



Adopting net-zero supply chains: Integrated model of TOE and TAM in emerging economy context

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ABSTRACT

Industries across the globe are making arduous efforts to mitigate emissions and use greener ways of transporting goods and delivering services. The supply chain includes all the activities which involve producing, transporting, and distributing goods and services, contributing to a major portion of worldwide emissions. Road transport contributes majorly to emissions; therefore, focusing on net-zero supply chains (NZSCs) is imperative. Yet, there are several challenges in the net-zero supply chain adoption pathway. Hence, in the presented study, the Technology, Organizational, and Environment and Technology Acceptance Model integrated framework determined behavioral intentions toward adopting NZSCs. The questionnaire was developed, and 206 responses were collected. Structural Equation Modeling was used to assess the proposed research model. Various constructs analyzed under the Technology, Organizational, and Environment framework were green modes of transportation (GMT), lean green integrated digital innovations (LGDI), Management Support (MS), Organizational Competency (OC), Industry Partnership and Collaborations (IPC), and Government Rules and Regulations (GRR). Similarly, perceived usefulness (PU) and perceived ease of use (PEU) constructs were analyzed under the Technology Acceptance Model framework. Moreover, the mediation analysis of perceived usefulness and perceived ease of use constructs was analyzed between distinct constructs and intention to adopt NZSCs. Government Rules and Regulations are found to have a strong role in mitigating environmental pollution and achieving sustainable development goals. Also, green modes of transportation do not have significant relationship between perceived usefulness. Likewise, relationship between organizational culture and perceived ease of use does not hold.

1. Introduction

Far-reaching impacts of global warming have become a major concern, adversely impacting human life [1,2]. Rapid industrialization has been cited as the major cause of global warming as it consumes natural resources beyond their replenishment capability and leaves an irreversible detrimental environmental impact [3]. Therefore, mitigating emissions has become a hot topic of discussion worldwide [4–6]. Digital technologies play a vital role in achieving net zero targets, helping to reduce energy consumption [7]. A study by Su et al. [8] compared the role of technological innovations and renewable energy to

combat environmental issues and achieve net zero goals, concluding that solar and wind energy significantly reduce carbon footprint. Stephenson et al. [9] reported similar findings and highlighted the role of technology in rescuing from the issues of environmental degradation and treading the pathways towards decarbonization. However, Mangudhla et al. [10] researched different aspects and highlighted emerging economies' challenges, the authors found financial barriers pivotal in impeding technological innovations and thus restrains in meeting net-zero targets. Another study by Manhood et al. [11] reported the positive impact of lean practices and big data analytics capabilities on green product and process innovations, which in turn helps

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organizations achieve competitive advantage and gain green performance. Singh et al. [12] also discovered similar findings and analyzed the role of an organization's abilities on net-zero supply chains; the authors concluded a positive significant relationship between knowledge and operational capabilities, which extends to achieving sustainable supply chain flexibility and net-zero objectives.

Furthermore, to lower global warming and streamline industrial activities, the United Nations have proposed sustainable development goals (SDGs) and urged the industrial community to incorporate sustainable practices [13]. Increasing societal environmental awareness and stringent environmental norms from the government are pressuring the industrial sector to adopt eco-friendly industrial activities [14]. In the recent past, supply chain (SC) activities are heavily criticized for their adverse environmental impact. Arif et al. [15] also highlighted that the SC emission contributes significantly to Greenhouse Gas emissions (GHGs). Thus, SC activities become a serious concern and have received greater attention from various stakeholders and industrial practitioners [16]. Over the past two decades, sustainability has become a niche topic among industrial practitioners and has been incorporated into all industrial activities [17]. Using suitable decision-making models, net-zero principles can be integrated with supply chain functions [18]. Also, Agrawal et al. [19] assessed the drivers of sustainable practices, including cost-effective resources, greater automation intensity, top management support, positive digital culture, and lower energy consumption. Another study by Singh et al. [20] explored drivers of a net zero economy as the provision of supportive government policies, financial growth, green resource utilization, and consumer awareness towards protecting the environment. Khan et al. [21] assessed the constructs of green supply chains as mitigating risks, examining utilities, green computing, developing green infrastructure, minimizing resource needs, and managing operations. Moreover, it has become necessary to integrate sustainable practices into supply chain operations in the 21st century [22].

Balancing the quantities between emissions of GHGs by various activities and their absorption by the surrounding atmosphere is called net-zero emissions (NZE) [23]. NZE practices have recently gained more importance in meeting the Paris Agreement. Scope 1 & scope 2 must be reduced by 90 % to achieve net zero by 2050 [24,25]. Accordingly, many countries were committed to lowering GHGs emissions drastically [26]. The adoption of Electric Vehicles (EVs) is one such initiative, which reduces carbon footprint significantly [27]. A study by Jaiswal et al. [28] concluded that perceived usefulness and perceived ease of use impact attitudes and intentions toward EV adoption. However, there are various barriers to EV adoption, which include incapability to sales conversion, lack of trust, high cost of purchase, and desirability concerns [29]. The transition towards net zero supply chains (NZSCs) activities has become mandatory to achieve carbon neutrality targets in different industrial activities and to adhere to the government's environmental norms. Wei and Wang [30] assessed the linkage between an organization's capability to reduce carbon footprint and government policies using differential game to promote sustainable practices. Challenges like financial constraints and stakeholder consensus have impeded the transition from conventional SC operations to NZSCs. Recent technological advancements have brought drastic changes in industrial activities. Interestingly, the utilization of these technological advancements is very high in SC activities [31]. With Industry 4.0 (I4.0) technologies, it is possible to optimize the SC activities and enhance the transparency in data sharing among the stakeholders. Srhir et al. [32] claim that I4.0 technologies, like blockchain, can track real-time movement and optimize energy usage throughout SC activities. Similarly, the circular economy concept has been adopted by firms to abate adverse environmental impacts. However, the success of circular economic practices depends mainly on collective effort. As multiple stakeholders were involved, it can be difficult for the firms to achieve their intended purpose. In the circular economy, it is not easy to monitor the capability of individual entities [33].

The lean concept initially applied to manufacturing activities is now applied to SC activities to reduce carbon emissions. Similarly, organizations are taking green SC initiatives to combat the carbon emissions [34]. Recently, steps have been taken to use the combined lean and green concepts in SC operations. Similarly, digital technologies enhance business processes and lean practices [35]. A study by Yadav et al. [36] examined that the combined lean green SC practices lack real-time tracking facilities, which are essential to curb carbon emissions. With integrated lean-green-digital innovations (LGDI), it would be possible to overcome this problem and realize NZSCs operations. Since the organizations are profit-oriented, they consider the cost-benefit of adopting lean-green-digital innovations. Several theories, like the Theory of Planned Behavior, have been used to examine the acceptance of innovation by society and organizations.

In scholarly literature, various research studies discussed the benefits of incorporating lean-green-digital innovations. However, less attention is paid to quantitative studies evaluating organizations' challenges, specifically in the emerging economy context. Moreover, emerging economies like India confront problems of scarcity of resources, lesser availability of funds, and also high population [37]. Also, emerging economies generate a lot of waste generation, so it becomes imperative to adopt circular economy measures [38]. Also, studies focusing on NZSCs have been scarce. Further, to the best of the author's knowledge, no studies have used the integrated Technology Acceptance Model (TAM) and the Technology, Organization, and Environment (TOE) framework in NZSCs operations. Thus, this study intends to develop a comprehensive model with TAM and TOE to examine the organizations' willingness to embrace NZSCs operations. Further, this study likes to answer the research questions as follows:

RQ. 1. *What are the primary variables influencing the adoption of NZSCs activities?*

RQ. 2. *How do TOE and TAM dimensions influence the adoption of NZSCs?*

To answer the above research questions, the following research objectives are framed as:

1. Identify the primary variables affecting the adoption of NZSCs activities.
2. Assess the role of technological, organizational, environmental, and perceived usefulness and perceived ease of use in NZSCs activities.

The research model has been developed and empirically tested. In this study, TOE and TAM models were used over other models like Unified Theory of Acceptance and Use of Technology (UTAUT), Diffusion of Innovations (DOI), and Resource-Based View (RBV), as it is an inclusive model with environmental, technological, organizational, and individual dimensions. Since the TOE approach examines technological, organizational and environmental aspects and captures context-specific factors across the organizations, TAM primarily focuses on user perceptions using perceived usefulness and perceived ease of use, thus making the study more comprehensive and explanatory. Moreover, this integrated approach helps to overcome the socio-technical complexity inherent to a particular technology. Next, Structural Equation Modeling (SEM) has been used to assess relationships and hypothesis testing. Initially, data was collected through a survey conducted with 206 respondents. Using SEM, it is possible to analyze complex relationships among the observed and latent variables [39]. Here, SEM has been used to explore and analyze the complex relationships between various variables influencing the adoption of NZSCs.

The remaining sections are presented as follows: Section 2 portrays theoretical development, i.e., underpinning theories and hypotheses development. Section 3 presents questionnaire development and data collection. Section 4 discusses the checks for data reliability and measurement model fit. The second last section presents the discussion of

results, managerial implications, and proposed model for net-zero adoption. Lastly, the conclusion and future avenues of research are discussed.

2. Theoretical background and hypotheses development

This section overviews factors impacting NZSCs. Also, this study analyzed TOE and TAM dimensions to analyze its significance. The framework proposes to analyze various contributing factors towards NZSCs by critically analyzing these dimensions. It can act as a benchmark in decision-making related to adopting NZSCs.

2.1. Overview of adoption theories

In the last few years, the number of innovations being developed and introduced has increased exponentially. However, only a few of these innovations have gained public attention and persisted, while most have faded over time [40]. Understanding the factors determining the acceptance and utilization of innovations is crucial to its success. When the technology is accepted, it will lead to adoption, which ultimately results in technology usability [41]. Thus, developing frameworks related to technology acceptance has been a central research topic in the research community. Most research uses the terms ‘technology acceptance,’ ‘technology adoption,’ and ‘technology usability’ interchangeably. Acceptance indicates the positive decision to use an innovation. According to Dissanayake et al. [42], adoption is integrating innovation into existing practice and followed for a long time. Adoption varies from person to person and may differ over time depending on many variables. Further, it may be either individual or aggregate adoption. So, knowing the variables that influence the users’ decisions is essential as it may help in the development phases. Both researchers and practitioners are finding answers to why people must accept new technologies. Technological behavior, a human behavioral facet, is being studied to understand behavioral changes to new digital innovations. Many authors have proposed several theories and models, like the Theory of Planned Behavior (TPB), the Unified Theory of Acceptance and Use of Technology (UTAUT), the Theory of Reasoned Action (TRA), the Diffusion of Innovation (DoI), and Social Cognitive Theory (SCT), for evaluating technology adoption. These models introduce variables that can impact user acceptance. These theories act at three levels, namely, user-centric, system-centric, and holistic [43].

TRA focuses mainly on variables that measure the behavioral intention of an individual. In TRA, attitude, belief, and outcome evaluation are analyzed as links between innovations and individual characteristics. These variables vary from individual to individual regarding how they feel about the same technology and how the attitude affects their perception [44]. TPB, an extension of TRA, includes perceived behavioral control in addition to the variables of TRA. It relies on the cognitive approach to justify concentrated behavior precisely. Also, with the ‘perceived behavioral control’ variable, TPB theory addresses the issue of being non-responsive to involuntary behavior, which TRA does not cover. According to TPB, an individual’s attitude toward certain behaviors and subjective norms affects behavioral intention. The level of individual control over certain behaviors impacts the ultimate decision of adoption behavior [45]. The DoI theory considers relative gain, compatibility, intricacy, trialability, and detectability as the crucial variables influencing the diffusion frequency of innovations [46]. It uses a framework to explain the diffusion of the innovation process and understand how users decide to accept or reject an innovation. Further, it discusses how information about new tools is transferred to members of society in several stages over time. The stages are understanding, persuasion, decision, implementation, and confirmation.

In SCT theory, habits, cognitive factors, and societal effects are the variables considered to determine an individual’s behavioral change. The advantage of this model is that it provides bidirectional interaction among the variables. It assesses an individual’s ability to use innovations

to accomplish a task [47]. The variables measured in UTAUT are perceived ease of use, complexity, perceived usefulness, extrinsic motivation, job-appropriateness, relative gain, outcome expectations, gender, experience, age, and voluntariness of use. Despite resolving several issues of other theories, the UTAUT model is limited to working environments and not suitable for large-scale applications [48]. Likewise, dynamic capability theory, an extension of resource-based view theory, examines companies’ ability to integrate, develop, and reconfigure internal and external competencies to cope with the rapidly changing business environment. It mainly works based on the strategies and experiences of firms over the years [49].

Though several theoretical frameworks, like TPB, UTAUT, and TRA, have been used to inspect the adoption of advanced technology, they lack inclusiveness. Most theoretical frameworks are technocentric and technologically deterministic; they fail to consider the readiness and concerns of firms [50]. Thus, there is a need for a holistic approach that measures the readiness of the firms and end-users. Therefore, in the presented study, integrated models of TOE and TAM is used.

2.1.1. Technology, organizational and environment (TOE)

TOE, introduced by Eveland and Tornatzky [51], has been commonly used in innovation adoption. It is a theoretical model that helps examine how organizations adopt and implement new technologies [52]. TOE framework applies to any business or industry irrespective of size and capability. It is also recognized as an effective model for examining value creation and innovation acceptance. Thus, the TOE framework is fundamental for analyzing the organization’s innovation adoption and utilization [53]. It focuses on the environmental and organizational elements while considering the unique characteristics of the innovation. Thus, this framework has been recognized as a holistic model for examining factors determining adoption [50]. According to TOE, the adoption of any innovation is impacted by environmental, organizational, and technological factors. Here, the technological factors indicate specific features needed for innovation’s effectiveness. In TOE, compatibility, observability, and perceived competitive advantages affect technology adoption. In addition, the technological factors include equipment and infrastructure available in the industry for usage. Organizational factors represent various perspectives, such as size, administrative structure, hierarchy, business structure, and workforce. Top management behavior is also important as it promotes or inhibits innovation adoption. Environmental factors include government norms, stakeholders, competitors and competitive pressure [41]. Scholarly literature shows that it is used in various applications, including risk management perspectives of smart cities [54] and ERP adoption [55].

2.1.2. Technology acceptance model (TAM)

TAM, introduced by Davis [56], is the concept used to measure the acceptance of an innovation. TAM has been considered a developed version of the Theory of Reasoned Action. It measures innovation acceptance from an individual and cognitive perspective [41]. Thus, this model is considered a primary tool for quantitatively examining customers’ attitudes toward innovations and their acceptance rate. Also, organizations recommend TAM, the introductory phase of technology acceptance. Perceived ease of use (PEU), perceived usefulness (PU), behavioral intention (INT) to use, attitude are the four important variables considered in this model to determine the adoption of innovations. Behavioral intention is an important determinant of technology adoption and use, and individual attitudes and perceptions of usefulness jointly influence it [57].

Meanwhile, PU and PEU significantly influence an individual’s attitude, whereas external factors influence both PU and PEU. The external factors are subjective norms and trust. Here subjective norms indicate the influence of society in innovation adoption, and trust indicates the optimistic belief in the reliability and efficiency of the technology [58]. Though the TAM framework applies widely, there are limitations. For example, TAM focuses only on PU and PEU and

overlooks individual characteristics [59]. Also, the TAM framework considers only positive perceptions, ignoring negative ones. Thus, examining the factors that facilitate and impede technological innovations is important. Considering these drawbacks, the original TAM framework has been improved by adding relevant factors divided into two groups: perceived and external factors [60]. According to the TAM framework, if the innovation enhances the performance and poses low difficulty in use, its acceptance rate is high.

2.2. Development of hypotheses

Based on the above literature review, the following hypotheses were developed. The details about the hypotheses are explained as follows:

2.2.1. Perceived ease of use (PEU), perceived usefulness (PU) and intention (INT)

Many organizations desire to achieve NZSCs but fail to embrace technological innovations. Several studies have advocated that adopting lean-green-digital innovations has helped achieve NZSCs [61,62]. PEU shows the magnitude to which a person or organization observes the impact and efficiency of the technology in the work. PEU explained how advanced and digital technological innovations may enhance NZSCs operations. According to the TAM framework, PEU influences the INT to embrace innovation directly and indirectly through PU [63]. Generally, PEU refers to the intensity with which a person can use innovations or technology effortlessly. Meanwhile, PU indicates how much an individual or organization understands the improvement of operations and efficiency with the specific technology.

Meanwhile, the INT to use determines the embracement of any technology. INT is considered the result of decision-making [64]. It captures the willingness towards the adoption of concept/technology. In the context of this study, PU facilitates improved environmental performance, reduced waste activities, reliable data transfer and better communication between the stakeholders [65]. The intention to adopt the innovations increases based on realizing the benefits of using lean, green and digital innovations. With better understanding, the process of using innovations becomes easy. Thus, the hypothesis has been developed as follows:

H1. PEU has a relationship with INT to adopt NZSCs

H2. PU has a relationship with INT to adopt NZSCs

H2a. PEU has a relationship with PU

2.2.2. Government rules and regulations (GRR)

Government rules and regulations (GRR) are important in steering industrial activities towards sustainable practices. The UN has appealed to global nations to reframe the environmental norms for the industrial community to lower the global warming effect [66]. Thus, through stringent environmental rules and regulations, the government can create intentions among the industrial community to move towards NZSCs practices [20]. Several studies have claimed that government support like incentives and encouraging policies have demonstrated positive impact on the acceptance of innovations [67,68]. Government tax incentives favor industrial organizations adopting net-zero activities, which help firms' lower expenses [69]. Providing financial assistance for the organizations by the government increases the INT's adoption of NZSCs. Moreover, creating awareness about the impact of lean, green and digital innovations on sustainable performance of industries is essential to instilling PU among the industrial community. Though the world is going through digital transformations, some companies are still reluctant to embrace [68]. Only through frequent awareness campaigns, the significance of innovation adoption in progress towards NZSC be imparted to the industrial community, and it can help in realizing PU [70]. Thus, PU could help organizations in adopting NZSCs. When the

PEU & PU gets understood, it can mediate the relationship between GRR and INT to adopt NZSCs. Therefore, we hypothesize that:

H3. GRR have a relationship with INT towards adopting NZSCs

H3a. GRR have a relationship with in PEU of NZSCs

H3b. GRR have a relationship with PU of NZSCs

H3c. PEU mediates the relationship between GRR and INT to adopt NZSCs

H3d. PU mediates the relationship between GRR and INT to adopt NZSCs

2.2.3. Industry partnership and collaboration (IPC)

NZSCs involve reducing GHGs emissions across various business functions and offsetting the remaining emissions to achieve net-zero emissions levels. Sustainable practices like waste reduction and circular economy adoption are quite helpful to achieve these objectives [23]. Various stakeholders are involved in supply chain activities, and industry partnership & collaborations (IPC) can make NZSCs practices easier. In IPC, stakeholders share knowledge about the best NZSC practices, which can reduce learning time. Further, it promotes PEU to the companies regarding NZSCs activities. Similarly, in IPC, stakeholders' INT to adopt innovations will be high when other stakeholders have embraced innovations and witnessed benefits [12]. Shared accountability and the pressure for collective effort in IPC increase the INT to adopt NZSCs. PU refers to how individuals perceive the usefulness of technology or innovation in achieving desired outcomes [71]. In the purview of NZSCs, PU refers to how companies perceive the usefulness of sustainability initiatives and technologies in achieving NZSCs [72]. Suppose companies perceive sustainability initiatives and technologies as useful in achieving NZSCs and can effectively collaborate with other companies, in that case, they are more likely to implement sustainable procedures and achieve NZSCs [73]. Based on the above information, the following hypothesis has been developed:

H4. IPC has a relationship with INT adopting NZSCs

H4a. IPC has a relationship with PEU

H4b. IPC has a relationship with PU

H4c. PEU mediates the relationship between IPC and INT to adopt NZSCs

H4d. PU mediates the relationship between IPC and INT to adopt NZSCs

2.2.4. Organizational competency (OC)

Organizations need to enhance their competency to sustain in the complex and uncertain business environment [74]. Since supply chain activities have become complex, organizations must improve their capability to adopt emerging disruptive technologies. To realize the potential, the organization must understand the perceived usefulness of the innovations. When an organization has adequate technological competencies and required infrastructure facilities, it will understand PU & PEU. Hence, the adaptation towards NZSC practices is possible only when the organization improves its OC [15]. The OC also indicates the capability of the companies to integrate and support innovations among the stakeholders. The management shows intent in innovation adoption only when it realizes the potential of technologies in enhancing performance [75]. The larger the OC embraces innovations, the more it enhances the INT's adoption of NZSCs. When the organizations are competent in adopting innovations and can provide employee training, it will be easy for the workers to perceive the ease of using them [11].

Therefore, PEU is a medium between the OC and INT to adopt innovations for NZSCs. Further, when the workers realize the PU of innovations, the usage of innovations will be high. Hence, the PU & PEU projects to play a mediating role between the OC and INT to adopt NZSCs. Therefore, we hypothesize that:

H5. OC have a relationship with the intention to adopt NZSCs

H5a. OC have a relationship with PEU

H5b. OC have a relationship with PU

H5c. PEU mediates the relationship between OC and INT to adopt NZSCs

H5d. PU mediates the relationship between OC and INT to adopt NZSCs

2.2.5. Management support (MS)

MS is crucial in achieving NZSCs and reaching the net-zero goals. Management can provide leadership by setting clear goals and strategies for sustainability [76]. They can allocate resources to support sustainability initiatives throughout the supply chain. Management can also engage employees to foster a culture of sustainability, develop performance metrics to track progress, and communicate sustainability initiatives and progress to external stakeholders [77]. PEU is the degree to which a person observes tools or innovation as easy to use and implement. In pursuit of achieving NZSCs, this refers to the degree companies view sustainability initiatives and technologies as simplified and effortless to use [78]. By doing so, management can promote sustainability throughout the organization, create a sustainable, responsive, resilient supply chain, and improve brand reputation and stakeholder trust [79–81]. The adoption of any innovation mainly relies on management support (MS). Only when management realizes the benefits and expected useful returns, it will show an intention to adopt technological innovations towards NZSCs.

Hence, the PU mediates between the MS and INT in adopting any innovation [82]. Alos, management must be accountable for facilitating enough employee training to adopt technological innovations (Lee & Tseng, 2024). These training courses must ensure that the workers are empowered and are comfortable with the latest technologies and innovations. Moreover, the workers must know how adopting innovations can streamline industrial operations. When workers perceive the ease of using innovations, the level of embracing NZSCs is very high [83].

Meanwhile, it is the responsibility of the management to select the innovations that are easy to integrate into the existing operations. Additionally, the clear commitment of management may increase the INT among workers and encourage them to adopt NZSCs. When the workers realize the PU of innovations in easing the work, the preference for embracing innovations is high. Therefore, we hypothesize that:

H6. MS have a relationship with INT to adopt NZSCs

H6a. MS have a relationship with PEU

H6b. MS have a relationship with PU

H6c. PEU mediates the relationship between MS and INT to adopt NZSCs

H6d. PU mediates the relationship between MS and INT to adopt NZSCs

2.2.6. Lean green integrated digital innovations (LGDI)

Organizations are adopting Lean, Green, and Digital innovations (LGDI) to lower the adverse environmental impact of SC activities. Numerous barriers often impede organizations' embarking on digital

technologies; organizations must tackle these barriers strategically. As the need for NZSCs has become essential, organizations must integrate lean-green-digital innovations [84]. Lean-green-digital innovations help lower carbon footprints, thus maintaining a sustainable society. Also, scholarly literature discussed the preparedness of companies to embrace lean-green-digital innovations. With LGDI, the organizations can augment the performance, resilience of SC activities and optimize the SC network [85,86]. The adoption of LGDI critically ensures the firm's sustainability, efficiency, and agility [83]. It helps with waste management, energy efficiency, and improved decision-making. Hence, LGDI raises the INT to follow NZSCs. By making the industrial processes more manageable, the LGDI makes it easier for the workers to understand the PU & PEU of innovations clearly. Also, directly explaining how efficient and impactful the LGDI is, helps the workers and stakeholders understand the PU of innovations [61]. Thus, PU motivates the organization to adopt LGDI. In the current times, most organizations have understood the PEU & PU of digital innovations [87]. Understanding the PEU increases the intention of organizations to adopt LGDI. Thus, PEU and PU also mediate the relationships between LGDI and NZSCs. Therefore, we hypothesize that:

H7. LGDI have a relationship with intention to adopt NZSCs

H7a. LGDI have a relationship with PEU

H7b. LGDI have a relationship with PU

H7c. PEU mediates the relationship between LGDI and INT to adopt NZSCs

H7d. PU mediates the relationship between LGDI and INT to adopt NZSCs

2.2.7. Green modes of transportation (GMT)

The growing environmental concern in society results in greater INT to use sustainable transport systems. Green modes of transportation (GMT) are crucial for NZSCs activities. Recently, electric cars have emerged as a sustainable transport system. Furthermore, renewable energy resources will generate the electricity required to charge electric vehicles rather than conventional-based systems [88]. Additionally, if the government provides sufficient subsidies and tax rebates, the INT of firms adopting GMT will improve [89]. The support of the organization and government play an important role in adopting GMT. To incorporate GMT, the organizations must possess the required technological facilities. AS GMT considers EVs a viable option, so it is essential to provide the necessary technical infrastructure and accessibility [90]. DeShazo et al. [91] also highlighted that incentive schemes can significantly impact consumer purchase intention of electric vehicles. When the users feel comfortable, the PEU improves. A holistic understanding of GMT may increase the INT of organizations to embrace GMT [92]. The usage of GMT helps in cost saving and lowering environmental pollution. Also, realizing the inclusive benefits of GMT increases the PU. Looking at all these views, a conceptual model is revealed in Fig. 1, and different items about distinct constructs were identified using literature, as shown in Table 1. Also, we hypothesize that:

H8. GMT has a relationship with INT to adopt NZSCs

H8a. GMT has a relationship with PEU

H8b. GMT has a relationship with PU

H8c. PEU mediates the relationship between GMT and INT to adopt NZSCs

H8d. PU mediates the relationship between GMT and INT to adopt NZSCs

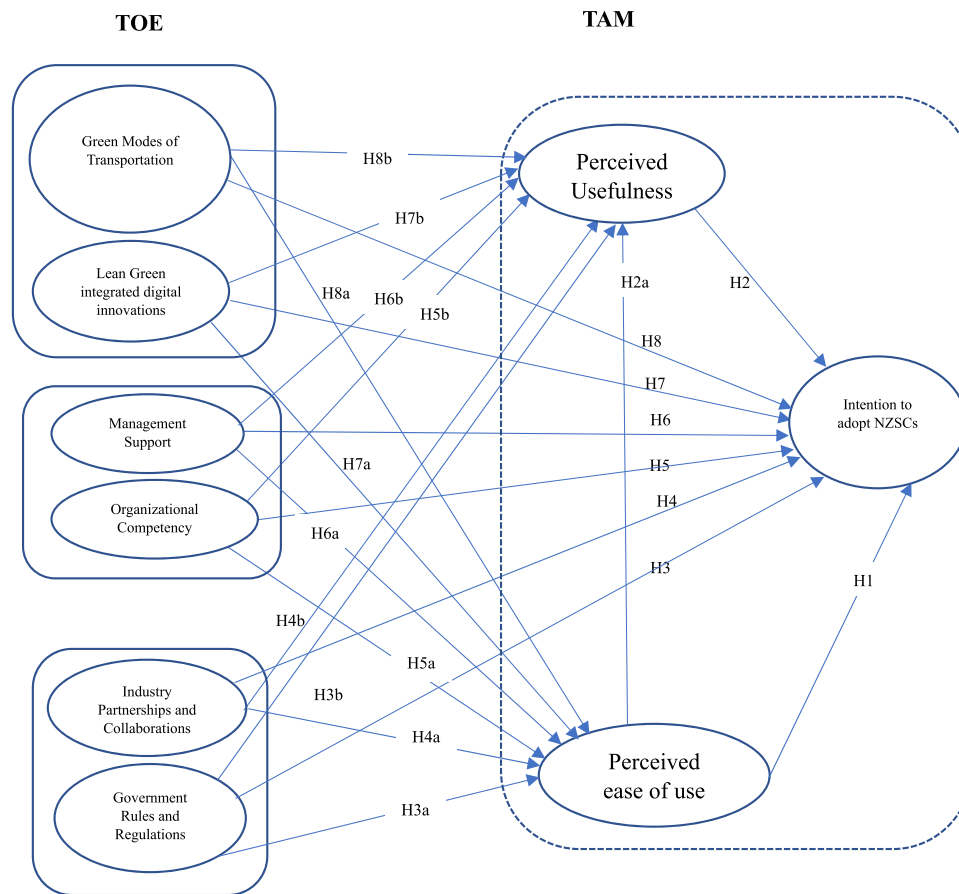


Fig. 1. Conceptual model.

3. Research methodology

Since the presented research involves causal analysis, the survey method is suitable for using a questionnaire instrument [125]. The research team developed a questionnaire using a literature survey and underpinning theories. Quantitative analysis and hypothesis testing were done to validate the conceptual model using survey data.

The questionnaire comprised distinct statements of items that signified the identified constructs. To confirm that the building questionnaire is correct and adequately covers the proposed research objectives, the developed instrument was pretested. The questionnaire was bifurcated into two main segments; the initial segment included questions related to demographic characteristics. The second segment primarily focused on questions about different constructs. All the items in distinct constructs were included based on scholarly literature and confirmed with area experts. Cross-sectional data was used to assess the proposed research model.

Before finalizing the questionnaire, a pilot study was conducted to ascertain that the questions were straightforward and unambiguous. The questionnaire was given to 45 senior managers with expertise in handling supply chain operations, sustainability concerns, and net zero aspects; the results were satisfactory. Simple random techniques were used to collect the responses to the main survey. The respondents who had sound domain knowledge were considered suitable to be respondents to our study. As the questions in our data collection procedure were compulsory, the presented study did not face a missing value issue. A total of thirty-two statements were developed from nine constructs. The questionnaire was sent to 400 experts in online form, of which 206 responses were received. It gives a response rate of 51.5 %. The average value of the content validity index (CVI) average is computed to be 0.91, which is far greater than the threshold value. To put the respondents at

ease while responding to the questions, they were assured that their identity would remain confidential and not be disclosed.

The profile of the respondents is depicted in Table 2.

The bifurcation of the respondent's profiles is as follows: based on gender, the majority of the respondents were males, i.e., 83.5 %; most were senior employees; 41.26 % had ages greater than 45. Most respondents had a bachelor's degree, i.e. 70.39 %, the remaining 25.24 % had master's degrees, and 4.36 % had PhD degrees.

Based on organization characteristics, 34.95 % had a turnover of 15–24 billion, 27.66 % had an interval of 25–34, 20.38 % in the range of 35–45, and 16.99 % >45 billion. Regarding the number of employees, 34.46 % had employees <150, 25.72 % had in a range of 151–300, and 39.80 % had employees >300. Similarly, the categorization using years of establishment was as follows: 19.41 % were <15 years old, 22.33 % were in the range of 15–24, 30.58 % were 25–35 years old, and 27.66 % were >35 years old. Lastly, on an industry-type basis, automobile industries account for 43.20 %, electronics for 31.07 %, and the remaining 25.72 % were from the oil & gas sector.

4. Measurement model

Data was collected on a 5-point Likert scale (extremely disagree to agree). Based on the Yamane [126] formula for computing sample size, shown on Eq. (1), sample size computes to be 194. Our sample size considered was 206, so found sufficient to carry out further analysis. Puviarasu et al. [127] examined 23 items and 99 was sample size, also Yadav & Tripathi [87] identified 39 items and took data from 262 respondents. This section consists of three sections, namely common method bias and non-response bias, construct reliability, structural model fit.

Table 1

Construct items.

S. No.	Construct	Description of Items	References
1	Green Modes of Transportation (GMT)	GMT is highly efficient compared to conventional vehicles, requiring less energy to travel the same distance.	Brown et al. [93]; Hossain et al. [94]
2		GMT reduces dependencies on fossil fuels by focusing on renewable energy sources.	Bellocchi et al. [95]; Moktadir & Ren [89]
3		GMT can meet the requirement for carrying out supply chain activities	Wang et al. [96]; Moktadir & Ren [89]
4	Lean Green integrated Digital Innovations (LGDI)	Real-time tracing and checking of shipments helps to improve visibility and mitigate the risk of wastages or overproduction	Javaid et al. [97]; Samanta et al. [98]; Fatorachian & Pawar [99]
5		Automated scheduling and routing systems to optimize delivery routes and reduce transportation-related emissions.	Leong et al. [100]
6		Cloud-based platforms for data sharing and supply chain collaboration	De Giovanni and Cariola [101]
7	Management Support (MS)	Senior management must demonstrate a commitment to sustainability and prioritize the lessening of GHGs emissions in the supply chain	Luo et al. [102]; Mazhar et al. [103]
8		The organization provides adequate training and educational programs to keep the employees educated about the significance of adopting green practices	Saturnino Neto et al. [104]; Sabale et al. [105]
9		Senior management must establish key performance indicators (KPIs) and reporting mechanisms to track NZSCs progress	Koh et al. [106]; Oladapo et al. [107]
10	Organizational Competency (OC)	Organizations must clearly understand supply chain operations and recognize opportunities to reduce the carbon footprint at each stage.	Rouyendegh et al. [108]
11		Organizations must continuously monitor and evaluate their NZSCs to identify areas for improvement.	de Oliveira et al. [109]
12		Organizations have sufficient capabilities to design products to enhance circular economy practices.	Schulze et al. [110]
13	Industry Partnerships and Collaborations (IPC)	Businesses can work together to promote government policies, rules and regulations that encourage the change to a low-carbon economy.	Zhang et al. (2022 a)
14		Businesses can collaborate to share best practices to improve supply chain operations.	Wang and Zhao [111]

Table 1 (continued)

S. No.	Construct	Description of Items	References
15		Businesses can work together to develop standardized methods for measuring the carbon footprint of distinct products and services.	Ravetz et al. [112]
16		Businesses can collaborate to invest in research and development of new technologies that decrease carbon emissions across supply chain linkages.	Mishra et al. (2022b)
17		Government incentive schemes help the organizations to achieve NZSCs.	Pandithawatta et al. [113]
18	Government Rules and Regulations (GRR)	Emissions reduction targets for businesses and industries, requiring them to set and meet specific reduction goals	Cantillo et al. [114]
19		Funding support for research and development helps to reduce carbon emissions in supply chains.	Wang et al. [115]
20		Public private collaborative programs facilitate businesses' transition to green energy resources.	Kashmanian (2017) Tzankova [116]
21	Perceived Ease of Use (PEU)	Providing simple and easy-to-use tools and systems such as carbon footprint calculators, sustainability dashboards, and reporting systems, can make it easier for them to adopt sustainable practices.	Xu et al. [117]
22		Integrating digital tools and systems into existing processes reduces cognitive load and make it easier to adopt sustainable practices	Wu et al., [118]; De Giovanni and Cariola [101]
23		Providing regular feedback and monitoring progress toward sustainability goals can help understand the impact of their actions	Zekhnini et al. [62]
24	Perceived Usefulness (PU)	Sustainable practices can also lead to improved product quality and minimizing carbon footprint.	Taleizadeh et al. [119]
25		Adopting green practices helps minimize energy and resource usage, resulting in cost savings.	[120]
26		Adopting sustainable practices can also increase a business's status and brand image.	Shin et al. (2022); Taleizadeh et al. [119]
27		Sustainable practices can also lead to increased efficiency, such as reducing waste and streamlining processes	Bai and Satir [121]
28		I understand the importance of Net-zero practices in enhancing	Adu-Gyamfi, et al. [70]

(continued on next page)

Table 1 (continued)

S. No.	Construct	Description of Items	References
29		supply chain performance. I am willing to invest time and resources and learn about NZSCs	Xiao and Goulias [122]
30		I am motivated to decrease the carbon footprint of our supply chain	Krishnan and Koshy [123]
31		I feel a sense of responsibility to reduce our organization's impact on the environment	Rodríguez-Espíndola et al. [124]
32		I have a moral obligation to adopt a NZSCs	Bai and Satir [121]

Table 2

Profile of respondents.

Variable	Sub-variable	Number	%
Profile of Respondents			
Gender	Male	172	83.50
	Female	34	16.50
Age (in years)	30–35	24	11.65
	36–40	61	29.61
	41–45	36	17.47
	> 45	85	41.26
Education Level	Bachelor	145	70.39
	Master	52	25.24
	PhD	09	4.36
Designation	Supply Chain Analyst	89	43.2
	Sustainable supply chain manager	78	37.86
	Net-Zero Consultant	39	18.93
Organization's characteristics			
Turnover (in billion \$)	15–24	72	34.95
	25–34	57	27.66
	35–45	42	20.38
	> 45	35	16.99
Number of employees	01–150	71	34.46
	151–300	53	25.72
	>300	82	39.80
Years of Establishment (years)	< 15	40	19.41
	15–24	46	22.33
	25–35	63	30.58
	> 35	57	27.66
Industry Type	Automobile	89	43.20
	Electronics	64	31.07
	Oil & Gas	53	25.72

$$n = \frac{N}{1 + N(e^2)} \quad (1)$$

where n , N , e indicates sample size, population size and precision level

4.1. Common method and non-response bias

Non-response bias (NB) and common method bias (CMB) were used to check the reliability of the respondents' data. To confirm NB, data collected from early respondents (first eighty respondents) and late respondents (last eighty respondents) were assessed using a standard t -test. The results indicated no statistically significant difference ($p < 0.05$), confirming NB's absence.

Both Harmon single factor and common latent factor tests were conducted to confirm the absence of CMB. The percentage variance is computed to be 27.8 %, which is extremely less than the acceptable limit, i.e. 50 %. Therefore, the data collected was free from NB and CMB.

4.2. Construct reliability

Compared with standard values, AVE and CR must be greater than 0.5 and 0.7, respectively. All values are satisfactory in our case, confirming internal consistency and construct validity. The AVE value ranges from 0.525 to 0.693, while the value of CR ranges from 0.760 to 0.899. Table 3 shows AVE, CR, and Cronbach values of all the constructs, computed using standard operating procedures, for example, the AVE & CR for GMT are 0.581 and 0.805 respectively. Furthermore, the Cronbach Alpha value for all constructs is above 0.7, which signifies that items pertaining to distinct constructs are reliable and consistent [128, 129]. Also, discriminant validity is depicted in Table 4, the diagonal element is represented by square root of AVE, for example, for construct GMT, the AVE value is 0.581, so its square root is 0.762.

4.3. Structural model fit

The method used for analyzing the structural model fit and hypotheses testing was a maximum likelihood. The results estimated show good model fit characteristics with the following values: $\chi^2/df=1.304$, RMSEA=0.039, NFI=0.832, TLI=0.948, CFI=0.954, GFI= 0.856. All the values are found to be satisfactory [130]. The path analysis & mediation results are shown in Table 5 & Table 6 respectively. The greatest value is observed of the path, i.e., GRR has a significant relationship with INT ($\beta=0.426$, $p = 0.013$). The variance inflation factor (VIF) is less than five, indicating the absence of multi-collinearity issues.

5. Results

The presented study significantly adds to the literature by analyzing behavioral intentions toward NZSCs. The objective was to explore and analyze the research model developed based on constructs using an integrated TAM-TOE framework. This section is divided into three parts:

Table 3

Item loadings, AVE and CR.

S. No.	Construct	Construct Item	Loading	AVE	CR	Cronbach Alpha
1	GMT	GMT 1	0.856	0.581	0.805	0.897
2		GMT 2	0.654			
3		GMT 3	0.765			
4	LGDI	LGDI 1	0.881	0.552	0.780	0.766
5		LGDI 2	0.533			
6		LDTI 3	0.772			
7	MS	MS 1	0.872	0.604	0.817	0.787
8		MS 2	0.878			
9		MS 3	0.534			
10	OC	OC1	0.833	0.619	0.825	0.810
11		OC 2	0.905			
12		OC 3	0.586			
13	IPC	IPC 1	0.790	0.557	0.833	0.829
14		IPC 2	0.607			
15		IPC 3	0.809			
16	IPC	IPC 4	0.764	0.629	0.869	0.861
17		GRR 1	0.708			
18		GRR 2	0.990			
19	GRR	GRR 3	0.759	0.525	0.760	0.734
20		GRR 4	0.679			
21		PEU 1	0.500			
22	PEU	PEU 2	0.877	0.693	0.899	0.897
23		PEU 3	0.746			
24		PU 1	0.779			
25	PU	PU 2	0.944	0.536	0.849	0.835
26		PU 3	0.719			
27		PU 4	0.871			
28	INT	INT 1	0.899	0.536	0.849	0.835
29		INT 2	0.638			
30		INT 3	0.555			
31	INT	INT 4	0.827	0.536	0.849	0.835
32		INT 5	0.687			

Table 4

Discriminant validity.

Constructs	GRR	IPC	MS	OC	LGDI	GMT	PU	PEU	INT
GRR	0.793								
IPC	0.072	0.746							
MS	0.020	0.054	0.777						
OC	0.049	0.081	0.172	0.787					
LGDI	0.014	0.167	0.057	0.067	0.743				
GMT	0.050	0.006	0.048	0.030	0.116	0.762			
PU	0.219	0.047	0.165	0.068	0.031	0.005	0.832		
PEU	0.290	0.228	0.175	0.097	0.048	0.177	0.242	0.725	
INT	0.026	0.086	0.135	0.168	0.004	0.161	0.084	0.238	0.732

Table 5

Hypotheses Results.

Hypothesis	Relationship	Beta	p value	Result
H1	PEU → INT	0.238	0.011	Supported
H2	PU → INT	0.184	0.027	Supported
H3	GRR → INT	0.426	0.013	Supported
H4	IPC → INT	0.286	0.026	Supported
H5	OC → INT	0.168	0.025	Supported
H6	MS → INT	0.165	0.036	Supported
H7	LGDI → INT	0.275	0.042	Supported
H8	GMT → INT	0.191	0.031	Supported
H2a	PEU → PU	0.127	0.014	Supported
H3a	GRR → PEU	0.290	0.005	Supported
H4a	IPC → PEU	0.228	0.007	Supported
H5a	OC → PEU	0.097	0.212	Not Supported
H6a	MS → PEU	0.175	0.035	Supported
H7a	LGDI → PEU	0.048	0.538	Not Supported
H8a	GMT → PEU	0.177	0.032	Supported
H3b	GRR → PU	0.219	0.004	Supported
H4b	IPC → PU	0.172	0.028	Supported
H5b	OC → PU	0.148	0.363	Not Supported
H6b	MS → PU	0.195	0.017	Supported
H7b	LGDI → PU	0.135	0.026	Supported
H8b	GMT → PU	0.105	0.942	Not Supported

the first presents the discussion, and the second explains managerial implications (theoretical, practical and higher Educational Institutes).

5.1. Discussion

As shown in Table 5, Management Support (MS) has a significant relationship with PU ($\beta=0.195$, $p = 0.017$). Suppose management officials understand the importance of NZSCs and focus on conducting training and development programs and providing substantial resources, thereby helping enhance PU among the organization's employees. Furthermore, MS has a significant relationship with PEU and is supported ($\beta=0.175$, $p = 0.035$). When management supports green

practices, it can help to increase the perceived value of those practices to stakeholders. It can be achieved by incentivizing and supporting suppliers who adopt green practices, such as lowering waste, using renewable energy, and promoting social responsibility. GRR have a significant relationship with PU is supported ($\beta=0.219$, $p = 0.004$). GRR can play a crucial role in increasing the PU towards adopting NZSCs. Also, GRR have a significant relationship with Intention to adopt NZSCs ($\beta=0.426$, $p = 0.013$).

GMT has a significant relationship with PEU is supported ($\beta=0.177$, $p = 0.032$). As more people switch to EVs, it becomes easier to envision a future where zero-emission transportation is the norm. In addition, adopting EVs results in green and efficient transportation infrastructure. For instance, installing charging stations and advancing battery technology can make EVs more pragmatic and convenient. Since customers were quite apprehensive about travel distance per single charge of EVs, to overcome this issue, Chinese manufacturer BYD has come up with the latest technology, which can charge a 1000 KW battery in just five minutes, with the travel of four hundred kilometers per single charge [131].

IPC has a positive role in achieving PEU is supported ($\beta=0.228$, $p = 0.007$). Collaboration and partnerships within industries can significantly aid in achieving NZSCs by enhancing the perceived feasibility of sustainable practices. When companies collaborate to reduce carbon footprint, they can combine their resources and knowledge to identify and implement more efficient and effective sustainable practices [12]. GMT has a significant relationship with intentions to achieve NZSCs ($\beta=0.191$, $p = 0.031$). Transportation significantly contributes to carbon emissions, and transitioning to EVs can help mitigate this issue. EV adoption offers benefits such as lower emissions, reduced costs, greater energy efficiency, and a more favorable public image for businesses committed to sustainability. Companies can take important steps toward reducing their carbon footprint and creating a more sustainable supply chain by choosing EVs for transportation.

OC positively associates with INT to achieve NZSCs ($\beta=0.168$, $p = 0.025$). The necessary competencies can enable an organization to implement sustainable practices more easily and effectively, resulting in a smoother transition towards achieving NZSCs. Competent organizations can achieve NZSCs by employing strategic planning, resource allocation, technology implementation and execution and continuous improvement. PEU positively associates with INT towards NZSCs ($\beta=0.238$, $p = 0.011$). R^2 value of PEU = 0.340, PU = 0.417, INT = 0.389. If supply chain participants perceive that adopting sustainable practices and technologies is easy, they are more inclined to do so, leading to net-zero adoption. Conversely, they are less likely to adopt it if they perceive it as challenging. It is important to note that other factors, such as the cost and availability of sustainable technologies, government regulations, and consumer demand, can also impact NZSCs. Thus, PEU can be a contributing factor but not the sole determinant. Chatterjee et al. [132] also analyzed the positive relationship between PEUs and intentions to adopt artificial intelligence.

The relationship between OC and PEU is not supported; the possible reason is explained as follows: it is quite important that organizational culture sets the tone for adopting advanced technologies, but perceived

Table 6
Mediation results.

	Hypothesis	Path	Direct Effect				Indirect Effect			Result
			Effect	t	LLCI	ULCI	Effect	LLCI	ULCI	
Mediation Effect of PEU	H3c	GRR → PEU	0.0405	3.5613	0.0182	0.0628	0.0037	0.0625	0.0644	Partial Mediation
	H4c	IPC → INT → PEU	0.0029	3.0544	0.0010	0.0048	0.008	-0.0466	0.0413	No Mediation
	H5c	OC → INT → PEU	0.1157	2.8841	0.0371	0.1943	0.0232	-0.0844	0.239	No Mediation
	H6c	MS → INT → PEU	0.1113	1.8488	-0.0067	0.2293	0.0676	0.0181	0.1302	Full Mediation
	H7c	LGDI → INT → PEU	0.1784	2.487	0.0378	0.3190	0.0538	0.0025	0.1189	Partial Mediation
	H8c	GMT → INT → PE U	0.2321	3.0145	0.0812	0.3830	0.0642	0.0025	0.1554	Partial Mediation
	H3d	GRR → INT → PU	0.102	2.1531	0.0091	0.1949	0.0542	0.0115	0.1138	Partial Mediation
	H4d	IPC → INT → PU	0.1029	1.6447	-0.0197	0.2255	0.0161	0.0026	0.0396	Full Mediation
Mediation Effect of PU	H5d	OC → INT → PU	0.1383	2.0356	0.0051	0.2715	0.0130	-0.0087	0.0439	No Mediation
	H6d	MS → INT → PU	0.1561	2.9361	0.0519	0.2603	0.0180	0.0070	0.0550	Partial Mediation
	H7d	LGDI → INT → PU	0.0638	2.8504	0.0199	0.1077	0.0098	0.0367	0.137	Partial Mediation
	H8d	GMT → INT → PU → INT	0.2786	3.3443	0.1153	0.4419	0.0083	0.0288	0.0545	Partial Mediation

ease of use is structured by system design, individual work skills and experiences. OC have a positive association with PU is also not supported; the possible reason can be the lack of human-centred equipment design, which enhances users' cognitive load. Another reason can be a lack of training and educational programs and the inability of management to communicate the advantages of high-end technologies, which causes employees to feel disengaged and not create interest and, thus, be resistant to change.

Likewise, LGDI does not affect PEU; the primary reason behind this can be that lean, green innovation is more concerned with reducing wastage, enhancing operational efficiency, and sustainability aspects; however, training and developing work skills play a pivotal role, which is not taken care of. As digital innovations evolve, design thinking plays a crucial role; therefore, designing advanced technological systems requires analyzing user perspectives regarding their comfort and cognitive understanding. Virmani et al. [133] discussed similar findings: human-centred design helps to enhance employee engagement and motivation.

GMT do not have a positive significant relationship with PU; the

possible reason can be that although green modes of transportation, like electric vehicles and green hydrogen, are upcoming, but because of lack of charging infrastructure and high initial costs, employees find it difficult to adopt and logistics activities are usually suffered.

The mediation results as shown in Table 6, the relationship between LGDI and INT has been found to be partially influenced by PEU. The integration of LGDI into the supply chain may necessitate significant changes such as restructuring processes, implementing new technologies, and adopting new practices. If stakeholders perceive adopting such changes as easy, they are more likely to accept the new practices, thereby supporting the adoption of NZSCs. In addition, PEU fully mediates the relationship between MS and INT in adopting NZSCs. Management support helps get the best of the resources and provides the right direction and leadership to facilitate the implementation of NZSCs. If stakeholders perceive the adoption of NZSCs practices as simple, they are more likely to welcome new technologies and support their integration into the supply chain. The PEU can also influence stakeholders' acceptance of new practices and technology, leading to a successful transition towards net-zero emissions. GRR has a partially mediated

effect on INT through PEU, GRR facilitates industries to adopt net zero practices through incentives, subsidies, and tax benefits. Also, GRR helps simplify the complexity of technological innovation. Still, the prior reason is to meet compliances, follow government rules and regulations to reduce carbon emissions and adopt green practices.

PU partially mediates the relationship between GRR and INT to adopt NZSCs. GRR can create a sense of urgency and importance for organizations to adopt NZSCs. When organizations perceive the rules and regulations set by the government as useful in achieving their net-zero goals, they are more likely to adopt these practices. The positive attitude of industries can lead to a greater willingness to invest resources and make necessary changes to adopt NZSCs. PEU partially mediates the relationship between GMT and INT to adopt net-zero practices. If individuals perceive EVs as easy to use, they are more likely to consider them a viable option for their transportation needs. It, in turn, can increase their intention to adopt NZSCs, as EVs are more environmentally friendly than traditional gasoline-powered vehicles.

5.2. Implications

The study theorized various dimensions of TOE, i.e., technological, social and environmental, in pursuit of adopting NZSCs. Various constructs, including government rules and regulations, industry partnerships and collaboration, lean, green and digital transformations, pave the pathway towards achieving zero carbon emissions and hence gain sustainable competitive advantage. TAM theory was integrated to unleash inner and outer antecedents for NZSCs. The combination of Lean, Green, and Digital innovations can bring significant changes to supply chain and logistics management in the context of the Net-Zero economy. Additionally, the use of green transportation methods helps organizations cut down on carbon emissions and achieve sustainable growth. LGDI facilitates organizations by providing cost-effective solutions for real-time tracing and tracking of goods and services. Further, PEU helps simplify the process by making it quicker and easier for the organization to adopt smart technologies to achieve operational efficiency and reduce environmental impact.

5.2.1. Theoretical implications

The presented study adds to the literature by integrating the TOE-TAM framework and assessing the impact of various key constructs, including MS, GRR, IPC, OC, and LGDI, GMT.

- Perceived ease of use (PEU) positively impacts the intention to adopt NZSCs. A comprehensive system helps minimize the cognitive load and hence helps quickly adopt advanced technologies. As discussed in scholarly literature, resistance to change is a major concern that impedes the integration of advanced technologies into circular practices and the adoption of net zero practices. Therefore, PEU helps simplify the work, reducing the transition time to adopt sustainable practices.
- The government must establish strict rules and regulations and facilitate the organizations to achieve net zero practices. Technical guidance must be provided, which can help better understand net zero principles and find the best possible ways to cut down pollutants. Already, the Indian government have taken the initiative to switch to electric vehicles by 2034 [134].
- Digital technologies can help create virtual carbon footprint maps of business operations, helping organizations monitor and control processes effectively. Therefore, it will help the managers streamline operations and eliminate wastage from supply chain activities. Also, focusing on NZSCs practices helps organizations gain a competitive advantage and increase profitability [135].
- Management helps set the stage for NZSCs adoption by providing a clear vision and mission, optimum resource allocation, a conducive working environment, and a work culture. It is equally important for

the organization to develop a robust performance monitoring system and promote cross-functional collaboration.

5.2.2. Practical implications

Industry managers and practitioners must take the following actions for successful NZC adoption.

- Developing strategic, tactical and operational goals to reduce carbon emissions is imperative. The organization's vision and mission must be aligned with these objectives. Furthermore, cross-sectorial collaboration can facilitate the quick adoption of NZSCs [136].
- Machine learning models can be used to detect sources of inefficiencies across different supply chain operations; accordingly, strategies can be developed. It is also essential to simulate the planned actions before their execution for better effectiveness.
- Industry partnership and collaboration can help develop scalable and creative solutions for NZSCs adoption. Common carbon exchange platforms can be developed so that the industry can get guidance from other industry leaders and exchange knowledge easily.
- Organizations must understand the importance of green modes of transportation. They must take suitable measures like shifting to electric vehicles logistics to reduce the impact of carbon footprint. Green hydrogen fuel has recently emerged, significantly contributing to achieving NZSCs target sustainable development goals.
- Organizations must also develop a supporting culture so employees can freely express their creative and innovative ideas. Moreover, if required, organizations can provide them with resources, including time and money, to further explore research ideas and develop the best possible solutions.
- Ohene et al. [137] analyzed sociocultural roadblocks toward net-zero adoption, which include a lack of consumer knowledge, change resistance, low customer demands, and risk aversion. Therefore, organizations must take appropriate measures and adopt change management strategies. Presently, most countries are in the initial phase of net-zero adoption, and as such, industries are quite hesitant, specifically in the context of economic gains considerations. Therefore, if the government provide technical guidance, funding and subsidies to the industry players, particularly micro, small and medium enterprises, it will help them understand the nitty-gritty of net-zero perspectives and quick adoption of green technologies.

5.2.3. Implications for higher educational institutes/academics

- Since the world is changing at a very fast pace, and so is the academic culture. In today's academic society, students are very tech-savvy. Therefore, academicians are required to be up to date to make classroom delivery effective. On the other hand, students will lose interest if faculty members use conventional curricula and traditional tools. Therefore, syllabus must include role of digital transformations in achieving NZSCs.
- Rather than theoretical or bookish language, industry-based assignments and real-life projects based on NZSCs must be given. Although lecture sessions are required for supply chain fundamentals, the prime focus should be more on a case-based approach or solving research problems using contemporary tools.
- Schools/Universities must update their curriculum rather than covering outdated classroom syllabi. It will help them become corporate-ready and ultimately reduce the unemployment rate, enhance sustainable supply chain performance, achieve net-zero targets.
- Simulations/use cases on recent technological innovations, digital supply chain management, circular economy, and net-zero can be discussed in classrooms to help students understand and learn better.

6. Conclusion, limitations and scope for future work

The importance of net-zero adoption has increased tremendously in the last decade to mitigate environmental concerns. Both talent and technology are the pivotal drivers, but due to intertwined challenges, the understanding becomes intricate. Therefore, the current study offers valuable insights into key constructs impacting NZSCs and adopting sustainable business practices. Developing a strong and positive organizational culture helps to bring positivity among employees and facilitates them to explore innovative ideas. Industry adoption of Lean, Green, and Digital technologies for Net-Zero economy supply chain and logistics management is increasing for multiple reasons. Firstly, as environmental awareness grows among consumers, they are becoming more conscious of the impact of their purchasing decisions on the planet. Furthermore, consumers expect organizations to adopt sustainable practices and take measures to reduce carbon footprint. Organizations demonstrating their commitment to sustainability stand to gain a competitive advantage in the marketplace.

Secondly, the Government is decisive in implementing regulations to curb greenhouse gas emissions and promote sustainable practices. Failure to comply with these regulations can result in penalties, loss of business opportunities, and reputational harm for organizations. Organizations are turning to Lean, Green, and Digital innovations to sustainably manage their supply chains and logistics to mitigate these risks.

Thirdly, incorporating sustainable practices can yield substantial cost savings for organizations. For instance, using renewable energy sources can reduce energy costs, and waste which minimizes expenses. By adopting Lean, Green, and Digital innovations, organizations can optimize their operations, decrease waste, and cut down on expenses, and attain sustained business performance. Besides this, technological innovations can be a game-changer for adopting sustainable and green practices. Embracing Lean, Green, and Digital innovations can generate fresh business prospects for organizations. For example, developing sustainable packaging materials or implementing circular economy practices can unlock new markets and revenue streams.

Also, as the world moves towards industrialization, it is obvious that the energy demand will rise. Therefore, organizations must enhance their renewable energy quotient to meet these requirements and achieve

sustainable supply chain performance. Also, most countries are developing supporting policies for green steel and green hydrogen adoption. Moreover, critical industrial sectors, including steel, cement, and power, are making significant attempts to shift to green supply chain practices.

Like every research study, the presented research also has some limitations that can provide future research avenues for budding researchers and practitioners. Since the presented research analyzes cross-sectional data, longitudinal data can be collected for future scope, and results can be compared. The stated results can be used to analyze the industries' intentions towards NZSCs. Since our research results are based on emerging economies, the results cannot be generalized. Similar research analysis can be conducted in a developed economic context, and results can be compared. The scale development of adopting net-zero practices in the supply chain can be established to provide more comprehensive insights to the researchers, practitioners and budding managers. Diffusion of Innovation Theory, Stimulus-Organism-Response (SOR) or similar frameworks can be conceptualized to assess the individual and industry-specific perspectives towards NZSCs. Also, the research results can be explored with the fuzzy-set qualitative comparative analysis (fs-QCA) approach.

CRediT authorship contribution statement

Naveen Virmani: Writing – original draft, Validation, Investigation, Data curation, Visualization, Methodology, Formal analysis, Conceptualization. **Pranav Kumar:** Writing – original draft, Validation, Investigation, Visualization, Software, Formal analysis. **Koppiahraj Karuppiyah:** Writing – original draft, Validation, Investigation, Visualization, Methodology, Formal analysis. **Sandeep Jagtap:** Supervision, Project administration, Formal analysis, Writing – review & editing, Resources, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix-A: Questionnaire

Name of the Respondent:
Name of Organization
Age:
Qualification:
Designation
Current Job Responsibilities:
Number of employees:
Gender
Years of Experience:
Year of Establishment of Organization:
Organization Turnover:

Rate the following items on 1-5 scale, 1-implies strongly disagree and 5 implies strongly agree

GMT is highly efficient compared to conventional vehicles, requiring less energy to travel the same distance.

GMT reduces dependencies on fossil fuels by focusing on renewable energy sources.

GMT can meet the requirement for carrying out supply chain activities

Real-time tracing and checking of shipments helps to improve visibility and mitigate the risk of wastages or overproduction

Automated scheduling and routing systems to optimize delivery routes and reduce transportation-related emissions.

Cloud-based platforms for data sharing and supply chain collaboration

Senior management must demonstrate a commitment to sustainability and prioritize the lessening of GHGs emissions in the supply chain

(continued on next page)

(continued)

The organization provides adequate training and educational programs to keep the employees educated about the significance of adopting green practices

Senior management must establish key performance indicators (KPIs) and reporting mechanisms to track NZSCs progress

Organizations must clearly understand supply chain operations and recognize opportunities to reduce the carbon footprint at each stage.

Organizations must continuously monitor and evaluate their NZSCs to identify areas for improvement.

Organizations have sufficient capabilities to design products to enhance circular economy practices.

Businesses can work together to promote government policies, rules and regulations that encourage the change to a low-carbon economy.

Businesses can collaborate to share best practices to improve supply chain operations.

Businesses can work together to develop standardized methods for measuring the carbon footprint of distinct products and services.

Businesses can collaborate to invest in research and development of new technologies that decrease carbon emissions across supply chain linkages.

Government incentive schemes help the organizations to achieve NZSCs.

Emissions reduction targets for businesses and industries, requiring them to set and meet specific reduction goals

Funding support for research and development helps to reduce carbon emissions in supply chains.

Public private collaborative programs facilitate businesses' transition to green energy resources.

Providing simple and easy-to-use tools and systems such as carbon footprint calculators, sustainability dashboards, and reporting systems, can make it easier for them to adopt sustainable practices.

Integrating digital tools and systems into existing processes reduces cognitive load and make it easier to adopt sustainable practices

Providing regular feedback and monitoring progress toward sustainability goals can help understand the impact of their actions

Sustainable practices can also lead to improved product quality and minimizing carbon footprint.

Adopting green practices helps minimize energy and resource usage, resulting in cost savings.

Adopting sustainable practices can also increase a business's status and brand image.

Sustainable practices can also lead to increased efficiency, such as reducing waste and streamlining processes

I understand the importance of Net-zero practices in enhancing supply chain performance.

I am willing to invest time and resources and learn about NZSCs

I am motivated to decrease the carbon footprint of our supply chain

I feel a sense of responsibility to reduce our organization's impact on the environment

I have a moral obligation to adopt a NZSCs

Data availability

Data will be made available on request.

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