Green Logistics Driven Circular Practices Adoption in the Industry 4.0 Era: The Moderating Effect of Institutional Pressure and Supply Chain Flexibility

Abstract

The purpose of this study is to understand how green logistics affects Circular Economy (CE) adoption in the era of Industry 4.0 (I4.0). By taking many green initiatives, the logistics sector is showing its serious concern towards environmental issues. Stakeholders look forward to implementing sustainable logistics and circular practices to deal with these critical issues such as waste generation, resource scarcity, use of renewable resources, climate change etc. This study examines the relationships between green logistics practices, I4.0 technologies, and CE adoption The study also examines the moderating effect of institutional pressure and supply chain flexibility on the aforementioned relationships. A total of 162 responses were collected and a Partial Least Square-Structural Equation Modelling (PLS-SEM) method was employed to analyse the data; this method has high predictive power. The results from the study are: a) firms can enhance CE adoption driven by I4.0 technologies with green logistics practices as a mediator b) the moderating effect of supply chain flexibility is found to be significant whereas the moderating effect of institutional pressure is found to be insignificant. This study provides several managerial and theoretical implications.

Keywords: Industry 4.0; Green logistics; Circular Economy; Supply chain flexibility; Institution pressure.

1. Introduction

The rise in environmental concerns that have threatened humanity has spotlighted the need to save the environment (Agyabeng-Mensah et al., 2020). Specifically, the manufacturing and logistics sectors are centre stage due to their large contributions to CO_2 emissions (Baah et al., 2020b). Many environmental initiatives have been undertaken to mitigate the negative impacts of the increasing number of vehicles, traffic congestions due to increasing e-commerce companies, delivery needs as well as global warming. The logistics sector needs to be thoroughly examined (de Mello Bandeira et al. 2019; Anosikea et al., 2021). It is vital to take green initiatives in the logistics sector. Green Logistics (GL) has been extensively discussed given recent technological advancement, enhanced competition and sustainable benefits (Jazairy et al., 2021; Feng et al., 2022). Continuous economic growth in countries flags up sustainable transportation, distribution, and green monitoring. GL have thus gained prominent attention in research (Baah 2019; Zhen, 2020; Suki et al., 2022). Studies have looked at how firms face challenges in implementing Green Logistics Practices (GLP) but due to the continuous stress on the planet's natural resources, organisations' operational practices are questioned given the need to adopt greener practices (Cousins et al., 2019; Kumar and Barua, 2022). The institutions of traditional linear economies are in a search for circular models, structures, and practices to move to the path of Circular Economy (CE) practices. Thus, more studies are required to examine the gap in current practices of organizations (de Kwant et al., 2021).

CE philosophy is not new but the concept, principles, practices and implementation are still in a nascent phase (Farooque et al., 2022). It has brought a new economic methodology that aims to reintroduce waste as a source, helping to transform from a linear model into a circular supply chain (Brändström and Eriksson, 2022). Although, the definition of CE still lacks consensus, the majority of countries have agreed that the existing business models, approaches and operational activities have to re-plan, rethink and redesign to reduce waste and environmental degradation (Stumpf, 2021; Sarkar et al. 2022). CE is achievable by sustainable practices in design, repair, reuse and recycling (Kamble et al., 2021; Charef et al., 2022). Countries such as France, Japan, Germany, UK and China have developed global CE policies and adopted practices to redesign their SCs, but in India, such development is still in the initial phase (Sawe et al., 2021; Luthra et al., 2022). Although many economies are emerging with majorities of young populations and developing industrial processes, they still face numerous challenges (Luthra et al., 2022). With the growing concern towards environmental issues caused by the logistics sector, sustainable practices have been initiated to conciliate stakeholders' worries (Kijewska et al., 2021). Stakeholders are looking forward to implementing sustainable logistics and circular practices to deal with critical issues such as waste generation, resource scarcity, use of renewable resources, climate change etc. to facilitate CE transition (Kristoffersen et al., 2020; D'Amico et al., 2021, Magazzino and Falcone, 2022). Also, firms now focus on reducing logistics costs, developing infrastructure and strengthening collaborative networks to enhance their contributions toward sustainable development (Wu and Yang, 2021). Advanced technologies, including the Internet of Things (IoT), Artificial Intelligence (AI), Augmented Reality (AR) and Digital Twins (DT) etc., optimize performance (Blichfeldt and Faullant, 2021; Rad et al., 2022). When usage of the cyber-physical system in manufacturing facilitates proper execution, scheduling of production and consumption, a reduction in total costs is expected (Blichfeldt and Faullant, 2021). In the transition to CE, the role of logistics is to facilitate the efficient flow of materials and embrace CE completely. Although the economy may benefit from CE practices in all industries, there is a need to evaluate the current practices of firms to enhance the transition.

The Indian manufacturing sector has emerged as one of the highest growing sectors and has the potential to reach 1 trillion US$ by 2025 (Javed et al., 2021). Firms are looking forward to adopting sustainable manufacturing with a CE perspective to achieve sustainable development (Bag and Pretorius, 2020; Shayganmehr et al., 2021; Lahane and Kant, 2022). Also, to optimise their performance level and achieve cost reduction, firms are sharing their supply chains and distribution network infrastructures to improve their environmental performance (Khan et al., 2021). Organizations in the current regulatory and economic environment face numerous blockades to supply chain flexibility for adopting CE (Bai et al. 2020; Dongfang et al., 2022). Also, with the changing environment, firms are absorbing flexibility in their supply chains. This flexibility can be explained as the ability to remain responsive to the fluctuating market affecting cost and effectiveness. It helps firms to respond to changing green requirements and regulations towards environmental protection (Bai and Sarkis 2019).

Previous studies have shown that Industry 4.0 Technologies (ITE) and green practices may provide impetus for development into a sustainable economy and to support CE adoption (Bag et al., 2021; Maiurova et al., 2022). But in India, research is limited only to the conceptual framework of CE practices. To date, CE in developing countries is associated with previous studies elaborating its inter-relationship through the maturity thinking model (Kristoffersen et al. (2020), but how both fields are influenced through GLP is still unexplored. The other issue is the limited knowledge of CE and its application (Walker et al., 2021). Previous models have shown optimism for proposing the CE model and thus it requires more in-depth examination (Awan et al., 2021). This study proposes to address this research gap and examine the influence of green logistics practices on CE practices (CEP) adoption in the presence of ITE in the context of the manufacturing industry. Further, Institution Pressure (IP) and the Supply Chain Flexibility (SCF) effect have been examined to understand the current pressure exerted by digital transformation. The research questions (RQs) based on this gap are as follows:

RQ1*: What is the impact of ITE on CEP adoption in manufacturing firms?*

RQ2*: Do GLP mediate the ITE and CEP adoption relationship?*

RQ3*: Do IP and SCF have a moderating influence on the interrelationships between GLP, ITE and CEP?*

The study has established a theoretical framework grounded on Resource Based View (RBV) and Institutional Theory. Previous studies have focused on green logistics (Khan, 2019; Liu and Ma, 2022) and CE practices but no study has empirically examined how green logistics affect circular practices adoption. This study has tested a hypothesized model through structural equation modelling and also the role of SCF and IP, moderating the relationship in emerging economies like India. The research objectives are as follows:

- To observe the influence of GLP on CEP in manufacturing firms in an emerging economy like India.
- To measure the mediating effect of GLP on the relationship between ITE and CEP adoption in manufacturing firms.
- To measure the moderating effects of IP and SCF on ITE and CEP adoption.

To achieve the above-mentioned objectives, the current study has proposed the model exhibited in Figure 1. Firstly, the operationalization of the constructs - GLP, CEP, ITE, and SCF - are explored through a review of previous literature. Further, a hypothesised model is developed; hypotheses are tested and relationships are established for predicting the model through Structural Equation Modelling (SEM). The moderating effects are measured using PROCESS MACRO 4.0 and interaction graphs are presented to show the relationships. The results are presented for decision makers to understand the contribution of green logistics. Circular economy practices adoption, moderating effects of institutional pressure and supply chain flexibility of manufacturing firms are explored.

The study is organised as follows. Section 2 presents the literature review and hypothesis development. Section 3 discusses the research methodology. Section 4 explains the research methodology. Section 5 elaborates on the findings of the study and discusses the main results. Section 6 concludes the study and notes the limitations of the study.

2. Literature Review

The current study has undertaken the theoretical foundation from two well-accepted theories i.e., Resource Based View (RBV) and Institutional Theory (IT). RBV is a popular theory that determines the resources that any firm can use to gain a competitive advantage (Barney, 1991). Previous research has recognized RBV as a theoretical lens to explain associations in the areas of management, supply chains, marketing etc. This theory asserts that resources can be combined and utilized together to create capabilities (Grant, 1991), helping to explore the internal sources of competitive advantage or how the resources of a firm have been supported to enhance performance (Mishra and Yadav, 2021). Golicic and Smith (2013) discussed the linkage between practices and operational performance, concluding that a firm could use a competitive advantage by knowing how it is related to the natural environment. RDV approach was utilised by Mao et al. (2017) to measure the inter-linkage between zero carbon commitment and firm performance. Ravichandran et al. (2005) showed that resources are possessed and are under the firm's control whereas capabilities represent the firm's ability to spot suitable resources to leverage business processes. Such capabilities are developed through the integration of technical, physical and human components. Previous studies have highlighted the interrelation between a firm's resources and performance outcomes (Kraatz and Zajac, 2001; Vrontis, 2020; Ansari et al., 2019). RBV is well accepted in disciplines such as operations management, supply chain management and sustainability etc., giving an appropriate lens on dynamic, environment and strategic management. This study has extended RBV theory with GLP focus on utilizing green practices to facilitate circular practices adoption for transformation into CE. Manufacturing supply chains are complex and to explore interrelationships among the concepts of GLP and CEP adoption, it is essential to develop a framework to explain these interrelationships.

Institutional theory states that an organization faces pressure from technical as well as institutional levels (Greening and Gray, 1994). With support from organizational institutional environments, the organisation's principles are shaped. This also ensures that the organization must comply with external regulations and norms (Oliver, 1991; Suchman, 1995). Institutional Pressure (IP) is the influence of the institutional environment including social norms, rules, and culture on the structure or behaviour of the organisation (Qian and Burritt, 2009). IP is divided into coercive, normative, and mimetic pressures. Previous studies have shown that rules, regulations, and government policies suggesting regulation for environmental protection and social responsibility substantially affect the sustainable supply chains of firms (Zhu et al., 2005; Bag et al., 2021). This theory is extended in the study by measuring the effect of institutional pressure on the GLP and CEP in the firms.

2.1 Green Logistics Practices (GLP)

GLP includes processing, sharing, transportation, storage and material handling, and distribution. Previous studies have discussed green transportation, sustainable distribution, monitoring and energy usage (Baah, 2020; Feng et al., 2022; Kumar and Barua, 2022). Li et al. (2021) showed that GLP have a positive effect on environmental performance. On the contrary, Khan (2019) argued that the effect of GLP is insignificant on the financial performance of firms. The logistics functions are interdependent, making decision-making complex; therefore, a reusable packaging system may increase resource efficiency and reduce cost (Coelho et al., 2020). Since the last decade, studies have focused on logistics to uncover GLP and their linkage with reverse logistics, sustainability and distribution etc. (Zhang et al., 2020). With support from sustainable transportation, firms are using cleaner production through alternative fuels, reduced pollution, and less emissions. Reverse logistics have been a solution to the concerns raised over the environment and have highlighted the significance of reuse of materials (Govindan and Gholizadeh, 2021; Mishra et al., 2022). This involves return of recyclable products to manufacturers and improves waste management. Another green practice is sustainable distribution, including the flow of goods with less environmental impact while enhancing efficiency. Green monitoring and evaluation are practices under green logistics that have been proven to be a vital source by many researchers as they serve as a check on supply chains (Mardani et al., 2020; Khan et al., 2022). Firms are more conscious of the environment and are now seeking logistics service providers, expecting their partners to follow their environmental practices. Firms are tracking systems and evaluating performance through real-time information sharing that accelerates their processes (Khan et al., 2022)

2.2 Industry 4.0 Technologies

Due to changing market dynamics and needs, organizations are revisiting and adapting their existing processes. Managers are constantly looking into the adoption of advanced ITE to improve their supplier network and achieve their sustainability goals (Yadav et al., 2020; Chauhan et al., 2021; Ghadge et al., 2022). The financial, environmental and societal dimensions of systems need to be considered and thus, organizations are exploring new technologies that might help them to succeed. Various alternatives such as Big Data Analytics (BDA) and AI etc. are being implemented by firms to improvise their processes and performance (Kamble et al., 2019; Maiurova et al., 2022). ITEs have emerged as a solution to achieve sustainability with a major objective to augment the responsiveness and efficiency of manufacturing systems. These technologies work on horizontal and vertical integration and real-time flow of information among supply chains and therefore enhance the visibility of supply chains (Yu et al., 2022).

With the help of IoT, a network of interconnected devices can be developed where each device uniquely identifies and communicates with other devices without any human intervention. Another technology, BDA, can develop integrated data-driven business models to improve the quality of both data analytics (Bag et al., 2020) and circular performance (Awan et al., 2021). Cloud computing helps firms to store data on the internet and brings economies of operation, faster services and ease in accessibility for organizations (Sharma et al., 2019). Virtual reality and robotics are required for simplifying and improvising manufacturing processes. The adoption of a 'smart factory' has automated the process leading to greater accuracy and saving time. Digital development has enhanced the level of accuracy and brought suppliers to a single platform (Ye et al., 2022).

2.3 Circular Economy Practices Adoption

The linkage between circular supply chains and ITE in the context of the manufacturing industry has been explored by Nascimento et al. (2019). Most organizations are adopting circular strategies in their business units to ensure their survival in the competitive globalised market (Govindan and Hasanagic, 2018; Kumar et al., 2022). CE adoption has a huge potential for augmenting performance in the area of sustainability (Farooque et al., 2019; Lahane and Kant,2022). For a better understanding of the CE model and its link to green SC, a holistic model has been proposed by Kazancoglu et al. (2018). Jiao and Boons (2017) elaborated on key performance results obtained through a CE adoption policy.

CE is an emerging concept across the world (Patwa et al., 2021). CE thoughts and practices are crucial for all businesses and achieving sustainable outcomes for all industries. But the challenges in different economies vary, with emerging economies facing a different set of challenges. Emerging economies like India need high economic growth, but with growing populations, they contribute towards the generation of enormous waste and depletion of resources. In India, several government initiatives such as 'Digital India' and 'Aatm Nirbhar Bharat (Self Reliant India)' could support these opportunities by embracing CE principles and practices. The tendency of buying new products by consumers is the main barrier to adopting processes for selling remanufactured products; thus, the government and industries should look into ways to enhance the quality of recycled products so that the maximum number of customers can be attracted. There are many other challenges in adopting CE practices such as high initial cost, non-cooperation among business partners, SC complexity, inadequate information regarding the design and manufacturing of a product, skills gaps and long lead times (Farooque et al. 2019; Khan et al., 2021).

2.1 Hypothesis Development

This study has developed a research model by extending RBV and Institutional Theory. The model shows the relationship between the dependent variable (CEP) and independent variables ITE, mediator (GLP) and moderators (SCF, IP).

2.1.1 Industry 4.0 Technologies and Circular Economy Practices

The application of practices in logistics is to maximise the material and energy efficiency, improve value creation from waste and apply bio-mimicry principles by moving from non-renewable to renewable resources. This is enhanced by ITE such as IoT, AI and blockchain technologies (BCT) (Di Maria et al., 2022). The adoption of ITEs such as BDA and virtual reality (VR) by firms to simplify their manufacturing processes and therefore enhance performance has been assessed (Bag et al., 2020; Li et al., 2020). These technologies are also helpful in reducing greenhouse emissions and wastages; they facilitate advanced tracking and monitoring systems that support companies to perform more efficiently to improve their environmental impact. Also, for the social dimension, these technologies improve the knowledge level of employees and provide a safer working environment for staff. ITEs signify the firm's capabilities of information processing that optimise decision-making processes to enhance circularity in the business (Büchi et al., 2020; Ghadge et al., 2022). All these technologies have a direct relationship with achievement and are significant in enhancing integration among supply chains, thus resulting in sustainable organizational performance. The products in circular supply chains can be placed on a spectrum between the different firms working collaboratively either sequentially or in a fully coordinated supply chain. The traditional manufacturing supply chain shifts from an open loop to a closed loop where the product moves back to the initial production after reaching its end of life. Manufacturing companies use CE as a strategic approach that can offer a competitive advantage through lowering energy consumption and optimum resource utilisation (Jayarathna et al., 2022). The closed loop production system includes recycling, remanufacturing and reuse as EOL strategies to improve environmental performance (Buchi et al., 2020).

H1: ITE has a direct and significant impact on CEP adoption in manufacturing firms.

2.1.2 Industry 4.0 Technologies, Green Logistics Practices and Circular Economy Practices

With RBV theory contribution, firms are implementing environmental practices to protect the planet's resources and recycling used products for remanufacturing purposes (Baah et al., 2020). Reverse loops are the means of developing a competitive advantage to reduce the burden on the environment and bring ecological balance (Seroka-Stolka and Ociepa-Kubicka, 2019). GLP not only reduce environmental degradation but also reduce the operating cost of products (Khan, 2019; Liu and Ma, 2022). It has been observed that GLP have gradually extended from a few activities to many more practices to reduce the environmental impacts caused by logistics (Souza et al., 2022). GLP is the foremost trend in the current logistics industry and a keystone transition to CE since reverse logistics is the base for developing performance. CE practices can bring social and economic benefits to society through conscious consumption along with environmental protection. Previous literature suggests that there is a link between GLP and the performance of a firm (Bag and Pretorius, 2020). But there is a need to empirically explore the impact of GLP on CEP of manufacturing firms in the Industry 4.0 era. Based on this, the following hypotheses are proposed.

H2: ITE has a direct and significant effect on GLP of manufacturing firms
H3: GLP has a meditating effect on CEP adoption in manufacturing firms

2.1.3 Moderation effect of Institution Pressure and Supply Chain Flexibility

Institutional Theory focuses on how external factors can influence the shape of organizations (DiMaggio and Powell, 1983). External environmental regulations include technical standards, tax systems, emission permit systems, and resource consumption to reduce harmful effects on the environment. This theory suggests that as a rule, social institutions have a significant effect on a firm's behaviour and strategies (North, 2005). The process of aligning strategies and behaviours with an expectation of institutions is called institutional isomorphism (Ang et al., 2015). It has been shown that rules, regulations, government policies suggesting regulation for environmental protection and social responsibility substantially affect the sustainable supply chains of companies (Zhu et al., 2005). This theory is extended in the current study by measuring the impact of Institution Pressure (IP) on the GLP and CEP in firms.

H4: IP has a significant moderating effect on GLP and CEP interrelationship in manufacturing firms

SCF has been undertaken as a competitive response to the uncertainty that exists in how to preserve the environment (Merschmann and Thonemann, 2011). Flexibility is also required to optimize the flow of goods in the network of supply chains (Garavelli, 2003) and to mitigate risk from environmental uncertainty. Previous studies have concluded that an environment and organizational structure match fit is critical for a firm's performance (Wu, 2014; Wong, 2015). Flexibility in the supply network enhances the ability to respond to external environmental changes through an optimum allocation of resources (Srinivasan and Swink, 2018). The flexibility of supply chains helps to anticipate and adapt according to the external environment needs. Also, it has been observed that developing a relationship with supply chain partners needs to be checked for uncertainty (Sreedevi and Saranga, 2017). The current study posits that SCF may play a moderating role in the mediated relationship of GLP and CEP in firms. Therefore, the following hypothesis is proposed.

H5: SCF has a moderating effect on the relationship between GLP and CEP in manufacturing firms.

Built on the above elaboration, a model is developed as presented in Figure 1.

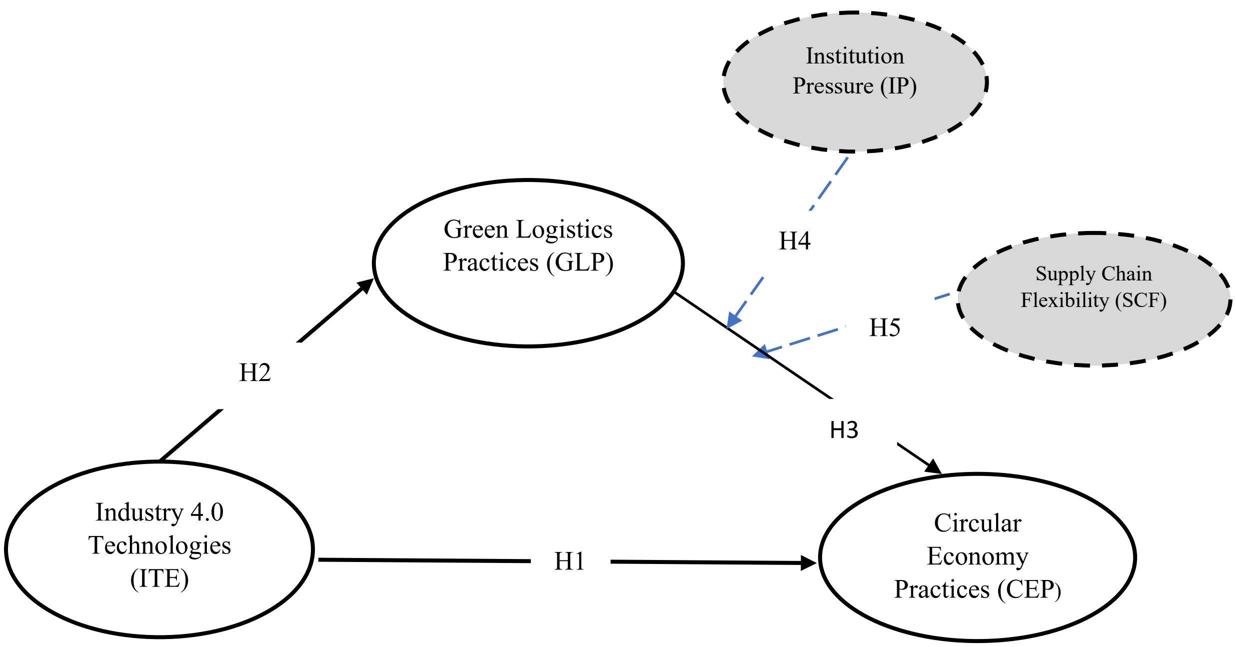

Figure 1: Proposed hypothesised model

3. Research Methodology

The current study has undertaken quantitative research using the survey method approach. A structured instrument was developed and shared via online and offline modes. The respondents were from North India from those distinct industries involved in electronic and electrical products, textiles, automobiles, and FMCG. A questionnaire was developed on the established scale from previous academic literature with a 5-point Likert scale and validation conducted in two phases. The framework for conducting the research has been shown in Figure 2.

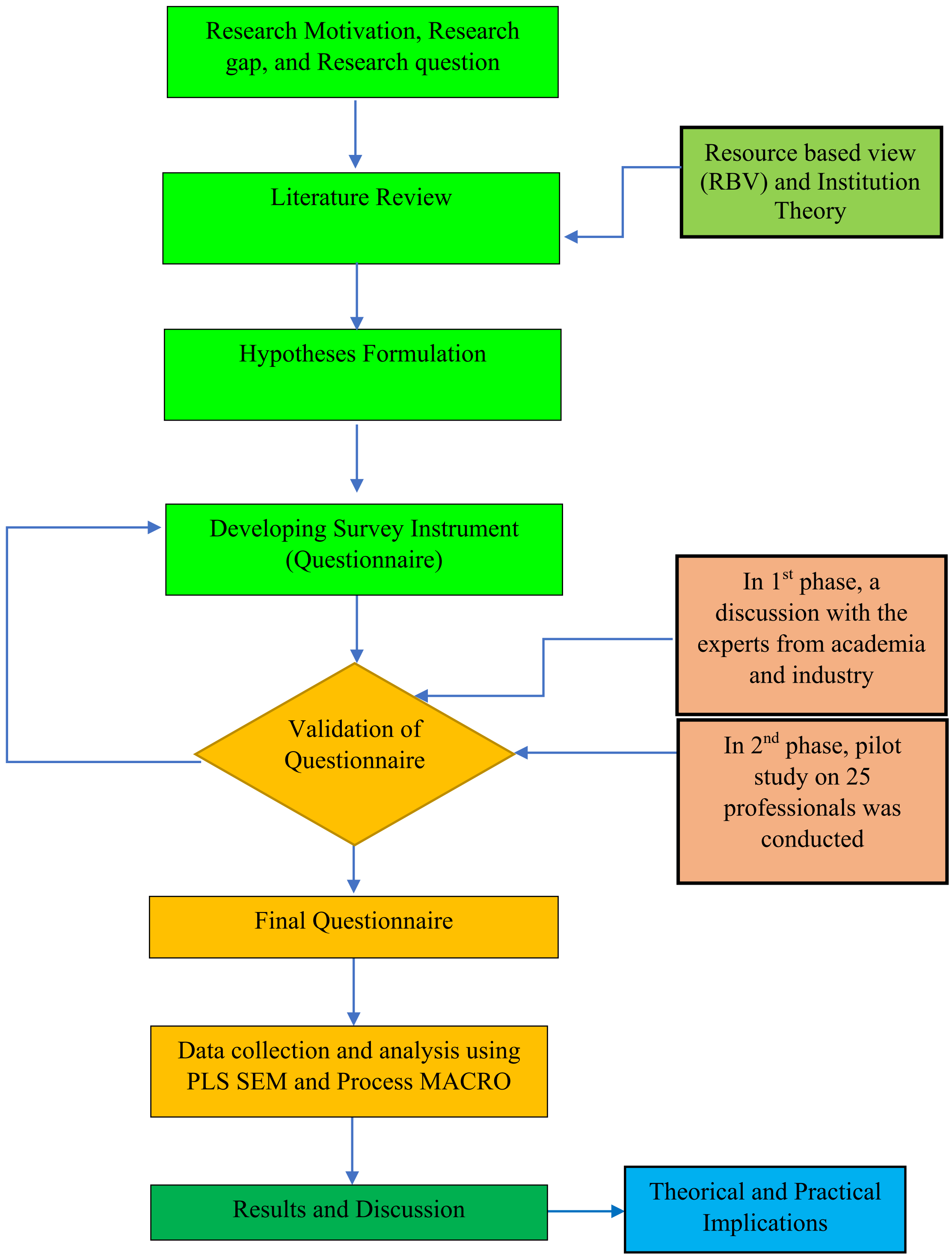

Figure 2: Research Framework

During the first phase, a dialogue with experts from academia and industry was arranged to check the measurement scales undertaken. The group of experts included five senior professors in the area of logistics and operations, and five professionals in the area of operations; all had experience of at least five years working in GLP and CEP. Based on the recommendations of these experts, the questionnaire was finalised. In the second phase, a pilot study was conducted with 25 professionals associated with logistics firms. The pilot study resulted in the acceptance of all the items undertaken in the study. Further, a total of 162 responses were received during the first quarter of the year 2022. Table 1 presents the demographic detail of the respondents.

Table 1: Sample description

Age of the respondents (in years)		
< 30	67	41.35
30-35	42	25.92
36-40	28	17.28
> 40	25	15.43
Industry		
Electronic and electrical products	55	33.95
Textile	15	09.25
Automobiles	57	35.18
FMCG	35	21.60
Position in the company		
Operations Manager	50	30.86
Logistics Manager	57	35.18
Sustainability Manager	54	33.33
Experience of the respondents (in Years)		
< 5	56	34.56
6-10	53	32.71
11-15	30	18.51
15+	23	14.19
Size of the firm		
< 100 employees	24	14.81
100-200 employees	37	22.84
200-300 employees	56	34.57
300+ employees	25	15.43

The age distribution included respondents in the age groups less than 30 years (41.35%), 30-35 years (25.92%), 36-40 years (17.28%), and > 40 years (15.43%). These managers are aware of GLP and CEP practices in organizations. The size of the firm has a distribution of <100 employees (14.81%); 100-300 employees (22.84%); 300-500 employees (34.57%); < 500 employees (15.43%). The respondents mainly belong to the automobile and electronics sectors and are designated in managerial positions. The established scales for GLP, IP, CEP, SCF and ITE were taken from previous literature (Benito and González, 2006; Colicchia et al., 2013; Baah, 2019) and items were modified as per the research questions. A model is built with five constructs and 23 variables. The study has employed a first order and reflective model to measure the measurement items of the constructs. The operationalization of the constructs is shown in Table 2.

Table 2: Constructs and Variables

Construct	Code	Variable	References
Industry 4.0 Technologies (ITE)	ITE1	The organization has implemented IoT in SCs partially or completely to enhance the circular loop model for reducing waste	Kamble et al., 2019; Frank et al., 2019
	ITE2	The organization has BDA in SCs partially or completely to enhance the circular loop model for reducing waste	
	ITE3	The organization has implemented CC partially or completely in SCs to enhance the circular loop model for reducing waste	
	ITE4	The organization has implemented AM partially or completely in SCs to enhance the circular loop model for reducing waste	
	ITE5	The organization has implemented AI partially or completely in SCs to enhance the circular loop model for reducing waste	
	ITE6	The organization has implemented Robotics partially or completely in SCs to enhance the circular loop model for reducing waste	
Green Logistics Practices (GLP)	GLP1	Using sustainable transportation for reducing CO_2 emissions	Benito and González, 2006; Sarkis et al., 2010; Colicchia et al., 2013; Bag et al., 2021
	GLP2	Preference for reusable and recyclable materials	
	GLP3	Promotion of sustainable packaging	
	GLP4	Enhances environmental information sharing related across the network	
	GLP5	Monitor and evaluation of environmental policies and practices	
Supply Chain Flexibility (SCF)	SCF1	Adjustment of the storage capacity if demand fluctuates	Sreedevi and Saranga, 2017
	SCF2	Adjustment of delivering capacity	
	SCF3	Making flexible multiple transportation modes for meeting the	

		delivery schedule	
Circular Economy Practices (CEP)	CEP1	Reduce practices for resource recovery	Calzolari et al., 2021
	CEP2	Redesign packaging	
	CEP3	Investments in plastic waste prevention	
	CEP4	Renewable energy & resource	
	CEP5	Reuse practices	
	CEP6	Recycle practices	
Institution Pressure (IP)	IP1	Regulations by central government towards the environment	Vanalle et al., 2019; Bag et al., 2021
	IP2	Regional environmental regulations	
	IP3	Environmental partnership with suppliers	

4. Results

The relationships among the GLP, CEP, ITE, IP and SCF are investigated with results shown in subsequent sub-sections. The values for AVE, Cronbach's alpha and composite reliability coefficients were computed.

4.1 Measurement Model

The measurement model is shown in Figure 3 presenting the variables of all the constructs. The following sections discuss the reliability and validity test.

4.1.1 Reliability

The reliability is checked through Composite Reliability (CR) and Cronbach's alpha. The Cronbach's alpha values are GLP = 0.759; CEP = 0.846; IP = 0.708; ITE = 0.897; SCF = 0.704. Composite Reliability values are GLP = 0.824; CEP = 0.886; IP = 0.810; ITE = 0.921; SCF = 0.839. These are presented in Table 3. Since Cronbach's alpha for all variables was greater than 0.7, these values were within the acceptable range as suggested by researchers (Cho, 2016; Hair et al., 2019). To assess the convergent validity, CR and Average Variance Extracted (AVE) estimates were calculated for each construct. CR values were greater than 0.8 for all constructs; AVE values are over 0.50. These are greater than the cut-off values as suggested by previous research (Fornell and Larcker, 1981; Hair et al., 2019).

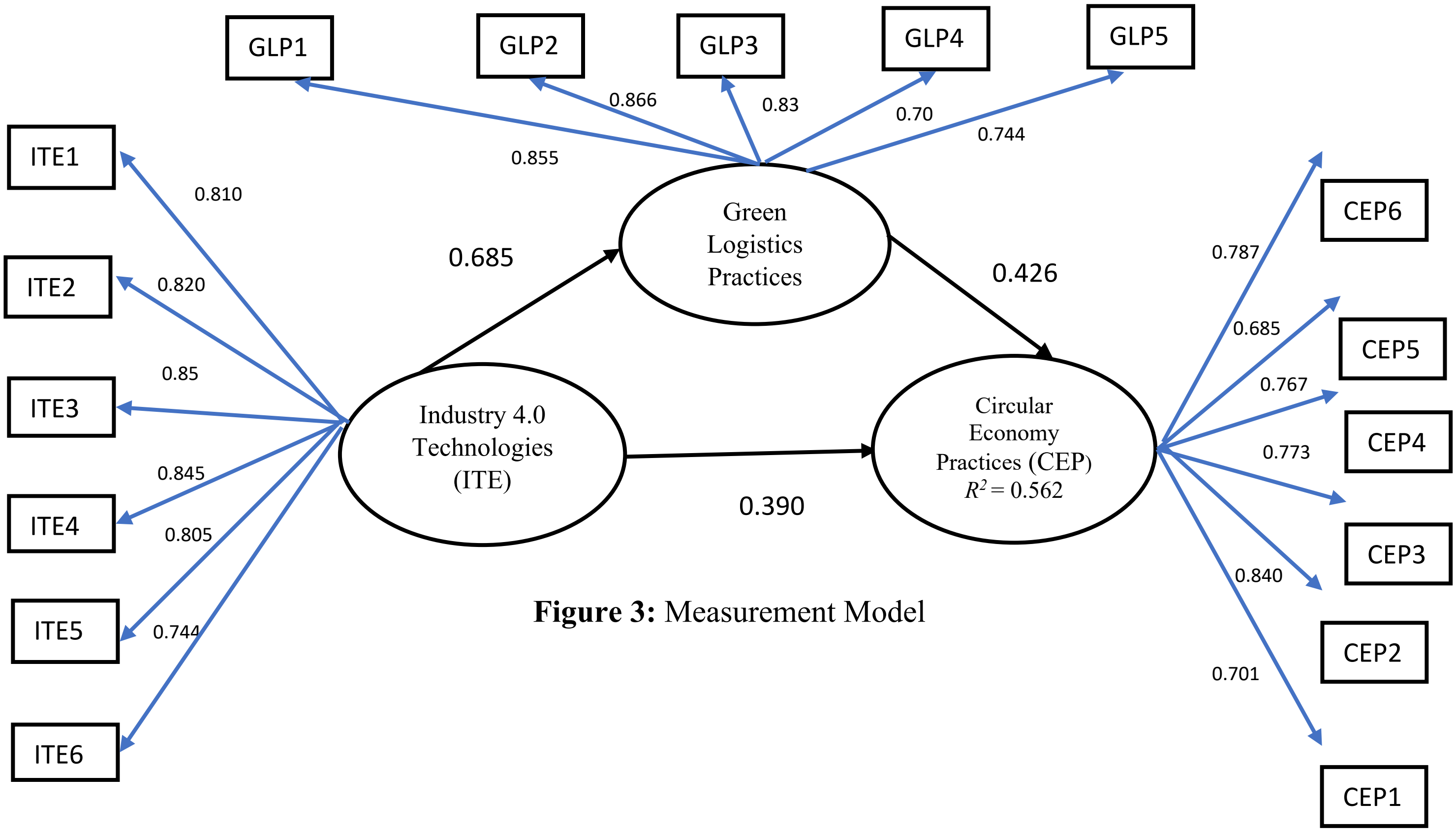

Figure 3: Measurement Model

4.1.2 Convergent Validity

This validity can be established if all the items load significantly on their denominated latent variables. The convergent validity has been assessed through factor loadings and average variance extracted (AVE). The values of factor loadings are shown in Table 3.

Table 3: Constructs Reliability and Validity

	Cronbach's Alpha	rho_A	CR	AVE
CEP ENV	0.846	0.856	0.886	0.567
GLP MEV	0.759	0.836	0.824	0.505
IP W	0.708	0.763	0.810	0.589
ITE EXV	0.897	0.902	0.921	0.661
SCF M	0.704	0.805	0.839	0.649

CEP=Circular Economy Practices adoption; GLP= Green logistics practices; IP= Institution Pressure; ITE= Industry 4.0 technologies; SCF= Supply chain flexibility; EXV=Exogenous Variable; ENV=Endogenous Variable; M=Moderator; W=Mediating Variable; AVE= Average Variance Extracted; CR= Composite Reliability

From Table 3, it is evident that the values have exceeded the recommended values. The values of composite reliability are more than 0.60 (Bagozzi and Yi, 1988) and values of AVE are higher than 0.50 (Fornell and Larcker, 1981) respectively.

4.1.3 Discriminant Validity

The discriminant validity was also checked based on the measurement given by Fornell and Larcker (1981) and through Hetero Trait Mono Trait (HTMT) ratio (Hair et al., 2019). It was found that the correlation values of HTMT ratio were far below the threshold values of 0.9, and hence provide additional support for the absence of discriminant validity. Further, in this study, the variance extracted estimates for all variables have a minimum value of 0.50, thus establishing the absence of discriminant validity. The values obtained are shown in Table 4.

Table 4: Discriminant validity (Fornell-Lacker Criterion)

	CEP	GLP	ITE
CEP	0.753		
GLP	0.694	0.709	
ITE	0.682	0.685	0.813

CEP=Circular Economy Practices adoption; GLP= Green logistics practices; IP= Institution Pressure; ITE= Industry 4.0 technologies; SCF= Supply chain flexibility

4.1.4 Common Method Bias and Non-Response Bias

The non-response bias was checked through the comparison of the first one hundred respondents (early respondents) and the other sixty-two respondents (late respondents) as suggested by earlier researchers (Lambert and Harrington, 1990; Chen and Paulraj, 2004). The *t*-test was conducted, and calculations made; based on the results, no significant difference was found between the groups' early respondents (n=100) and late respondents (n = 62). To check CMB, a full collinearity assessment approach is used. The researchers also conducted a statistical check of multi-collinearity by examining the Variance Inflation Factor (VIF) for each independent variable; these values are less than 3.3, as suggested by Hair et al. (2019). Harman’s single-factor analysis was performed showing that a single factor accounted for 42 per cent of variance. This indicates that common method bias has no adverse impact on the findings of the study (Podsakoff, 2003).

4.2 Structural Model

The bootstrapping method was used in PLS-SEM to check the direct and indirect effects on CEP. The hypotheses results obtained are shown in Table 5.

Table 5: The hypotheses results

	Direct effect	**Original Sample (O)**	**Sample Mean (M)**	**Standard Deviation (STDEV)**	**T Statistics (|O/STDEV|)**	**p-value**	**Decision**
Direct effect on CEP							
H1	ITE-> CEP	0.390	0.398	0.078	5.019	0.000	Significant
H2	ITE->GLP	0.685	0.686	0.042	16.15	0.000	Significant
H3	GLP->CEP	0.426	0.421	0.080	5.356	0.000	Significant
Mediating effect on CEP							
	ITE -> GLP -> CEP	0.292	0.289	0.059	4.923	0.000	Significant

CEP=Circular Economy Practices adoption; GLP= Green logistics practices; ITE= Industry 4.0 technologies.

4.3 Moderating Effects of IP and SCF

The moderating effects of IP and SCF have been measured through PROCESS MACRO 4.0. Using model 14, the moderating effect of IP and SCF on CEP adoption has been measured with the results shown in Table 6.

Table 6: Moderating effect of Institution Pressure

Model Summary	**Coeff.**	**SE**	***t***	***p***	**LLCI**	**ULCI**
constant	1.87	.1589	11.82	0.000	1.565	2.1934
ITE (X)	.2244	.0503	4.4598	0.000	.1250	.3238
GLP (M)	.3858	.0417	9.2529	0.000	.3035	.4682
IP(W)	.0178	.0293	.6065	.5451	-.0401	.0756
INT_1	.0094	.0268	.3521	.7252	-.0435	.0634
Product terms key:						
Int_1: GLP x IP						
Test(s) of highest order unconditional interaction(s):						
	R2-chng	F	df1	df2	p	
M*W	.0001	.1240	1.000	157.000	.752	
Direct effect of X on Y						
	Effect	se	t	p	LLCI	ULCI
	.2244	.0503	4.45	.0000	.1250	.3238
INDIRECT EFFECT: ITE -> GLP -> CEP						

Index of moderated mediation:						
	Index	BootSE	BootLLCI	BootULCI		
IP	.0098	.0277	-.0432	.0653		

CEP=Circular Economy Practices adoption; GLP=Green logistics practices; IP=Institution Pressure; ITE =Industry 4.0 technologies

The analysis is conducted at a level of confidence of 95 and the number of bootstrap samples for percentile bootstrap is 5000. The results of the moderating effect of SCF on GLP and CEP in manufacturing firms are shown in Table 7.

Table 7: Moderating effect of SCF

Model Summary	**Coeff**	**SE**	***t***	***p***	**LLCI**	**ULCI**
constant	2.0173	.1455	13.86	0.000	1.729	2.304
ITE(X)	.1916	.0457	4.187	0.000	.1012	.2819
GLP(M)	.3174	.0399	7.961	0.000	.2387	.3962
SCF (W)	.4207	.0813	5.171	.0000	-.2600	.5813
INT_1	-.2175	.0690	-3.150	.0020	-.3538	.0811
Product terms key:						
Int_1: GLP x SCF						
Test(s) of highest order unconditional interaction(s):						
	R2-chng	F	df1	df2	p	
M*W	.0098	9.26	1.000	157.000	.0020	
	Effect	Se	t	p	LLCI	ULCI
Direct effect of X on Y	.1916	.0457	4.187	.0000	.1012	.2819
INDIRECT EFFECT: ITE -> GLP -> CEP						
Index of moderated mediation:						
	Index	**BootSE**	**BootLLCI**	**BootULCI**		
SCF	-.2251	.0671	-.3522	-.0899		

CEP=Circular Economy Practices adoption; GLP= Green logistics practices; SCF=supply chain flexibility; ITE= Industry 4.0 technologies

The results obtained from PROCESS MACRO for both moderating variables are shown in Tables 6 and 7. Further, the effect of moderators is shown in Figures 4 and 5.

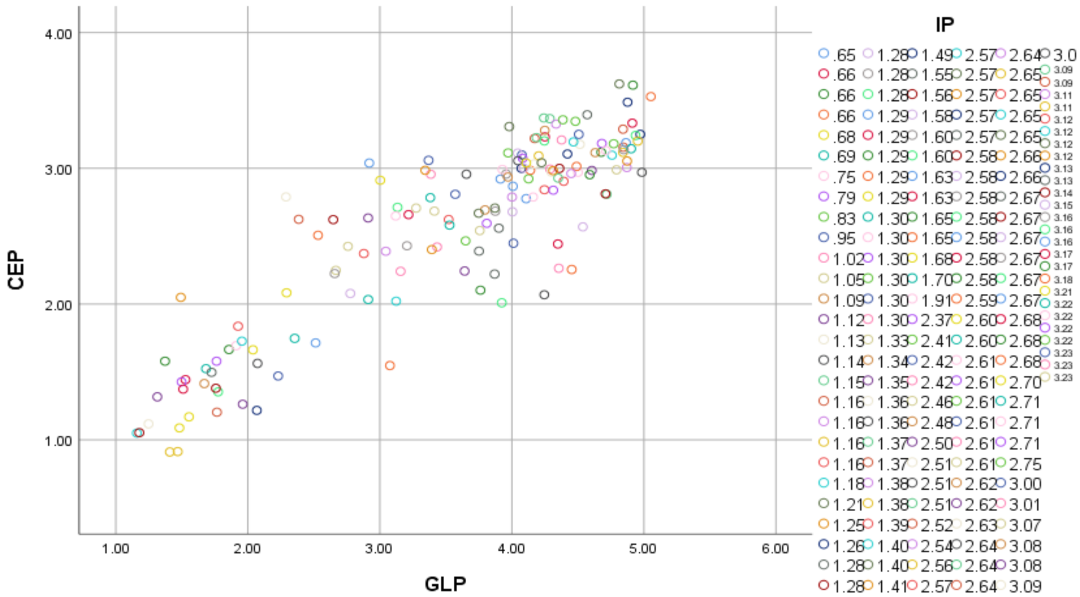

Figure 4: Moderating Effect of IP

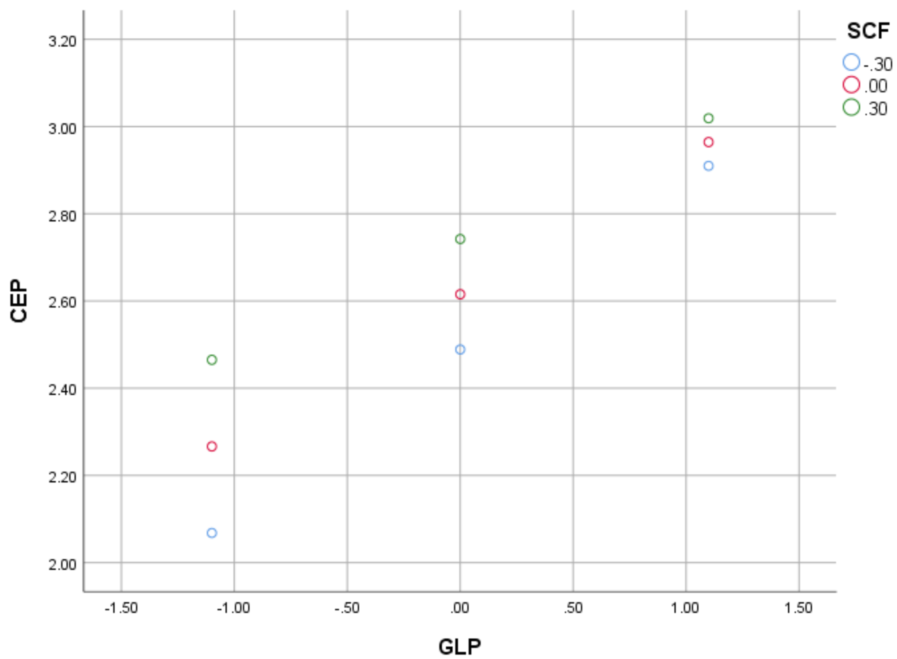

Figure 5: Moderating Effect of SCF

The interaction effect for IP is found to be insignificant (*p*-value = 0.725); the value is greater than 0.05, showing the insignificant moderation effect of IP at a 5% level of significance. Therefore, it is concluded that IP does not act as a moderator for GLP and CEP interrelationships. Table 6 shows the moderation effects of IP; hypothesis H5 is therefore rejected. (p-value >0.05). The moderation effect of SCF is found to be significant (*p*-value = 0.02); hence hypothesis H6 is accepted. The moderation effect of SCF is significant at a 5% level of significance. The results of moderating variables indicate that when the moderation level is medium, SCF does not moderate the relationship between GLP and CEP but when the level is low or high, it significantly affects the GLP and CEP interrelationship. When SCF levels are low, it moderates the relationship between GLP and CEP. This indicates that GLP is highly dependent on SCF for improved CEP adoption. Similarly, when SCF levels are high, the dependence on SCF for GLP is relatively less for improved CEP.

5. Discussion of Findings

The study has observed the impact of GLP on CEP adoption in manufacturing firms through a hypothesized model. A total of five hypotheses were proposed to test the relationships shown in Figure 1. A significant effect has been shown in the measurement model. The findings showed that GLP significantly influences a firm's performance since the significance level was less than 0.05. The study subsequently adds to current literature by confirming the positive link between GLP, ITE and CEP. Firms adopt CEP because of the distinct types of benefits such as economic, environmental, and social. The adoption of CEP will help in waste reduction, the optimum consumption of natural resources, and minimizing carbon emissions. Particularly in manufacturing firms, CEP pertain to both a) a facility of closed-loop for valuable materials and b) establishing the prototypes of product-as-a-service approaches. The examples of Volkswagen, and Renault show the development of specific product lines of remanufacturing (Calzolari et al., 2021). The findings show that ITE is implemented by firms to simplify their manufacturing processes; this consequently enhances the CEP of the firms. *Thus, hypothesis H1 is accepted (p<0.05; significant) showing that ITE has a significant effect on CEP adoption in manufacturing firms.* This finding aligns with previous research by Kristoffersen et al. (2021). This study observed that ITE helps in reducing greenhouse emissions and wastages and facilitates advanced tracking and monitoring systems that support companies to perform more efficiently from the environmental dimension. These technologies improve the knowledge level of employees and provide a safer working environment for staff (Herrmann et al., 2014). ITEs signify the firm's capabilities of information processing that optimise decision-making processes and make CEP more convenient for firms. Karaman (2020) viewed the substantial influence of GLP on a firm's performance. In the last 50 years, the energy consumption in the industrial sector has doubled and the cost has increased substantially. The sources are mainly non-renewable, and their environmental effects are significant. The goal of manufacturing firms is to minimize energy consumption through energy-efficient production processes that are made possible through green logistics practices and circular economy transition (Lui et al., 2021). GLP not only reduce environmental degradation but also reduce the operating cost of products (Khan, 2019). It has been seen that GLP have gradually extended from a few activities to a much larger number (Souza et al., 2022). *The hypothesis H2; ($p<0.05$; significant) shows that ITE has a direct significant effect on GLP implementation in manufacturing firms*. Along these lines, Bhattacharya and De, 2020 and Khan and Qianli (2020) observed that using renewable energy in operations may improve environmental performance, reduce carbon emissions and enhance the economic development of businesses. Thus, green logistics decisions related to renewable sources for transportation are anticipated to further support both the environmental (green) and economic performance of firms. With CEP adoption, social and economic benefits for society can be enhanced through conscious consumption along with environmental protection (Bag and Pretorius, 2020). Moreover, energy consumption can be reduced through more energy-efficient logistics and distribution processes including energy-efficient transportation. RBV theoretical perspective is highly significant in exploring the role of GLP adopted by firms to implement CEP in their practices. This theory is extended by considering that GLP may act as a competitive advantage for transformation into circular chains (*H3 is supported; $p < 0.05$; significant) showing that green logistics has a significant effect on CEP adoption in manufacturing firms*. Based on H1, H2 and H3, the mediating effect of GLP has been evident. From Table 5, it is observed that GLP have a partial mediating effect interrelation between ITE and CEP of manufacturing firms as both direct and indirect effects are significant. The mediating effect shows that ITE contributes to CEP through GLP. This effect justifies the growing concern towards logistics to safeguard the sustainable development of the economy.

In India, manufacturing firms experience the strong effect of IP including stakeholders' competitive pressure. It becomes less significant for firms to comply (Mathivathanan et al, 2022) as there is no penalty or punishment if firms do not comply with the norms for GLP and CE practices. *This aligns with the current findings that the moderating effect of IP was found to be insignificant ($p > 0.05$) and hence H4 is rejected.* The findings from the study indicate the urgent need for strict regulations and policies to be mandatorily followed by manufacturing firms to move towards sustainable development. It has been observed that traditional firms were concerned more with routine business operations, whereas very little focus was on logistics practices for the achievement of a sustainable future. These findings complement Jazairy (2020) who stressed that IP drives firms to adopt internal GLP practices but excludes the external ones. The moderating impact of IP is found to be insignificant as shown in Figure 4. The findings show that the GLP and CEP relationship is not affected by pressure exerted by stakeholders. Therefore, with higher IP, there is no change in the CEP adoption in manufacturing firms with enhanced GLP. From the results in Table 7, it is evident that SCF helps firms to mitigate risk related to environmental uncertainty. Studies have shown that the environment and structure match fit is essential for business performance. The current study posits that SCF may affect the GLP and CEP of firms *(H5 is accepted; $p < 0.05$)*; thus, the moderating effect of SCF is found to be significant. This is in confirmation of earlier research by Sreedevi and Saranga (2017) who suggested that SCF could give a firm competitive advantage that may support them to align with the changing environment. As the environment is uncertain and dynamic, SCF will help in adopting CEP in firms. The moderating effect of SCF is shown in Figure 5. This indicates the higher the SCF, the higher the adoption of CEP with enhanced GLP in manufacturing firms. The current study reveals that CEP can be achieved in the manufacturing industry by implementing GLP and ITE. This will develop supply chain efficiency, reduce carbon emissions and reduce waste. The impact of SCF will also help supply chain firms to monitor and deftly adapt changes in their processes and systems to enhance the transition to CE. This supports hypothesis H5.

5.1 Theoretical Implications

This study advances knowledge of GLP and its influence on CEP adoption in manufacturing firms driven by ITE; this is a gap that has been identified in previous literature. It examines the effect of GLP including sustainable transportation, green management practices and reverse logistics practices on CEP adoption in manufacturing firms. Rather than being underpinned by a single theory, this study has undertaken contributions from both RBV and Institutional Theory. Based on the discussion, the theoretical contributions are presented arising from this study based on RBV. GLP utilize resources optimally to act as a competitive advantage and enhance the impact of ITE on CEP adoption in manufacturing firms. This theory is extended by considering that GLP may act as a competitive advantage for those firms in transition to becoming CE. Primarily, this study has extended the understanding of GLP, ITE, IP, SCF and CEP. The findings have enriched the literature relevant to the GLP and CEP relationship of manufacturing firms. The results also extend substantial implications for the area of logistics and operations where GLP may enhance the transition to CE and more sustainable outcomes. This study provides an opportunity for researchers to extend work into GLP, CEP and other logistics functions.

This paper suggests an appropriate theoretical outline to lead to improvement of specific factors including GLP and CEP of manufacturing firms. Furthermore, it is suggested that GLP, including sustainable transportation, reverse logistics, green monitoring and evaluation, may influence CEP adoption in manufacturing firms to build a path towards CE. The significant effect of GLP offers insights for cleaner and sustainable production, processes and systems, plus reduction in costs through efficient waste management practices; this is a crucial need of linear economies currently. The results of the study clearly show that implementation of GLP is significant for transitioning into CE and enhancing circularity in companies. Also, the study reflects the lack of stringent regulations in India which is equally important to implement CE in firms. A rigorous government policy for transition to CE is an urgent need in emerging economies like India. Lastly, this paper successfully confirms the view from past literature that SCF can influence GLP and CEP adoption in manufacturing firms.

5.2 Practical Implications

This research helps decision makers to promote a synergistic approach towards the development of policies and strategies for the promotion of green practices in the logistics sector. Firms must undertake environmental practices to build capacity in GLP. For practitioners and policymakers, exploring the relationship between GLP and CE will assist in the quest to enhance the transition toward developing circular supply chains. Firms need to enhance facilities for recycling and reuse of harmful materials, and thus GLP need to be enhanced. In today's scenario, firms are constantly competing to enhance their business performance; GLP may lead firms to achieve sustainable outcomes and circular economy transition. With GLP, ITE and CEP, supply chains will become more efficient, and reduce carbon emission and waste; this is a great need of the economy presently.

The study has shown the numerous benefits of ITE which not only help firms to adopt GLP but also in the adoption of CEP in manufacturing firms. ITE implementation is dependent upon the specific goals and objectives set by managers; hence they need to understand the changing market conditions and requirement of flexibility in their supply chains. Managers can consider ITE practices to improve the firm's triple bottom line results and move towards CE practices. Further, the lack of stringent policies and IP is also responsible for the weak relationship between GLP and CEP, suggesting that stakeholders need to take actions on policies to accelerate CEP adoption in manufacturing firms. Secondly, firms cannot depend solely on ITE. Instead, the adoption, as well as the implementation of GLP, is required in manufacturing firms to support the CE transition. With this aim, the authors have evaluated the mediating role and the results posit that GLP can facilitate the smooth transition to CE.

5.3 Unique Contribution

The current study is a pioneer in identifying the impact of GLP on the ITE and CEP relationship in manufacturing firms. The findings of this paper offer insights into the augmented effect of ITE through GLP in businesses i.e., including sustainable transportation, sustainable packaging, reverse logistics and recycling etc. These findings uncover the significant effect of GLP in CE. Moreover, this study has identified the insignificant moderating effect of IP and the positive moderating effect of SCF on the GLP and CEP relationship. This research is the first attempt to show the influence of IP and SCF in the adoption of CEP and shows how GLP may give a competitive advantage for CE adoption.

6. Conclusion

GLP has gained prominent attention in research because of its numerous benefits including sustainable transportation, distribution, monitoring etc. Existing literature has shown rigorous work in the area of ITE and CE adoption in firms. This study has explored the contribution of

GLP in CE adoption of firms in an environment of Industry 4.0 technologies. A research model has been developed between GLP, ITE, and CE and the relationship between the pre-established constructs has been measured. Moreover, the moderating impact of the external variables IP and SCF have been also measured on the mediated relationship of GLP and CEP. The model is tested using SEM and the results show that GLP has a significant mediating effect on ITE and CEP adoption in firms. With the partial mediating effect via GLP, ITE has a significant effect on CEP adoption in manufacturing companies. The moderating effect of IP is found to be insignificant; this provides insights to decision makers and policymakers to formulate a stringent policy for CEP. Further, the moderating effect of SCF is found to be significant in the relationship between GLP and CEP. The empirical outcome of the paper has contributed to the understanding between ITE, IP, GLP, CEP and SCF. Understanding GLP and its influence on CEP is a crucial step toward transition to CE, as there is continuous pressure on adapting greener practices and absorbing circularity into organizational practices.

This study helps decision makers to focus on a synergistic approach toward the development of policies and strategies for enhancement of green initiatives in the logistics sector. For practitioners and policymakers, exploring the relationship between GLP and CEP will help in the quest to enhance the transition from a linear economy. GL and ITE can make supply chains more efficient while reducing carbon emissions and waste; this is a vital requirement of the economy. These findings will help researchers and managers to prioritise the GLP that encourage the circular and sustainable behaviours driven by ITE. Our study triggers great interest to explore specific factors that drive the effective implementation of GLP to enhance circular and sustainable performance based on organisational theories (institutional theory, resource base view, technology adoption theory, technology acceptance model). These complement each other to advance perspectives of GLP and CEP of manufacturing firms. Methodological limitations such as small sample size and single country data can be overcome with future studies. Future research may extend the role of organisation size, level of CE implementation etc. The current study can be tested in other industries as well.

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