products, and waste produced during the production process.	1	2	3	4	5

(Continues)

	Factors and observed variables (Các yếu tố và biến quan sát)	1	2	3	4	5
	Trong mô hình kinh tế tuần hoàn và công nghệ 4.0, logistics xanh và chuỗi cung ứng bền vững được kích hoạt bằng cách tái cấu trúc chuỗi cung ứng, bao gồm các quy trình thu lợi nhuận cuối đời sản phẩm; quản lý các sản phẩm phụ, và chất thải tạo ra trong quá trình sản xuất.					
II.3	In the CE & ID4.0 model, GLS is enabled by a greater structural flexibility of the supply chain that breaks the "linear lock-in" and geographical barriers. *Trong mô hình kinh tế tuần hoàn và công nghệ 4.0, logistics xanh và chuỗi cung ứng bền vững được kích hoạt nhờ sự linh hoạt hơn về cấu trúc chuỗi cung ứng, giúp phá vỡ các rào cản địa lý.*	1	2	3	4	5
III	**Green Logistics and Sustainable Supply Chain_GLS (*Các hoạt động logistics xanh và chuỗi cung ứng bền vững*)**					
III.1	In the CE and ID4.0 model, the operations of GLS are in compliance with the applicable environmental laws and regulations by adopting of circular economy practices *Trong mô hình kinh tế tuần hoàn và công nghệ 4.0, hoạt động logistics xanh và chuỗi cung ứng bền vững tuân thủ các luật và quy định hiện hành về môi trường bởi ứng dụng các thực hành kinh tế tuần hoàn.*	1	2	3	4	5
III.2	In the CE & ID4.0 model, the operations of GLS in reducing energy consumptions by the adoption of circular economy practices. *Trong mô hình kinh tế tuần hoàn và công nghệ 4.0, hoạt động logistics xanh và chuỗi cung ứng bền vững giảm tiêu thụ năng lượng bằng cách áp dụng các phương thức kinh tế tuần hoàn.*	1	2	3	4	5
III.3	In the CE & ID4.0 model, the operations of GLS in reducing the usage of hazardous/toxic material by the adoption of circular economy practices. *Trong mô hình kinh tế tuần hoàn và công nghệ 4.0, hoạt động logistics xanh và chuỗi cung ứng bền vững giảm thiểu việc sử dụng vật liệu nguy hiểm/độc hại bằng cách áp dụng các thực hành kinh tế tuần hoàn.*	1	2	3	4	5
III.4	In the CE & ID4.0 model, the operations of GLS in enhancing the green information technology and communication by adopting circular economy practices. *Trong mô hình kinh tế tuần hoàn và công nghệ 4.0, vận hành logistics xanh và chuỗi cung ứng bền vững tăng cường công nghệ thông tin và truyền thông xanh bằng cách áp dụng các thông lệ kinh tế tuần hoàn.*	1	2	3	4	5
III.5	In the CE & ID4.0 model, the operations of the GLS in enhancing green transportation by adopting circular economy practices. *Trong mô hình kinh tế tuần hoàn và công nghệ 4.0, vận hành logistics xanh và chuỗi cung ứng bền vững tăng cường vận chuyển xanh bằng cách áp dụng các phương thức kinh tế tuần hoàn.*	1	2	3	4	5
III.6	In the CE & ID4.0 model, the operations of the GLS in enhancing green manufacturing by the adopting circular economy practices. *Trong mô hình kinh tế tuần hoàn và công nghệ 4.0, vận hành logistics xanh và chuỗi cung ứng bền vững tăng cường sản xuất xanh bằng cách áp dụng các phương thức kinh tế tuần hoàn.*	1	2	3	4	5
III.7	In the CE & ID4.0 model, the operations of the GLS in enhancing the green storage and packaging by the adopting circular economy practices. *Trong mô hình kinh tế tuần hoàn và công nghệ 4.0, vận hành logistics xanh và chuỗi cung ứng bền vững tăng cường tồn trữ và đóng gói xanh bằng cách áp dụng các phương thức kinh tế tuần hoàn.*	1	2	3	4	5

	Factors and observed variables (Các yếu tố và biến quan sát)	1	2	3	4	5
III.8	In the CE & ID4.0 model, the operations of the GLS in enhancing the green procurement by the adopting circular economy practices. *Trong mô hình kinh tế tuần hoàn và công nghệ 4.0, vận hành logistics xanh và chuỗi cung ứng bền vững tăng cường mua sắm xanh bằng cách áp dụng các phương thức kinh tế tuần hoàn.*	1	2	3	4	5
III.9	In the CE & ID4.0 model, the operations of the GLS in enhancing the reverse logistics and renewable materials by the adopting circular economy practices. *Trong mô hình kinh tế tuần hoàn và công nghệ 4.0, vận hành logistics xanh và chuỗi cung ứng bền vững tăng cường logistics ngược và vật liệu tái tạo bằng cách áp dụng các phương thức kinh tế tuần hoàn.*	1	2	3	4	5
IV	**CE adoption_CEA (*Ứng dụng kinh tế tuần hoàn*)**					
IV.1	A mutual understanding of CE principles and insights by management and employees enables a transition to GLS. Sự hiểu biết lẫn nhau về các nguyên tắc và giá trị ngầm của kinh tế tuần hoàn giữa ban *quản lý và nhân viên sẽ giúp chuyển đổi sang logistics xanh và chuỗi cung ứng bền vững.*	1	2	3	4	5
IV.2	General awareness of sustainability by management and employees enables a transition to GLS. Nhận thức chung về tính bền vững của cấp quản lý và nhân viên giúp chuyển đổi sang logistics *xanh và chuỗi cung ứng bền vững.*	1	2	3	4	5
IV.3	An awareness of the potential of CE for economic performance such as revenue gains and cost savings by management and employees enables a transition to GLS. Nhận *thức về tiềm năng của kinh tế tuần hoàn đối với các mục tiêu kinh tế như tăng doanh thu và tiết kiệm chi phí của ban quản lý và nhân viên sẽ cho phép chuyển đổi sang logistics xanh và chuỗi cung ứng bền vững.*	1	2	3	4	5
IV.4	An awareness of the potential of CE for environmental performance such as reduction on CO_2 emission and hazardous materials by management and employees enables a transition to GLS. Nhận thức về tiềm năng của kinh tế tuần hoàn đối với các mục tiêu môi trường như việc *giảm phát thải CO_2 và giảm sử dụng vật liệu nguy hiểm của ban quản lý và nhân viên sẽ cho phép chuyển đổi sang logistics xanh và chuỗi cung ứng bền vững.*	1	2	3	4	5
IV.5	An awareness of the potential of CE for social performance such as reduction in the unemployment rate and covid-19 affects by the management and employees enables a transition to GLS. Nhận *thức về tiềm năng của kinh tế tuần hoàn đối với các mục tiêu xã hội như việc giảm tỉ lệ thất nghiệp và các tác động của covid-19 của ban quản lý và nhân viên sẽ cho phép chuyển đổi sang logistics xanh và chuỗi cung ứng bền vững.*	1	2	3	4	5
V	**CE Framework Design_CEF (*Thiết kế khung kinh tế tuần hoàn*)**					
V.1	Design for "systems change" when considering any circular design strategy such as the framework of various Rs strategies, for example, the 3R (reduce-reuse-recycle)/4R/10R/ReSOLVE/other CE strategies. *Thiết kế để "thay đổi hệ thống" khi xem xét bất kỳ chiến lược thiết kế tuần hoàn nào, chẳng hạn như các chiến lược R, ví dụ: chiến lược 3R (giảm thiểu-tái sử dụng-tái chế), hoặc 4R/10R/ReSOLVE/các chiến lược CE khác.*	1	2	3	4	5
V.2	Design follows the basic principles, such as Design out waste (reduce)/Design for reuse (reuse)/Build resilience through	1	2	3	4	5

(Continues)

	Factors and observed variables (Các yếu tố và biến quan sát)	1	2	3	4	5
	diversity (recycle)/Rely on energy from renewable sources (recovery)/Think in "systems" *Thiết kế luôn theo các nguyên tắc cơ bản: thiết kế loại bỏ chất thải (giảm thiểu)/Thiết kế để tái sử dụng (tái sử dụng)/Xây dựng khả năng phục hồi (tái chế)/Dựa vào năng lượng từ các nguồn tái tạo (phục hồi)/Tư duy hệ thống.*					
V.3	Design by systematic thinking for optimization. *Thiết kế theo tư duy hệ thống để tối ưu hóa.*	1	2	3	4	5
V.4	Design with different participants in the value chain. *Thiết kế với nhiều thành phần tham gia khác nhau trong chuỗi giá trị*	1	2	3	4	5
V.5	Design with "hands-on" experiences. *Thiết kế với trải nghiệm "thực hành."*	1	2	3	4	5
VI	ID4.0 Technology_ID4.0 (*Ứng dụng công nghệ 4.0*)					
VI.1	High-tech applications are one of the fundamental values in the organization, such as IoT, artificial intelligence, robot applications, blockchain technologies, etc. *Ứng dụng công nghệ cao là một trong những giá trị nền tảng của tổ chức, như ứng dụng internet vạn vật (IoT), Trí tuệ nhân tạo, người máy, các công nghệ blockchain, ….*	1	2	3	4	5
VI.2	Level of modern systems applied in the operations: MRP/MRPII/ERP, machine learning, etc. *Mức độ ứng dụng các hệ thống hiện đại trong các hoạt động doanh nghiệp, như ứng dụng hệ thống hoạch định nguồn nguyên liệu/nguồn lực sản xuất/nguồn lực doanh nghiệp (MRP/MRPII/ERP), máy học, ….*	1	2	3	4	5
VI.3	Level of model and algorithms applied in the systems: optimization models/heuristic/meta-heuristic algorithms, and/or continuous improvement projects deployment, etc. *Mức độ ứng dụng các mô hình và các thuật toán tối ưu trong các hệ thống, như thuật toán heuristic/meta-heuristic, tối ưu hóa, và/hoặc thực hiện các dự án cải tiến liên tục, ….*	1	2	3	4	5
VII	Government Policies_GOP (*Chính sách, luật nhà nước*)					
VII.1	The appropriate level of legislation, regulation, and standards development as well as definitions of policy-related barriers for GLS in the CE context. *Mức độ quan trọng của việc phát triển các luật định, quy định và tiêu chuẩn phù hợp, cũng như việc xác định các rào cản liên quan đến chính sách đối với logistics xanh và chuỗi cung ứng bền vững trong bối cảnh kinh tế tuần hoàn.*	1	2	3	4	5
VII.2	Government policies promote the capacity building for GLS in the context of CE. *Các chính sách của chính phủ thúc đẩy xây dựng năng lực cho logistics xanh và chuỗi cung ứng bền vững trong bối cảnh kinh tế tuần hoàn.*	1	2	3	4	5
VII.3	Plan of education and training to support and facilitate the thinking, behavior, and operations of organizations with a green and sustainable mindset. *Kế hoạch giáo dục và đào tạo nhằm hỗ trợ và tạo điều kiện cho tư duy, hành vi, và hoạt động của các tổ chức theo tư duy xanh và bền vững.*	1	2	3	4	5
VII.4	Urban planning: Construction of synchronous infrastructure for GLS in the context of CE. *Quy hoạch đô thị: xây dựng cơ sở hạ tầng đồng bộ cho logistics xanh và chuỗi cung ứng bền vững trong bối cảnh kinh tế tuần hoàn.*	1	2	3	4	5

II. Phần câu hỏi mở.

1. Do you have any comments on the integrated CE & ID4.0 model for GLS above?

Anh/Chị có đóng góp ý kiến gì cho mô hình trên?

.....

.....

2. In addition to the above factors, what factors belong to the CE & ID4.0 model for GLS that I have not mentioned (for example, your own way for the application of CE and ID4.0 in your company).

Ngoài các yếu tố trên, theo Anh/Chị các yếu tố nào thuộc mô hình CE & ID4.0 trong lĩnh vực logistics xanh và chuỗi cung ứng bền vững mà tôi chưa nhắc đến (Ví dụ như việc áp dụng cụ thể về CE và ID4.0 trong doanh nghiệp của Anh/Chị).

.....

.....

III. General information section *(Phần thông tin tổng quan).*

1. **Please tell us about the field of the company for which you are working:**

Vui lòng cho biết về lĩnh vực hoạt động của công ty Anh/Chị đang làm việc:

☐ Universities (*Các trường đại học*).
☐ Government/state sectors (*Các tổ chức công, nhà nước*).
☐ Companies (*Các công ty đa quốc gia, công ty nhà nước, công ty tư nhân*).
☐ Others (*Khác*).

2. **Please tell us about your position:**

Xin vui lòng cho biết về vị trí Anh/Chị đang làm việc:

☐ Directors/entrepreneurs (*Tổng giám đốc/chủ doanh nghiệp*).
☐ Managers/officers (*Giám đốc/trưởng/phó phòng*).
☐ Supervisors (*Quản đốc*).
☐ Professor/lecturers (*Giáo sư/Giảng viên*).
☐ Others (*Khác*).

3. **How long have you worked?**

Vui lòng cho biết số năm kinh nghiệm của Anh/Chị?

☐ Under 5 years (*Dưới 5 năm*) ☐ 5–10 years (*5–10 năm*)
☐ 11–15 years (*11–15 năm*) ☐ 16–20 years (*16–20 năm*)
☐ Above 20 years (*Trên 20 năm*).

Thank you very much for your cooperation.

QUESTIONNAIRE (ENGLISH AND CZECH); *SOURCE*: OWN PROCESSING

My name is Luu Van Thanh, a Ph.D. student at Tomas Bata University in Zlin, the Czech Republic. I am investigating an integrated model of Industry 4.0 and Circular Economy for Green Logistics and Sustainable Supply Chain. I am looking forward to receiving your comments on the model. I promise that the information you provide will be kept confidential and only used for the research process. I thank you very much for your answer.

Jmenuji se Luu Van Thanh, Ph.D. jsem student Univerzity Tomáše Bati ve Zlíně, Česká republika. Zkoumám integrovaný model Průmyslu 4.0 a cirkulární ekonomiky pro zelenou logistiku a udržitelný uzavřený dodavatelský řetězec. Budu rád za Vaše komentáře k uvedenému výzkumu. Vámi poskytnuté informace budou důvěrné a budou použity pouze pro výzkumný proces. Děkuji moc za odpověď.

I—Integrated Industry 4.0 (ID4.0) and Circular Economics (CE) Model and for Green Logistics and Sustainable Supply Chain (GLS).

Integrovaný model Průmyslu 4.0 a cirkulární ekonomiky pro zelenou logistiku a udržitelný uzavřený dodavatelský řetězec.

Circular economy and Industry 4.0 are emerging concepts. While ID4.0 resulted from technological innovation that focuses on production, a CE was formed from social innovation that focuses on consumption. There are cross-cutting and influencing business models and strategies. The concepts benefit each other (Cagáňová et al., 2020). ID4.0 technology is a foundation for CE strategies by addressing those technologies as a basis for sustainable management decision making.

There is a need for a better understanding of an integrated framework of ID4.0 and CE for green logistics and sustainable supply chain (GLS) that aims to improve three pillars of their sustainability performance, that is, economic, environmental, and social objectives.

The proposed framework for GLS is constructed of 7 factors (32 observed variables) with three main aspects of government, enterprise, and university. This research involves how CE and ID4.0 can influence and adopt for logistics and supply chain field to solve problems that arise in their operations along with the new trend of a green and sustainable mindset. In general, the circular economy can be considered as a tool to solve social-economic-environmental problems to achieve sustainable development goals in the context of environmental pollution and resource depletion.

Cirkulární ekonomika (CE) a Průmysl 4.0 (ID4.0) jsou nově se objevující pojmy. Zatímco ID4.0 je výsledkem technologické inovace, která se zaměřuje na výrobu, CE byla vytvořena ze sociální inovace, která se zaměřuje na spotřebu. Existují průřezově a ovlivňující obchodní modely a strategie. Koncepty si navzájem prospívají (Cagáňová, Chromjaková, and Sujanová, 2020). Technologie ID4.0 je základem strategií CE tím, že tyto technologie řeší jako základ pro rozhodování v oblasti udržitelného managementu.

Je potřeba lépe porozumět integrovanému rámci ID4.0 a CE pro zelenou logistiku a udržitelný uzavřený dodavatelský řetězec, jehož cílem je zlepšit tři pilíře výkonnosti v oblasti udržitelnosti, tj. ekonomický, environmentální a sociální.

Navrhovaný rámec pro GLS je sestaven ze 7 faktorů (32 pozorovaných proměnných) se třemi hlavními aspekty vládním, podnikovým a univerzitním. Tento výzkum se týká toho, jak mohou firmy pro CE a ID4.0 ovlivnit a přijmout koncept logistiky a dodavatelského řetězce, aby vyřešily problémy, které vznikají v jejich provozech spolu s novým trendem zeleného a udržitelného myšlení. Obecně lze oběhové hospodářství považovat za nástroj k řešení sociálně-ekonomicko-environmentálních problémů k

dosažení cílů udržitelného rozvoje v kontextu znečišťování životního prostředí a vyčerpávání zdrojů.

1. Please give some information about your understanding of CE and ID4.0? Please tick (X) on the correct box.

Uveďte prosím informace o tom, jak rozumíte CE a ID4.0? Zaškrtněte (X) ve správném políčku.

☐ Your organization has applied new business models and high-tech in its operations. (*Vaše organizace ve svých operacích aplikovala nové obchodní modely a špičkové technologie*).

☐ You have knowledge/information of CE & ID4.0 (*Máte znalosti/informace o CE a ID*4.0).

☐ You have been trained in CE for the last 5 years (*Posledních 5 let jste byli vyškoleni v CE*).

☐ You have been trained in the new technologies in ID4.0 for the last 5 years (*Posledních 5 let jste byli školeni v nové technologii v ID4.0*).

☐ You have studied, researched, and taught on the application of CE, ID4.0 and GLS (*Studovali jste, zkoumali a učili jste se o aplikaci CE, ID4.0 a GLS*).

If you choose any of the above options, please continue the survey. Thank you very much.

Pokud nerozumíte CE a ID4.0, průzkum zde končí. Pokud zvolíte některou z výše uvedených možností, pokračujte prosím v průzkumu. Děkuji mnohokrát.

2. The factors of CE and ID4.0 model for GLS (Faktory modelu CE a ID4.0 pro GLS).

Please rate the importance of the factors in the proposed CE and ID4.0 model for GLS that I have given by ticking (X) in the appropriate boxes with the following convention:

(1: least important; 2: less important; 3: moderately important; 4: more important; 5: most important).

You rate the factors based on your knowledge and experience to answer the question "What factors are important for the proposed CE & ID4.0 model?" This question is NOT about evaluating the implementation in your company.

Ohodnoťte prosím důležitost faktorů v navrhovaném modelu CE a ID4.0 pro GLS, které jste uvedli zaškrtnutím (X) v příslušných polích s následující konvencí:

(1: nejméně důležité; 2: méně důležité; 3: středně důležité; 4: důležitější; 5: nejdůležitější)

Faktory hodnotíte na základě svých znalostí a zkušeností, abyste odpověděli na otázku „Jaké faktory jsou důležité pro navrhovaný model CE & ID4.0?"

Tato otázka NENÍ o hodnocení implementace ve vaší společnosti.

	Factors and observed variables (Faktory a proměnné)	1	2	3	4	5
I	**Supply Chain Collaboration_COL (*Spolupráce v dodavatelském řetězci*)**					
I.1	In the CE & ID4.0 model, GLS is enabled by collaboration with supply chain partners within and beyond the immediate industrial boundaries. *V modelu CE & ID4.0 je GLS umožněna spoluprace s partnery v dodavatelském řetězci v rámci bezprostředních průmyslových hranic i za nimi.*	1	2	3	4	5
I.2	In the CE & ID4.0 model, GLS is enabled by a supply chain wide responsibility for implementing CE principles. *V modelu CE & ID4.0 je GLS umožněná široká odpovědnost dodavatelského řetězce za implementaci principů CE.*	1	2	3	4	5
I.3	In the CE & ID4.0 model, GLS is enabled by enhanced information sharing and technical support within the value chain. *V modelu CE & ID4.0 je GLS umožněné zlepšené sdílení informací a technická podpora v rámci hodnotového řetězce.*	1	2	3	4	5
II	**Supply Chain Configuration_ (*Konfigurace dodavatelského řetězce*)**					
II.1	In the CE and ID4.0 model, GLS is enabled by the application of similar operational and logistical practices across the supply chain network *V modelu CE a ID4.0 je GLS umožněná aplikace podobných provozních a logistických postupů v celé síti dodavatelského řetězce.*	1	2	3	4	5
II.2	In the CE & ID4.0 model, GLS is enabled by supply chain restructuring to include processes for end-of-life returns, managing the by-products, and waste produced during the production process.	1	2	3	4	5

	Factors and observed variables (Faktory a proměnné)	1	2	3	4	5
	V modelu CE & ID4.0 je GLS umožněná restrukturalizace dodavatelského řetězce tak, aby zahrnovala procesy návratupo skončení životnosti, správu vedlejších produktů a odpadu produkovaného během výrobního procesu.					
II.3	In the CE & ID4.0 model, GLS is enabled by a greater structural flexibility of the supply chain that breaks the "linear lock-in" and geographical barriers. *V modelu CE & ID4.0 je GLS umožněná větší strukturální flexibilita dodavatelského řetězce, která překonává „lineární uzamčení "a geografické bariéry.*	1	2	3	4	5
III	**Green Logistics and Sustainable Supply Chain_GLS (*Zelená logistika a udržitelné operace s uzavřeným dodavatelským řetězcem*)**					
III.1	In the CE and ID4.0 model, the operations of GLS in compliance with the applicable environmental laws and regulations by adopting of circular economy practices *V modelu CE a ID4.0 jsou operace GLS v souladu s platnými zákony a předpisy o životním prostředí přijetím postupů oběhového hospodářství.*	1	2	3	4	5
III.2	In the CE & ID4.0 model, the operations of GLS in reducing energy consumptions by the adoption of circular economy practices. *V modelu CE & ID4.0 operace GLS při snižování spotřeby energie přijetím postupů oběhového hospodářství.*	1	2	3	4	5
III.3	In the CE & ID4.0 model, the operations of GLS in reducing the usage of hazardous/toxic material by the adoption of circular economy practices. *V modelu CE & ID4.0 operace GLS umožňují snižování používání nebezpečných/toxických materiálů přijetím postupů oběhového hospodářství.*	1	2	3	4	5
III.4	In the CE & ID4.0 model, the operations of GLS in enhancing the green information technology and communication by adopting circular economy practices. *V modelu CE & ID4.0 operace GLS přispívají zlepšování zelených informačních technologií a komunikace přijetím postupů oběhového hospodářství.*	1	2	3	4	5
III.5	In the CE & ID4.0 model, the operations of the GLS in enhancing green transportation by adopting circular economy practices. *V modelu CE & ID4.0 operace GLS umožňují zlepšování zelené dopravy přijetím postupů oběhového hospodářství.*	1	2	3	4	5
III.6	In the CE & ID4.0 model, the operations of the GLS in enhancing green manufacturing by the adopting circular economy practices. *V modelu CE & ID4.0 operace GLS zlepšují procesy zelené výroby přijetím postupů oběhového hospodářství.*	1	2	3	4	5
III.7	In the CE & ID4.0 model, the operations of the GLS in enhancing the green storage and packaging by the adopting circular economy practices. *V modelu CE & ID4.0, operace GLS prospívají zlepšování ekologického skladování a balení přijetím postupů oběhového hospodářství.*	1	2	3	4	5
III.8	In the CE & ID4.0 model, the operations of the GLS in enhancing the green procurement by the adopting circular economy practices. *V modelu CE & ID4.0 operace GLS přispívají zlepšování zeleného zadávání zakázek přijetím postupů oběhového hospodářství.*	1	2	3	4	5

(Continues)

	Factors and observed variables (Faktory a proměnné)	1	2	3	4	5
III.9	In the CE & ID4.0 model, the operations of the GLS in enhancing the reverse logistics and renewable materials by the adopting circular economy practices. *V modelu CE & ID4.0 operace GLS přispívají zlepšování zpětné logistiky a obnovitelných materiálů přijetím postupů oběhového hospodářství.*	1	2	3	4	5
IV	**CE adoption_CEA (*Přijetí CE*)**					
IV.1	A mutual understanding of CE principles and insights by management and employees enables a transition to GLS. Vzájemné *porozumění principům CE a postřehů ze strany vedení a zaměstnanců umožňuje přechod na GLS.*	1	2	3	4	5
IV.2	General awareness of sustainability by management and employees enables a transition to GLS. *Obecné povědomí o udržitelnosti ze strany vedení a zaměstnanců umožňuje přechod na GLS.*	1	2	3	4	5
IV.3	An awareness of the potential of CE for economic performance such as revenue gains and cost savings by management and employees enables a transition to GLS. Povědomí *o potenciálu CE pro ekonomickou výkonnost, jako jsou zisky z příjmů a úspory nákladů ze strany vedení a zaměstnanců, umožňuje přechod na GLS.*	1	2	3	4	5
IV.4	An awareness of the potential of CE for environmental performance such as reduction on CO_2 emission and hazardous materials by management and employees enables a transition to GLS. Povědomí *o potenciálu CE pro environmentální výkonnost, jako je snížení emisí CO2 a nebezpečných materiálů ze strany vedení a zaměstnanců, umožňuje přechod na GLS.*	1	2	3	4	5
IV.5	An awareness of the potential of CE for social performance such as reduction in the unemployment rate and covid-19 affects by the management and employees enables a transition to GLS. Vědomí *potenciálu CE pro sociální výkonnost, jako je snížení míry nezaměstnanosti a dopadů Covid-19 ze strany vedení a zaměstnanců, umožňuje přechod na GLS.*	1	2	3	4	5
V	**CE Framework Design_CEF (*Návrh rámce CE*)**					
V.1	Design for "systems change" when considering any circular design strategy such as the framework of various Rs strategies, for example, the 3R (reduce-reuse-recycle)/4R/10R/ReSOLVE/other CE strategies. *Design pro „změnu systémů "při zvažování jakékoli cirkulární dizajnové strategie, jako je rámec různých strategií Rs, například strategie 3R (snížit-znovu použít-recyklovat)/4R/10R/ReSOLVE/další strategie CE.*	1	2	3	4	5
V.2	Design follows the basic principles, such as Design out waste (reduce)/Design for reuse (reuse)/Build resilience through diversity (recycle)/Rely on energy from renewable sources (recovery)/Think in "systems." *Dizajn se řídí základními principy, jako je navrhnout odpad (snížit)/navrhnout pro opětovné použití (opětovné využití)/ vybudovat odolnost prostřednictvím rozmanitosti (recyklovat)/ spoléhat se na energii z obnovitelných zdrojů (rekuperace)/ uvažovat v "systémech."*	1	2	3	4	5
V.3	Design by systematic thinking for optimization. *Navrhování systematickým myšlením pro optimalizaci.*	1	2	3	4	5
V.4	Design with different participants in the value chain. *Dizajn s různými účastníky hodnotového řetězce.*	1	2	3	4	5

	Factors and observed variables (Faktory a proměnné)	1	2	3	4	5
V.5	Design with "hands-on" experiences. *Dizajn s ‚praktickými'zkušenostmi.*	1	2	3	4	5
VI	**ID4.0 Technology_ID4.0 (*Technologie ID4.0*)**					
VI.1	High-tech applications are one of the fundamental values in the organization, such as IoT, artificial intelligence, robot applications, blockchain technologies, etc. *High-tech aplikace jsou jednou ze základních hodnot v organizaci, jako je IoT, aplikace umělé inteligence, robot, a technologie blockchain, atd.*	1	2	3	4	5
VI.2	Level of modern systems applied in the operations: MRP/MRPII/ERP, machine learning, etc. *Úroveň moderních systémů aplikovaných v provozech: MRP/MRPII/ERP, strojové učení atd.*	1	2	3	4	5
VI.3	Level of model and algorithms applied in the systems: optimization models/heuristic/meta-heuristic algorithms, and/or continuous improvement projects deployment, etc. *Úroveň modelu a algoritmů používaných v systémech: optimalizační modely/heuristické/metaheuristické algoritmy a/nebo zavádění projektů neustálého zlepšování atd.*	1	2	3	4	5
VII	**Government Policies_GOP (*Vládní politiky*)**					
VII.1	The appropriate level of legislation, regulation, and standards development as well as definitions of policy-related barriers for GLS in the CE context. *Odpovídající úroveň legislativy, regulace a vývoje norem, stejně jako definice bariér souvisejících s politikou pro GLS v kontextu CE.*	1	2	3	4	5
VII.2	Government policies promote the capacity building for GLS in the context of CE. *Vládní politiky podporují budování kapacit pro GLS v kontextu CE.*	1	2	3	4	5
VII.3	Plan of education and training to support and facilitate the thinking, behavior, and operations of organizations with a green and sustainable mindset. *Plán vzdělávání a školení na podporu a usnadnění myšlení, chování a provozu organizací s ekologickým a udržitelným myšlením.*	1	2	3	4	5
VII.4	Urban planning: Construction of synchronous infrastructure for GLS in the context of CE. *Urbanismus: výstavba synchronní infrastruktury pro GLS v kontextu CE.*	1	2	3	4	5

II. Phần câu hỏi mở

1. Do you have any comments on the integrated CE & ID4.0 model for GLS above?

Máte nějaké připomínky k výše uvedenému integrovanému modelu CE & ID4.0 pro GLS?

……
……

2. In addition to the above factors, what factors belong to the CE & ID4.0 model for GLS that I have not mentioned (for example, your own way for the application of CE and ID4.0 in your company).

Kromě výše uvedených faktorů, jaké faktory patří k modelu CE & ID4.0 pro GLS, které jsem nezmínil (například Váš vlastní způsob aplikace CE a ID4.0 ve Vaší společnosti).

……
……

III. General information section (*Obecné informace*)

1. **Please tell us about the field of the company for which you are working:**

☐ Universities (*Univerzitním*).
☐ Companies (*Podnikovým*).
☐ Government/state sectors (*Vládní/státní sektory*).
☐ Others (*Ostatní*).

2. **Please tell us about your position:**

Řekněte nám prosím o své pozici:

☐ Directors/entrepreneurs (*Ředitelé/podnikatelé*).
☐ Managers/officers (*Manažeři/Administrativa*).
☐ Supervisors (*Supervizoři*).
☐ Professor/lecturers (*Profesor/lektoři*).
☐ Others (*Ostatní: Konzultant/výzkumník/atd*).

3. **How long have you worked?**

Jak dlouho jste zaměstnán?

☐ Under 5 years (*Méně než 5 let*) ☐ 5–10 years (*5–10 let*)
☐ 11–15 years (*11–15 let*) ☐ 16–20 years (*16–20 let*)
☐ Above 20 years (*Víc než 20 let*).

Thank you very much for your cooperation.

Děkuji za Váš čas a spolupráci.

APPENDIX D

TABLE D1 Sample distribution.

Indicators		Frequency	Percentage
Working fields	Universities	76	36.2
	Companies	70	33.3
	Government sectors	39	18.6
	Others	25	11.9
Working positions	CEOs	37	17.6
	Managers	53	25.2
	Supervisors	14	6.7
	Professors/ lecturers	64	30.5
	Others	42	20.0
Working years of experience	Under 5 years	52	24.8
	5–10 years	36	17.1
	11–15 years	36	17.1
	16–20 years	47	22.4
	Above 20 years	39	18.6

Source: Own processing.

APPENDIX E

TABLE E1 The measurement model assessment.

Metrics		Indicators	Thresholds
Reliability	Indicators	Outer loadings	>0.70
	Constructs	Dijkstra-Henseler's rho (ρA)	>0.70
		Jöreskog's rho (ρc)	>0.70
		Cronbach's alpha (CA)	>0.70
Convergent validity		Average variance extracted (AVE)	>0.50
Discriminant validity		Heterotrait-monotrai (HTMT)	<0.85
		HTMT values by bootstrapping process	<1.00

Source: Hair et al. (2017).

TABLE E2 The structural model assessment.

Metrics	Thresholds	References
The coefficients of Pearson's determination (R^2)	• 0.02: small effect • 0.13: median effect • 0.26: large effect • 0.25: small effect • 0.50: median effect • 0.75: large effect	Cohen (1988) Hair et al., 2017, 2019
Predictive relevance (Q^2)	• >0.00: small predictive relevance. • >0.25: medium predictive relevance. • >0.50: large predictive relevance. • ≤0.00: lacks predictive relevance.	Hair et al., 2014
The standardized root means square residual (SRMR)	• =0.00: perfect fitting model • <0.08: good fit	Henseler et al., 2014 Hu & Bentler, 1998
Significant test	• *p*—value ≤0.05 or 5% • *t*—value ≥1.96	Hair et al., 2014, 2017, 2019

Source: Hair et al. (2017, 2019).