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The relationship between information processing capabilities, Net-Zero capability, and supply chain performance

Abstract

Purpose – This study views Net-Zero as a dynamic capability for decarbonising supply chains. It aims to investigate the relationship between three information processing-related capabilities (supply chain visibility, supply chain integration, and big data analytics) as its antecedents and supply chain performance as its competitive advantage outcome.

Methodology/Design - The authors conceptualise a research model grounded in the literature based on dynamic capabilities and information processing views. The study uses a structural equation modelling technique to test the hypotheses' relationship using the survey data from 311 industrial enterprises.

Findings – The results show that supply chain integration and big data analytics positively and directly influence the Net-Zero capability. No significant direct impact is found between supply chain visibility and Net-Zero capability. Big data analytics fully mediates supply chain visibility and partially mediates supply chain integration in their relationship with Net-Zero capability. The results also confirm that Net-Zero capability positively impacts supply chain performance.

Originality – This study contributes to operations management and supply chain literature by extending the knowledge about Net-Zero supply chains through an empirical investigation. In particular, the study suggests big data analytics is essential to enhance Net-Zero capability as supply chain visibility alone does not significantly contribute. The study also documents the benefit of Net-Zero capability on supply chain performance, which can encourage more volunteer actions in the industry.

Keywords – Net-Zero, supply chain, decarbonisation, Scope 3 emissions, big data analytics, visibility, performance

Paper type – Research paper

1. Introduction

Net-Zero is defined as the balance between the greenhouse gas (GHG) emissions produced and the amount removed from the atmosphere (United Nations, 2023). Excessive GHG emissions by humans and inefficient production processes across the Supply chains (SC) are some of the reasons that have caused this environmental imbalance. SCs play a vital role in succeeding this target as they cause a large portion of the total annual GHG in the world – a total of eight SCs (food, construction, fashion, FMCG, Electronics, Auto, Professional services and other freight) cause over 50% of total emissions (Burchardt et al., 2021). Therefore, it requires an organisational effort to effectively measure Net-Zero (CO_2 emissions) and sustained reduction throughout their operations and supply chains.

The necessity of SCs becoming Net-Zero does not only originate from the pressure of customers and stakeholders (Zhang, Tay, et al., 2022b), but also the fact that many large developed and developing countries such as the EU, USA, Australia, Vietnam and Brazil have set a target to achieve Net-Zero by 2050. Consequently, SCs need to achieve Net-Zero emission targets in only a few decades. Achieving Net-Zero emission targets, on the other hand, is a challenging task to accomplish. It requires not only the focal company's direct emissions, i.e. from its own operations (Scope 1) or emissions related to the electricity purchased for operations (Scope 2), but also emissions related to outsourced manufacturing, purchased goods or services and usage of goods sold (Scope 3) (Schulman et al., 2021). Net-Zero is a complex challenge for SCs that requires overcoming multi-dimensional barriers (Vimal et al., 2022). The challenge mainly arises from the Scope 3 emissions as most of the supply chain emissions – up to 90% for end products SCs – originate from SC partners in the upstream activities (WEF, 2021). The literature also emphasises the criticality and difficulty of decarbonising Scope 3 emissions in SCs. For instance, Schulman et al. (2021) investigated Scope 3 emissions of Wallmart's food SC, while Radonjič & Tompa (2018) underlined the importance of focusing more on Scope 3 emissions by analysing carbon emissions of telecommunication companies. Gopalakrishnan (2022) illustrated the complication of Scope 3 emissions, particularly regarding data sharing and measurement.

Data sharing and analysis are pivotal to tackling Scope 3 emissions as they require tracking, collecting, analysing, and reporting of emissions in upstream and downstream activities of SC partners (Schulman et al., 2021). Stenzel & Waichman (2023) also highlighted the benefits and challenges of SC data sharing and analysis in tackling Scope 3 emissions. The data issue is recognised by many – including the Paris Agreement – which identified the lack of transparency as the major challenge (King et al., 2022; Vimal et al., 2022). World Economic Forum report also underlines data sharing as the core barrier of upstream Scope 3 emissions (WEF, 2021). The underscored importance of the data sharing issue makes sense as hundreds of SC partners in different tiers carry out numerous activities, each causing emissions. Consequently, the problem with Net-Zero SC is that although most carbon emissions originate from SC partners, the data sharing and analysis between them become problematic.

Data analytics is the key to overcoming carbon emission data issues as the accurate and complete analysis of the data sourced from multiple stakeholders and SC operations require data analytics capabilities. For instance, Ramaswami et al. (2021) underline data analytics' importance in achieving Net-Zero for sustainable cities. Big data analytics (BDA) can help organisations accurately measure and report their carbon emissions consistently (Zaman et al., 2017). BDA can also help organisations identify the sources of carbon emissions across their operations and SCs to pinpoint the areas responsible for major carbon footprints (Sundarakani et al., 2021). The literature also suggests that BDA can help in low-carbon supplier selection, such as in the beef supply chain (Singh et al., 2018). However, despite the potential capability of BDA in achieving Net-Zero SC, there exists a gap in the literature regarding examining the positive role of BDA on Net-Zero SC.

In addition to BDA, SC visibility (SCV) is also propounded as a prerequisite of Net-Zero SCs. Visibility powered by state-of-the-art technology such as Blockchain or Industry 4.0 could enhance the SC decarbonisation process (Bin et al., 2022). Lack of visibility is considered a major barrier to decarbonising SC operations, as focal firms cannot see and monitor their SC network emissions (Accenture, 2022). Supply chain integration (SCI) is another core capability that can help to achieve Net-Zero targets by improving transparency and data sharing among SC partners. For instance, Daryanto et al. (2019) documented that SCI can help reduce carbon emissions. Despite the propounded benefits of SCI, SCV and BDA as dynamic capabilities that lead to Net-Zero as a second-order capability (NZC), the literature suffers from empirical studies examining the relationship between these constructs. Therefore, it is unknown whether those capabilities can help to reduce Scope 3 carbon emissions in SCs. For instance, although visibility is believed to contribute to achieving Net-Zero emissions, it is not documented whether SCV directly improves Net-Zero achievement or even indirectly that is through BDA capability. Hence, the first aim of this study is to examine the relationship between SCI, SCV and BDA on Net-zero SC by introducing Net-Zero as a reconfigured dynamic capability (NZC).

Another gap in the literature is the lack of studies investigating the benefits of Net-Zero practices to SCs. Professional service networks in the industry suggest that Net-Zero initiatives can positively transform SCs and improve performance indicators such as efficiency, cost, and customer service (PwC, 2023). Prior seminal studies in the literature also mention the potential benefits of Net-Zero economy. Yet, most of these are society-level benefits, such as public health protection, while the organisational-level benefits are mostly overlooked (Singh et al., 2022). Furthermore, the literature is silent about how NZC could positively influence business and supply chain performance (SCP). The positive impact of environmental performance is documented in the literature (Layaoen et al., 2023). Yet, more empirical studies are needed to test the positive impact of NZC on SCP. Documenting these benefits is vital to motivate more SCs to take voluntary actions to pioneer Net-Zero facilities. Gaining a competitive advantage over competitors attracts businesses to take more voluntary environmental actions (Ahmadi-Gh & Bello-Pintado, 2022; Videras & Alberini, 2000). Thus, if SCs recognise the positive role of NZC on SC performance, then more SCs can make voluntary Net-Zero pledges and target earlier Net-Zero dates, such as Amazon, P&G, and Philips, which have already pledged to accomplish Net-Zero targets by 2040. Accordingly, the second aim of this study is to examine the impact of NZC on SCP.

The study adopts the dynamic capabilities view (DCV) as the theoretical underpinning to rationalise those relationships. The study models BDA, supply chain visibility (SCV), and supply chain integration (SCI) as dynamic capabilities that lead to Net-Zero as a second-order capability as NZC while considering superior SC performance as a competitive advantage tool. NZC in our study refers to tracking, collecting, analysing, and reporting Scope 3 emissions in a transparent, accurate, consistent, and complete manner in upstream and downstream SCs. The relationship between Net-Zero and its antecedent capabilities is further rationalised by underpinning the information process view (IPV). Accordingly, the study utilised SCV, SCI, and BDA as information processing capabilities. A theoretical model is generated to test the relationship between SCV, SCI, BDA, NZC, and SCP. The model is tested through structural equation modelling based on a survey of industrial enterprises.

The study offers significant contributions to literature and makes important implications for the practice. The study expands the knowledge regarding Net-Zero SCs by empirically investigating the impact of BDA, SCV, SCI on Net-Zero SCs and by testing the impact of NZC on SCP. Testing these relationships helps validate whether those anticipated positive impacts exist, and if so, how do they occur, i.e., directly or through a mediator capability. SCV, for instance, is proposed as a prerequisite for carbon-neutral SCs (Zhang, Tay, et al., 2022b), yet our findings suggest that SCV can positively influence Net-Zero SC through the mediation of BDA. The study considers Net-Zero as SC capability (NZC) and develops it as a construct contributing to the literature. Results of the study show that building a NZC can also positively influence the SCP. This result implies that SCs can demonstrate NZC as a competitive advantage tool by facilitating a superior SCP.

2. Literature review and theories

2.1 Dynamic capabilities view (DCV) and Net-Zero

In recent years, DCV (Teece, 2012) has attracted considerable interest as a theoretical lens within the operations management literature to explain superior organisational performance. DCV focuses on environmental turbulence by integrating, building and reconfiguring the dynamic capabilities to address the changing environment and remain competitive (Teece, 2012). DCV accepts the premise of a resource-based view (RBV), that the organisations achieve competitive advantage over their competitors based on a combination of valuable, rare, inimitable and non-substitutable resources to build capabilities (Barney, 1991; Grant, 1991). Moreover, the research on RBV and DCV argues that organisational resources should transform into dynamic capabilities that enable them to address turbulent environments and gain a competitive advantage (K. Z. Zhou & Wu, 2010). Several authors have used DCV to explore the potential of analytics as unique resources and capabilities for improving performance (Behl et al., 2022; Dubey et al., 2020; Gupta et al., 2020; Munir et al., 2022).

DCV is also proved to be useful in the SC context. DCV constitutes resources that organisations align into their processes to build dynamic capabilities. These capabilities help organisations to address market changes and enhance organisational performance. Dynamic capabilities are of absolute necessity for organisations depending on environmental turbulence and market conditions. Net-Zero could be considered as an organisational capability to measure carbon emissions across the SC. Net-Zero is defined as the balance between the greenhouse gas (GHG) emissions produced and the amount removed from the atmosphere (United Nations, 2023). Excessive GHG emissions mainly cause this environmental disbalance by humans, inefficient production processes and supply chains. Therefore, it requires an organisational effort to effectively measure Net-Zero (CO_2 emissions) and sustained reduction throughout their operations and SCs.

The social and environmental campaigns and regulatory pressures are forcing big companies such as Asia Paper and Pulp, Nike, Kimberly Clark, Lego and General Mills to minimise unsustainable practices to protect the climate (Gunther, 2015). Toxic chemicals, plastics, food spoilage, use of resources, and production emissions are the major contributors to GHG emissions (McKinsey & Company, 2022). One way to achieve Net-Zero SC is to quantify SC emissions using carbon-accounting tools (McKinsey & Company, 2021). Some companies have taken inspiring initiatives to minimise emissions, such as Hewlett-Packard, which has designed a carbon reporting tool to audit GHG emissions; Apple pledged to plant 27,000 trees in mangrove forests to support biodiversity and minimise carbon emissions; Apple and Microsoft are already running their facilities on renewable energy to minimise the impact on the environment; Google using eco-friendly materials and renewable energy to minimise waste and be carbon-free till 2030; Ford, the largest manufacturer, has made a comprehensive environmental policy to produce eco-friendly fabrics and recycling paint fumes (TravelPerk, 2021).

Production and SC activities are the major contributors to Net-Zero (CO_2 emissions) (CDP, 2019). Therefore, extant literature has explored various practices and environmental capabilities to minimise Net-Zero at the SC level. Subramanian & Abdulrahman (2017) proposed that if manufacturing companies implement low carbon capabilities in their product redesign, then it will result in performance improvement.

Several studies have discussed the challenges in measuring accurate Net-Zero emissions. Rehman Khan & Yu (2021) have assessed the eco-environmental performance by collecting data from 415 manufacturing firms. They found that internal environmental management information systems help the firm quantify its environmental impact and facilitate adopting green supply chain management practices. These practices will eventually achieve competitiveness and improve economic and environmental performance. Sharma et al. (2022) have analysed the impact of environmental dynamism on low carbon. They concluded that low-carbon practices in digital supply chain networks partially mediate sustainable performance. Wanke et al. (2021) have evaluated the low-carbon operations in an emerging market by adopting the information-entropy model. They found that CO_2 emissions are perceived differently among the stakeholders. The main reasons were a lack of low-carbon adoption practices and manufacturing processes in product design.

Reducing environmental disbalance requires effective measurement of emissions and rapid, sustained reduction of Net-Zero. Organisations must use effective measurement and reporting to meet the United Nations 2050 mission (Zhang et al., 2022). Following the mission, many global organisations have started planning climate policies to reduce emissions from their operations and supply chains. CDP report has identified that the supply chain Net-Zero emissions are 5.5 times higher than the direct emissions by operations of organisations (CDP, 2019). To meet the Net-Zero goals, organisations have to develop an inter-organisational mechanism by utilising resources to engage all SC partners to measure accurate emissions (Gong et al., 2018). Existing research has explored the coordinated efforts to meet the Net-Zero goals by incorporating innovation into business processes for achieving growth (Stern & Valero, 2021), identifying barriers to SC decarbonisation through case studies (Zhang et al., 2022), identifying the challenges in building Net-Zero SCs through network relationship mapping (Vimal et al., 2022), exploring the drivers, barriers and practices in Net-Zero economy from a multi-stakeholder perspective (Singh et al., 2022), listing carbon neutrality drivers to achieve SC and firm performance (Zhang al., 2022). The aforementioned research tends to focus more on Net-Zero policies, identifying barriers and challenges with limited empirical evidence from SCs and organisational resources to meet the Net-Zero goals. Hence, we draw from prior studies and argue that Net-Zero as an organisational complementary dynamic capability has gained less attention and has been largely ignored. This study will enrich the DCV by highlighting the importance of Net-Zero as a reconfigured dynamic capability (NZC) that will help the organisation in achieving competitive advantage under the changing volatile environment.

2.2 Information processing view and Net-Zero

The information processing view (IPV) suggests that organisations operate and evolve in social systems with task uncertainty and equivocality due to incomplete and inadequate information for decision-making (Galbraith, 1974). While uncertainty stems from sources such as insufficient knowledge and information, modes of coordination across organisations and sub-units, the mechanisms for hierarchical referral and operating procedures, complex and interdependent tasks, and equivocality resulting from ambiguity of information (Daft & Lengel, 1986; Galbraith, 1974; Gattiker & Goodhue, 2004; Li et al., 2019). To address uncertainty and equivocality, organisations need to organise and utilise additional information (Wong et al., 2020).

The IPV constitutes 3 primary components pertaining to information such as: information processing needs, information processing capabilities and the fit between the needs and capabilities (Tushman & Nadler, 1978). Information processing needs can be considered as information systems and skills required by the organisation to make the right decisions, while information processing capability is the organisational capacity to collect, integrate, interpret and analyse information for effective decision-making (Ferraris et al., 2019). The fit between information processing needs and capabilities is the alignment between the two to satisfy the organisational needs in reducing uncertainty, equivocality and subsequently improving performance (Wu et al., 2013).

Net-Zero has not been studied in detail in the context of supply chains (Table 1).. The researchers have taken a holistic view of Net-Zero operations and economies. In this respect, we maintain that organisations should consider Scope 3 emissions from sub-tier suppliers and operations as the carbon footprint is multiplied by 10 times in a sub-tiered SC (Bataille et al., 2016). To measure Net-Zero and develop it as a dynamic capability (NZC), organisations need BDA and SCV as prerequisites. Limited analytics capability and lack of visibility are major barriers to decarbonising SC operations, as focal organisations cannot see, analyse and monitor their SC network emissions (Accenture, 2022). SCI is another core capability that can help to achieve NZC, i.e., by improving information sharing and operational coordination among SC partners. Hence, the development of NZC through BDA, SCV and SCI can help to collect and measure all carbon emissions data across the SC (Al-Khatib, 2022). NZC should also help to establish long-term strategic partnerships to achieve carbon neutrality (Labanca et al., 2020).

The literature on IPV suggests that organisational investments in information sharing and processing can lead to information processing capabilities to improve SCP (Mishra et al., 2021). Hence, the need for effective collaborative relationships with sub-tier suppliers to capture, analyse and transmit a large amount of carbon emission data is important to reduce environmental uncertainty (Schoenherr, 2023).

The sub-tiered supply chain operations are information-intensive, and as per IPV the SCP depends on organisational information processing capabilities (Galbraith, 1974; Zhou et al., 2023). Previous SC management literature has demonstrated that information processing capabilities such as big data, AI and machine learning can help organisations quickly collect, integrate, interpret and analyse hidden patterns within the SC to improve supply chain performance (Belhadi et al., 2022; Liu & Chiu, 2021). Zhang et al. (2022a) conducted a case study on early movers of carbon neutrality and supported the collaborative relationships across the sub-tier suppliers to achieve firm and supply chain performance. Hence, NZC would act as a crucial information processing capability that increases information visibility in the dynamic environment and helps organisations to conduct SC operations more efficiently while achieving SCP.

Table 1: Earlier research on Net-Zero and decarbonisation (Source: Authors own work)

Study	Purpose	Context
Govindan (2023)	Digitisation to develop a smart circular economy to meet sustainable development goals (SDGs) and Net-Zero	Smart circular economy
Patil et al. (2023)	Digital transformation strategies of supply chains to achieve carbon neutrality	Strategic roadmap for decision makers in achieving carbon neutrality
Okorie et al. (2023)	Integration of digital technologies in manufacturing to achieve Net-Zero emission goals and circular economy	Net-Zero manufacturing

Kumar et al. (2023)	Analysis of adoption barriers to low carbon operations in emerging economies	Emerging economy operations
Sharma et al. (2022)	The impact of the digital supply chain on sustainable performance by considering environmental dynamism, low carbon practices in manufacturing firms	Manufacturing firms
Singh et al. (2022)	Investigation of drivers, barriers, and policies in Net-Zero economy	Net-Zero economy
Kannan et al. (2022)	Identification of barriers to carbon regulatory environmental policies in emerging economies	Emerging economy supply chains
Vimal et al. (2022)	Net-Zero resilient supply chain implementation challenges	Supply chain roadmap to Net-Zero
Stern & Valero (2021)	Climate crisis and innovation-led approaches to address opportunities, drivers and policies	Long term policy
Mahapatra et al. (2021)	Analysis of factors that influence carbon emission	Company's Supply Chain
Nelson & Allwood (2021)	Disruptive technologies and individual behaviour to possible decarbonisation in UK	Supply chain decarbonisation in UK
Bataille et al. (2021)	System modelling and policy needs to address Net-Zero emissions in the world	Global Net-zero emissions in industry

2.3 Review of big data analytics (BDA) and Net-Zero as a dynamic capability (NZC)

In the digital economy, organisations progressively leverage the latest technologies to increase information exchange, responsiveness, visibility and transparency in and across their supply chains (Dubey et al., 2022). As a result, data-driven organisational resources require big data techniques, which results in accumulating big data categorised in terms of high velocity, volume, value, variety and veracity - 5V's (Behl et al., 2022; Bag et al., 2021). However, the accumulated big data is of little or no value to organisations if not properly searched, analysed, and visualised i.e. Big Data Analytics (BDA) (Akter et al., 2021; Gunasekaran et al., 2017; Zhang et al., 2020).

BDA is an organisation-specific resource that is easy to adopt but difficult to develop into a capability to help organisations achieve a competitive advantage (Fosso Wamba & Akter, 2019). However, past research showed that the BDA capability (BDAC) has emerged as a game-changer in SCs by enabling organisations to enhance demand forecasting, optimize their transportation, effective inventory management, quality improvement, reduce safety stocks, supply chain resilience, and improve supplier performance (Dennehy et al., 2021; Inamdar et al., 2021; Morimura & Sakagawa, 2023; Raut et al., 2021). In addition, BDAC contributes to organisational performance by integrating other capabilities such as SC analytical capabilities (Cadden et al., 2022), green capabilities (Khan et al., 2023), dynamic capabilities (J. L. Mishra et al., 2022) and innovation capabilities (Ashrafi et al., 2019).

Generally, BDAC relates to organisations' information processing capacity or capability, enabling them to acquire big data from SC partners to gain insights into the changing environment and remain competitive through effective decision-making. For example, Wong et al. (2021) argue that information processing can be enhanced through the timely acquisition and processing of SC big data, which is possible through SC integration. Similarly, Agrawal et al. (2022) explored that advanced information processing tools such as BDA and technologies enhance SCV to mitigate uncertainty. Hence, SCV and SCI offer opportunities for SC partners to collaborate SC data, gain valuable insights to respond to market changes and remain competitive (Cadden et al., 2022).

Net-Zero or carbon neutrality has gained significant attention from organisations after the 26th Climate Conference of the Parties (COP26), which identified the importance of climate threats. It emphasised organisations' need for joint efforts to minimise Net-Zero emissions in their operations and supply chains (COP26, 2021). Hence, organisations have to perform organisational activities in collaboration with SC partners to measure Net-Zero emissions and accordingly adapt to market changes. This requires a proactive organisational stance to reconfigure its resources and respond to market needs. Although, prior research has explored various industrial environmental conditions, such as environmental velocity (Li, Easterby-Smith, et al., 2019), and environmental dynamism (Gutierrez et al., 2022), as complementary BDA resources and capabilities to enhance organisational performance. Surprisingly, no study has investigated the possibility of Net-Zero as a second-order capability (NZC). Therefore, it is unknown whether NZC and other capabilities (SCI, SCV and BDA) can help reduce Scope 3 carbon emissions in SCs. For instance, although visibility is believed to contribute to effectively measuring the Net-Zero emissions, however, it is not documented in earlier research that whether SCV directly improves NZC or even indirectly that is through BDA capability. NZC has a distinctive role in leveraging information exchange, integration, responsiveness, visibility and transparency of Net-Zero data in and across their supply chain. Furthermore, the complementary relationship between BDA and NZC provides increased information processing capability to organisations. This capability can assist decision-makers in preparing better, timely responses to market changes and remaining competitive under turbulent conditions.

3. Hypothesis development

3.1 Supply chain visibility, Big data analytics and Net-Zero capability

Information technology and connected information systems create an inter-organisational linkage for information sharing. Information shared is essential for achieving SCV that should be accurate, timely, trusted and useful to facilitate decision-making processes (Williams et al., 2013). Barratt & Oke (2007) define SCV as "the extent to which actors within a supply chain have access to or share the information which they consider as key or useful to their operations and which they consider will be of mutual benefit." SCV aids in the efficient and effective execution of upstream and downstream operations across the SC (Sodhi & Tang, 2019). The extant literature discusses that increased information processing capability improves SCV, SCI, SC collaboration, SC flexibility, and SC transparency to make informed strategic and operational decisions (Agrawal et al., 2022; Belhadi et al., 2022; Iranmanesh et al., 2023; Kazancoglu et al., 2022; Wong et al., 2021). BDA is also an information processing capability with tools and techniques that enable an organisation to collect, integrate, interpret and analyse big data, thereby gaining insights to mitigate uncertainty and prepare under turbulent market conditions (Dubey et al., 2022). The enhanced SCV and BDA facilitate organisations to understand complex interactions better and help them to prepare for and respond to market changes (Srinivasan & Swink, 2018). Thus, we see that SCV and BDA capabilities are complementary, enabling data-driven insights and preparing organisations specifically by exchanging information, solving problems to reduce uncertainty and responding to market needs effectively. Thus, we hypothesise that:

H1: SCV has a positive impact on BDA

The 26th Climate Conference of the Parties (COP26) has identified the importance of climate threats. Hence, it has become a significant hassle for policymakers and organisations to minimise Net-Zero emissions throughout their SCs (Kannan et al., 2022). To address environmental turbulence, existing literature has explored information processing capabilities such as SCV, BDA, SCI and emerging technologies to acquire and process data to minimise the environmental impact (Agrawal et al., 2022; Ardito et al., 2019). Recent research highlights the importance of Net-Zero emissions and explores Net-Zero at SC levels. Burchardt et al., (2021) have suggested that organisations should have visibility of their upstream and downstream SCs to measure and analyse the carbon emission data. McKinsey & Company (2021) highlights the importance of quality data, carbon-accounting foundations, uncertainty in cost, technical feasibility, and industry-wide collaborations to meet the Net-Zero target. Hence, collecting, processing, and analysing Net-Zero SC data is vital for carbon minimisation. The IPV contends that information processing needs, information processing capabilities and the fit between the needs and capabilities improve organisation performance. Building on IPV, the SCV facilitates the visibility of carbon emission data across the SC partners. Hence, the development of NZC through SCV can help organisations to cultivate the huge volume of SC carbon emission data to make data-driven decisions; the fit between the two is the technological infrastructure that provides a means and alignment to satisfy the organisational needs in improving the SC performance under uncertain environment (Cadden et al., 2022; Yu et al., 2021). Thus advancing the following hypothesis:

H2: SCV has a positive impact on NZC

3.2 Supply chain integration, Big data analytics and Net-Zero capability

Supply chain integration (SCI) is a strategic intra (internal), inter (external) organisational integration and alignment of processes between supply chain partners for an adequate flow of goods, materials and information (Wong et al., 2021). The previous studies divided SCI into two interrelated dimensions. The first dimension is *information sharing,* which refers to the exchange of information between supply chain partners (Li, Cui, et al., 2019). The second dimension is *operational coordination*, which refers to aligning processes between SC partners to coordinate operational activities, such as the physical flow of goods or services, to create mutual value (Prajogo & Olhager, 2012). Thus, the information-sharing dimension provides organisations with an information processing capability to capture and analyse reliable data from SC partners to extract valuable insights, allowing decision-making to increase SC performance (Dubey et al., 2022; Oliveira & Handfield, 2019). Many leading organisations (e.g. Apple, Procter and Gamble, Nestle, BMW, Samsung) progressively leverage information processing capability to optimise supply chain activities and improve performance (Dubey et al., 2022). Hence, SCI is an information processing capability that has attracted the attention of several academics and practitioners under the pressure of environmental regulations (Benzidia et al., 2021). SCI relates to the effective collaboration and knowledge sharing between supply chain partners to gain insights for effective decision-making on environmental and SC performance (Fontoura & Coelho, 2022).

BDA is an organisational resource to analyse large-scale big data to generate meaningful insights (Kamble et al., 2021; Williams et al., 2013). As discussed earlier, SCI enables effective collaboration with SC partners, thus allowing more accurate and timely data, which helps organisations sense opportunities and develop new competencies. Furthermore, given that the rich data collected from SCI is properly searched, analysed and visualised by BDA, organisations can better prepare and respond to environmental changes under changing conditions (Gunasekaran et al., 2017). Accordingly, we propose the following hypotheses:

H3: SCI has a positive impact on BDA

Generally, SCI results in a collaborative relationship between SC partners. Organisations acquire SC data to gain insights and comply with environmental regulations while reducing uncertainty (Y. Liu et al., 2022). In recent research, environmental competitiveness is a link between organisational initiatives, capabilities and performance (He & Zhang, Schoenherr, 2023). COP26 emphasised organisations' need for joint efforts to minimise Net-Zero emissions in their operations and supply chains. SCI has the potential to acquire reliable and timely carbon emission data from SC partners. Thus, SCI is another core capability that can help to achieve NZC, i.e., by improving information sharing and operational coordination among SC partners. As a result, organisations can better control the overall operations and flow of goods and information. Thus, advancing the following hypothesis:

H4: SCI has a positive impact on NZC

3.3 Big data analytics and Net-Zero Capability

Big data analytics (BDA) is a dynamic organisational capability to support complex environmental enhancements for competitive differentiation (Schoenherr, 2023). Previous research has highlighted environmental competitiveness to develop a relationship between environmental practices and sustainable performance (Sharma et al., 2022a). Organisations have utilised BDA in varied contexts to achieve environmental competitiveness (Zhu et al., 2022). BDA facilities in timely response to SC partner needs by analysing data and taking timely decisions (Dubey et al., 2022). To comply with environmental regulations, SC partners should maintain a real-time flow of carbon emission data to meet Net-Zero targets through NZC. This results in increased information processing capability, which BDA facilitates by capturing, consolidating and analysing data. Organisations can then analyse the data concerning environmental criteria and should address changes in the business environment to remain competitive. Hence, BDA is an organisational capability that helps organisations identify and prepare for environmental needs (Zhu et al., 2022). It helps in the timely analyses of SC partners' carbon emission data and prepares the organisations to respond to the environmental needs in addressing the uncertainty of the turbulent markets. Thus, we hypothesize that:

H5: BDA has a positive impact on NZC

3.4 Net-Zero capability and supply chain performance

Empirical research on NZC and assessment from a SC perspective is limited and scattered. Earlier research primarily focussed on focal organisation carbon emissions, mainly from its operations, i.e., marketing, logistics, and warehousing. However, the research is shifting towards organisations' need for joint efforts to minimise Net-Zero emissions in their operations and SCs (Scope3) (COP26, 2021). The goal of Net-Zero could be achieved through NZC, i.e. by collecting and measuring all carbon emissions data across the SC (Al-Khatib, 2022). When a company actively pursues NZC by tracking and analysing carbon emissions arising from the operations of its SC members, the organisation can better control the overall operations and flow of goods and information. This improved control can eventually improve its downstream SCP, such as on-time and consistent deliveries (Prajogo & Olhager, 2012).

Furthermore, NZC is a green practice and the positive impact of green practices and environmental sustainability results in achieving SCP. Green practices such as eco-friendly product design, green procurement, and emission reductions often require collaboration and integration with supply chain partners (Khan et al., 2023). The improved connection with supply chain partners for green practices is expected to improve supply chain performance, as indicated in the study of Azevedo et al. (2011), who find that green practices in the Portuguese automotive industry positively impact SCP dimensions, including customer satisfaction. Zhang et al. (2022a) conducted case studies with the early mover of carbon neutrality and found that carbon neutrality initiatives can positively impact various firm performance indicators, including the downstream ones, such as route optimising. Katiyar et al. (2018) conducted a survey study in India and found that sustainability performance significantly affects the SCP. Therefore, NZC provides new insights related to environmental aspects, leading to improving SC processes and improving SC performance (SCP). Hence, we propose to examine the following hypothesis:

H6: NZC has a positive impact on SCP

3.5 Mediation effects of big data analytics

SCV aims to access accurate, timely, trusted and useful information to achieve organisational environmental goals, which are then positively reflected in SC performance (Bechtsis et al., 2022). In addition, SCV increases the collaboration among the SC partners and facilitates the flow of material and information across the

SC (Al-Khatib, 2022). BDA is an organisational information processing capability to analyse the data and gain insights. In the extant literature, BDA improves organisational performance (Agrawal et al., 2022; Ardito et al., 2019). However, the empirical evidence on the mediation role of BDA to NZC is scarce and inconclusive. From the DCV perspective, organisations adopting environmentally oriented dynamic capabilities will create a competitive advantage (Qiu et al., 2020). Hence, it is assumed that the organisation's capabilities, such as SCV and BDA, positively impact NZC. The previous discussion on H1 and H2 elaborates on the significance of SCV as a precursor of BDA and NZC. Thus, the following hypothesis can be assumed:

H7a: BDA mediates the relationships between SCV and NZC

SCI is the intra and inter-organisation collaboration of SC partners to comply with environmental regulations to remain competitive (Wong et al., 2021). The big amount of data collected due to SCI needs to be analysed to gain insights. IPV posits the information processing needs, information processing capabilities and the fit between the needs and capabilities (Tushman & Nadler, 1978). The information processing need comes from the big amount of data generated by SC partners. BDA refers to the organisational capability to analyse big data and generate new insights (Dubey et al., 2022). Thus, BDA provides organisations with an information processing capability to capture and analyse reliable data from SC partners to extract valuable insights, allowing decision-making to increase SC performance (Dubey et al., 2022; Oliveira & Handfield, 2019). The existing literature provides sufficient empirical evidence that SCI and BDA complement each other in increasing organisational performance (Al-Khatib, 2022; Schoenherr, 2023). By arguing that SCI facilities' information processing capabilities with BDA (H2), we posit that BDA can indirectly affect NZC to increase the organisational environmental capability (H4). Our study suggests the following hypothesis:

H7b: BDA mediates the relationships between SCI and NZC

The hypothetical model for the study is illustrated in Fig 1.

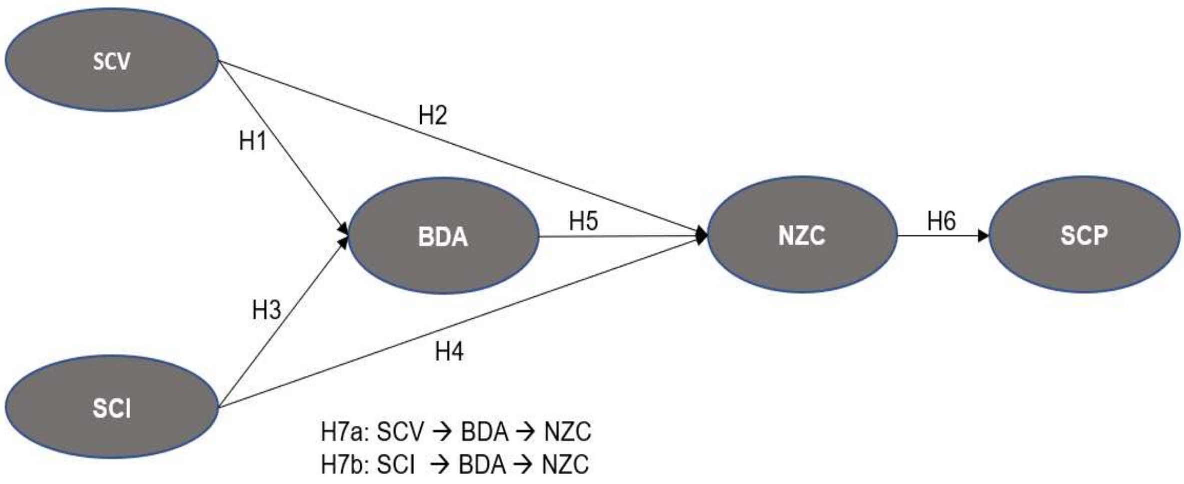


Figure 1: Hypothetical Model (Source: Authors own work)

4. Methodology

4.1 Sampling, data collection, non-response bias, and common method bias

A self-administered online survey is implemented on industrial enterprises (extracting raw materials and producing finished and intermediate goods) in Turkiye (previously named Turkey). This region is chosen for several reasons. Turkiye is among the top 25 countries considered in the Net-Zero Readiness Index research conducted by KPMG (KPMG, n.d.). Despite the relatively lower country index, it is home to many local and international large organisations which voluntarily publish GHG emissions (KPMG, 2021). As an official candidate for EU membership, Turkiye has introduced several carbon monitoring schemes and announced a Net-Zero target by 2053 (World Bank, 2022).

Moreover, sustainability and Net-Zero studies need more empirical evidence from emerging economies (Virmani et al., 2022). Hence, Turkiye is considered an ideal location for the study as it is a developing country. Its manufacturing and trading activities are highly connected to developed and main trading regions (i.e., Turkiye is the sixth largest trading partner of the EU and EU's exports account for approximately 40% of Turkiye's total) (Eurostat, 2022). Top trading partner countries are Germany, the UK, and the US. In addition, many international SCs have a large-scale manufacturing facility in Turkiye, including Ford, Toyota, Bosch, Unilever, Coca-Cola, Cargill, and Bayer.

A self-administered online survey was created for data collection. The clarity and appropriateness of questions were checked with preliminary interviews involving 8 supply chain experts (3 academics and 5 industry practitioners) with at least 7 years of experience. The survey consists of two parts involving demographics and measurement questions. The list of the top 1000 industrial enterprises, issued by Istanbul Chamber of Industry, is selected as the population (Istanbul Chamber of Industry, 2021). These companies are ideal for responding to Net-Zero and SC questions as large companies in Turkiye must publish their GHG emissions and are more likely to have an established SC than SMEs. The list is also appropriate regarding representation as it involves different industries (see Table 2). The list does not include service companies, which is appropriate for the study because our SCP involves indicators relevant to the delivery of physical goods and materials. The survey was collected from managers who could have an overall understanding of the organisation's SC. Accordingly, either top managers (i.e., CEO, country or regional manager) or managers from relevant divisions such as SC and logistics, production, operations, and procurement marketing managers are also included because they have an overall understanding of SC processes due to their managerial roles, and they are particularly knowledgeable about the downstream SCs. Moreover, anybody with less than 4 years of experience in the industry is excluded. A total of 311 responses were collected (31% response rate).

We checked if a non-response bias exists by comparing early responses accepted to participate in the study in the first invitation and late responses collected after a reminder was sent. No significant difference between early and late responses should exist regarding measured variables to ensure that non-response bias is an issue in the survey. One-Way ANOVA is conducted by considering the first 50 and last 50 responses as the independent variable, and a total of five dependent variables from constructs are considered. No significant difference exists between early and late responses($p>0.05$). Hence, it is unlikely that the survey suffers from non-response bias.

We applied several ex ante and post ante measures to prevent the survey from common-method bias concerns following the suggestions of MacKenzie & Podsakoff (2012). Regarding ex ante, we used different wordings in scale anchoring of dependent and independent variables, e.g., none – high for SCI, totally disagree – totally agree for Net-Zero, much worse – much better for SCP (see Table 2). Independent and dependent variables are positioned as far as possible based on the proximity separation method suggested by Kock et al. (2021). Clarity of survey items is ensured through preliminary expert interviews while the survey is kept as short as possible to avoid incorrect answers. Respondents were informed that the survey was anonymous to motivate more accurate answers. Regarding post ante, Harman's single-factor test was applied. The unrotated principal component analysis test results show that less than 50% of the variance is explained by the first factor, which indicates it is not likely the survey suffers from common-method bias (MacKenzie & Podsakoff, 2012).

4.2 Measurement development

The survey adopted measurement constructs and their items from the literature except for the Net-Zero capability (NZC), as no tested suitable construct was identified in the literature. NZC items are adopted based on Article 4 Section 13 of the Paris Agreement (UNCC, 2022) and a United Nations report, a technical handbook for developing nations (UNCC, 2019). Accordingly, the construct involves five main components of Net-Zero measurement: Transparency, accuracy, completeness, comparability, and consistency. According to Paris Agreement and the UN report, Net-Zero measuring should involve collecting, tracking, monitoring, analysing, and reporting carbon-emission data. Expert interviews also ensure the content validity of the construct. Exploratory and confirmatory factor analyses are conducted to check the overall validity and reliability of the construct.

The SCI construct is borrowed from Menor et al. (2007) as this construct is a concise, first-ordered one. It is also a suitable one as an independent variable of NZC because the construct involves integration with suppliers, customers, and within departments. The visibility construct is adopted from Brusset (2016), as it involves various visibility

Table 2. Survey measures (Source: Authors own work)

Measurement Items	Source(s)
Supply Chain Integration *(How integrated is your supply chain? 1: None, 5: High)*	
1) Integrated closely within your own organisation (e.g., cross-functional management).	(Menor et al., 2007)
2) Integrated closely with raw materials suppliers.	
3) Integrated closely with distributors or retailers.	
4) Integrated closely with customers	
Supply Chain Visibility *(Please indicate your level of agreement with following statements, 1: Totally disagree, 5: Totally Agree)*	

1) Integrating ERP with other SCM tools 2) Deploy track & trace IT tools 3) Deploy reporting tools (IT) 4) Develop web collaborative platforms	(Brusset, 2016)
Big Data Analytics *(Please indicate your level of agreement with following statements, 1: Totally Disagree, 5: Totally Agree)* 1) We use advanced tools (like optimisation/regression/ simulation) for data analysis 2) We use data gathered from multiple sources (like company reports, tweets, Instagram, YouTube) for data analysis 3) We use data visualisation techniques to assist decision-makers in understanding complex information extracted from large data 4) Our dashboards display information, which is useful for carrying out the necessary diagnosis 5) We have connected dashboard applications or information with the manager's communication devices	(Dubey, Gunasekaran, Childe, et al., 2019)
Net-Zero Capability (*(Please indicate your level of agreement with following statements, 1: Totally Disagree, 5: Totally Agree)* 1. We collect complete data on carbon emissions from our supply chain members (suppliers and customers). 2. We analyse comparable data on the carbon emissions of our supply chain members. 3. We track the consistency of our supply chain members' carbon emissions 4. We transparently monitor the carbon emissions of our supply chain members 5. We accurately report the carbon emissions of our supply chain members	Own elaboration based on interviews, Article 4 Section 13 of Paris Agreement (UNCC, 2022), and the United Nations report (UNCC, 2019)
Supply Chain Performance *(Please indicate your level of agreement regarding your performance compared to your competitors, 1: Much worse, 5: Much better)* 1. Provision of desired quantities on a consistent basis 2. Meeting quoted or anticipated delivery dates and quantities on a consistent basis 3. Meeting customer satisfaction with a supply chain performance on a consistent basis 4. Time between order receipt and customer deliver	(Mishra et al., 2016)

tools and technologies that can help better track and monitor Net-Zero emission data. BDA is borrowed from Dubey, Gunasekaran, & Childe (2019) as it is a comprehensive yet concise one. It involves data analysis through visualisation and usage of dashboards. Finally, SCP is utilised by Mishra et al. (2016) by asking for performance indicators and comparing respondents' competitors. SCP is considered an outcome reflecting competitive advantage in the dynamic capabilities. The construct uses a total of four indicators, mainly focusing on downstream SCP – involving commonly used SCP indicators such as delivery time, consistency of orders, and customer satisfaction. The focus on downstream is a commonly adopted approach in the literature (Wei et al., 2022; Zhou et al., 2023). Whitten et al. (2012) underlines the importance of focusing on satisfying customer needs when measuring SCP. Hence, we focused on the downstream facet of SCP.

4.3 Profile of respondents

Table 3 illustrates the profile of respondents and their companies. Respondents in our survey are quite experienced in their industries as all of them have at least 4 years of experience, more than 70% with at least 7 years of experience, and almost 50% with at least 11 years or more experience. Respondents work either in the top management team as CEOs or general managers or as managers in relevant business units such as logistics, production and operations, procurement, and sales and marketing. The respondent organisations show great diversity regarding their industries. Food and beverages, textile and fashion, automobile, and steel manufacturing generate the majority of respondent industries. More than 60% of companies produce finished products, approximately 25% produce finished products, and 13.5% produce raw materials.

5. Results

5.1 Exploratory and confirmatory factor analyses

The reliability and validity of measures (Table 4) were analysed first, since the measurement model was developed by utilising the existing literature, expert interviews, and Net-Zero reports. Principal component analysis with Varimax rotation and Eigen values greater than one is used for factor extraction (Hair et al., 2006). The sample is deemed satisfactory as the Kaiser–Meyer–Olkin test of sampling adequacy was 0.936, with Bartlett's test of sphericity being significant ($p<0.001$). EFA produced a total of 5 constructs, as expected. NZC items have high factor loadings ranging between 0.776 – 0.817. All other measurement items were factored in their own constructs with high Cronbach's alpha values (over the recommended threshold of 0.7), suggesting a good initial result.

The reliability and validity of constructs are further tested through CFA. The internal consistency is checked through composite reliability and Cronbach's alpha scores, which should be above the recommended cut-off value of 0.7 (Bagozzi & Yi, 1988). The convergent validity of constructs is checked through standardised factor loadings (SFL) and average variance extracted (AVE) values (Hair et al., 2006). The minimum SFL scores of all items are 0.60 or more, satisfying the minimum requirement suggested by Bagozzi & Yi (1988). AVE values of all constructs are above 0.50 except the visibility construct, which is close to the recommended value. This is not considered a serious concern in the model as the score of SFL meets the minimum requirement of 0.60, its AVE value is close to 0.50, and its composite reliability score exceeds 0.70, in which case less conservative AVE values do not create a major concern for the model (Fornell & Larcker, 1981; Lam, 2012).

Table 3. Respondent demographics (Source: Authors own work)

Profile	Frequency	Percentage %
Age		
25-34	77	24.7
35-44	138	44.4
45-54	68	21.9
55 and more	28	9.0
Experience in the industry		
4-6 years	86	27.7
7-10 years	77	24.8
11-14 years	60	19.3
15 years and more	88	28.3
Department in the organisation		
Top management *	36	11.6
Supply chain & Logistics	64	20.6
Production, planning and operations	137	44.1
Procurement	48	15.4
Sales and Marketing	12	3.9
Others	14	4.5
Industry		
Food and beverage	83	26.7
Textile and fashion	61	19.6
Consumer electronics	13	4.2
Automotive	37	11.9
Machinery and industrial equipment	21	6.8
Papers	17	5.5
Steel and other metals	33	10.6
Chemical & plastic	32	10.3
Minerals extraction	6	1.9
Others	8	2.6
Product type		
Finished products	194	62.4
Intermediate products	75	24.1
Raw materials	42	13.5

* Top-level of managers not being a part of a specific department, e.g., country managers, regional managers, CEO, or founders,

Table 3. Reliability and validity analysis of constructs (Source: Authors own work)

Construct	**Cronbach's Alpha**	**Composite Reliability**	**AVE**	**MSV**	**SFL**	**Number of items**
Visibility	0.767	0.769	0.457	0.417	0.60 – 0.73	4
SCI	0.835	0.838	0.564	0.511	0.68 – 0.81	4
BDA	0.850	0.851	0.535	0.511	0.65 – 0.79	5

NZC	0.946	0.948	0.784	0.501	0.87 – 0.90	5
SCP	0.835	0.842	0.573	0.410	0.68 – 0.84	4

The discriminant validity (Table 5) is measured by checking maximum shared variance (MSV) values, which should be lower than AVE values, and the squared root of construct's AVE values, which should be higher than correlations with other constructs (Fornell & Larcker, 1981; Hair et al., 2006). MSV constructs are lower than their AVE values, while AVE values are higher than correlations with other constructs.

Table 5 Discriminant validity results (Source: Authors own work)

	Net-Zero	Visibility	SCI	BDA	SCP
Net-Zero	**0.885**				
Visibility	0.476	**0.676**			
SCI	0.646	0.512	**0.751**		
BDA	0.708	0.646	0.715	**0.731**	
SCP	0.640	0.326	0.518	0.562	**0.757**

The measurement model illustrates a good model fit as well. Our model has a satisfactory χ2 score (1.458) as Hu & Bentler (1999) suggest the data have a good fit with the model if / degrees of freedom is lower than 2. RMSEA (a badness-of-fit measure) score in our model is 0.38 (good fit; Browne & Cudeck, 1993), while CFI score is 0.977 (good fit; Hu & Bentler, 1999). Other commonly used fit indices also present evidence for a good model fit (TLI: 0.973 SRMR: 0.455).

5.2 The structural model analysis

Hypotheses are tested through SEM by using Amos 28. The model presents a good fit as fit indices meet suggested threshold levels, CMIN/DF= 0.1450, CFI= 0.975, TLI= .971, RMSEA= .038, SRMR= .0480 (Hu & Bentler, 1999). Figure 2 illustrates coefficient values and significance levels of the relationship between constructs. Red lines indicate a nonsignificant relation. Accordingly, both SCV and SCI have significant positive impact on BDA (β=0.38, p < 0.001; β=0.52, p < 0.001), confirming our H1 and H3. Our H2 is not confirmed as the path relation between SCV and NZC is not significant (β=0.00, p > 0.05), while H4 and H5 are confirmed as both SCI and BDA significantly influence NZC of SCs (β=0.28, p < 0.001; β=0.51, p < 0.001). H6 is also confirmed as NZC has a significant effect on SCP (β=0.64, p < 0.001). Finally, the industry of the respondent company is used as a control variable on two main dependent variables in the model. The organisation's industry segment does not significantly affect NZC or SCP (p>0.05).

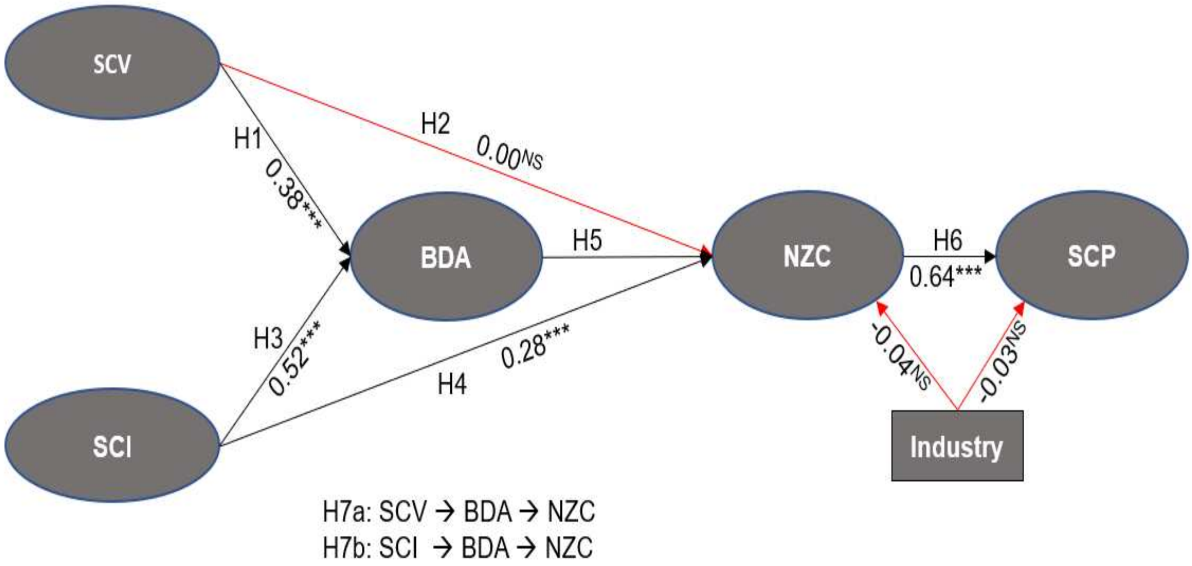
We implemented a bootstrapping method to test the mediation effect illustrated in our conceptual model (Figure 1). Random sampling with replacement with 5,000 reiterations with 95% level of bias-corrected confidence interval is used to measure the direct, indirect, and total effect of estimates (Zhao et al., 2010). The bias-corrected two-tail significance test shows that the indirect relation between SCV and NZC and between SCI and NZC are statistically significant (β=0.194, p < 0.001; β=0.266, p <

0.001, respectively). This mediation effect analysis shows a significant indirect relation that confirms the acceptance of H7, which posits a mediated model (Table 6).

Table 6. Mediation effects (Source: Authors own work)

Hypothesis	Direct effect	Indirect effect	Total effect	Result
H7a SCV → BDA → NZC	0.00(ns)	0.194 ***	0.194***	Full mediation
H7b SCI → BDA → NZC	0.28***	0.266***	0.550***	Partial mediation

*** (p < 0.001), ns= not significant



Notes: *** Statistically significant (p<0.001); NS, statistically nonsignificant (p>0.05)

Figure 2: Hypothesis results (Source: Authors own work)

Comparing results of our study with relevant papers implementing the same methodology, the path analysis confirms the positive impact of SCV on BDA (Srinivasan and Swink, 2018). Our results also confirm the positive relationship between BDA and SCI (Feng et al., 2022). The impact of BDA on NZC is also validated in similar studies measuring the impact of BDA on sustainability and green SC practices (Al-Khatib, 2022; Zhu et al., 2022). Our results also prove the mediating role of BDA between various competitive capabilities, such as marketing and firm performance (Morimura and Sakagawa, 2023). Finally, the impact of green practices and sustainability also validates the positive impact of NZC on SCP (Katiyar et al., 2018).

6. Discussion and implications

6.1 Discussion

The study's two aims are to identify and analyse the relationship of critical reconfigured dynamic capabilities such as SCI, SCV and BDA on achieving NZC and the impact of NZC on enhancing SCP. The existing literature discussed various inter-organisational mechanisms by utilising resources to engage all SC partners to measure accurate Net-Zero emissions (Gong et al., 2018), coordinated efforts to build innovative business processes to measure Net-Zero (Stern & Valero, 2021), exploring the drivers, barriers and practices in Net-Zero economy from a multi-stakeholder perspective (Singh et al., 2022; Zhang, Tay, et al., 2022). However, the focus has been more on Net-Zero policies, identifying barriers and challenges with limited empirical evidence from SCs and organisational resources to share, measure and analyse the carbon emissions from the SC partners to meet the Net-Zero goals. SC partners across the firms use many organisational resources and capabilities to cope with environmental challenges (Subramanian & Abdulrahman, 2017), resulting in SC performance improvement (Sharma et al., 2022). This study tries to fill the gap in the existing literature by examining the relationship between SCI, SCV and BDA as dynamic capabilities that lead to Net-Zero as a second-order capability (NZC), which impacts the organisations in achieving SCP as a competitive advantage.

Building on the DCV, the study's findings confirm that resources such as SCV and SCI have a significant positive impact on capabilities such as BDA that organisations align into their processes to share, measure, and analyse the carbon emissions data from the SC partners to meet the Net-Zero goals. This allows a better understanding of organisational resources that should transform into dynamic capabilities to enable them to achieve a competitive advantage. Our findings complement the existing research arguing that effective measurement of emissions and rapid, sustained reduction of Net-Zero (CO_2 emissions) is critical. However, that is only possible if organisations have resources such SCI to integrate inter and intra-organisation data and BDA capability to analyse that data for effective decision-making. These resources and capabilities will help organisations meet the United Nations 2050 mission of decarbonisation (Zhang et al., 2022). Hence, this study offers empirical evidence for the organisations explaining the type of resources and dynamic capabilities needed to address the Net-Zero goals in the ever-changing environment and remain competitive.

The study extends the IPV and suggests that BDA is an information processing capability required to measure Net-Zero across the supply chain partners. The findings of the study confirm the positive impact of BDA on NZC. The BDA capability provides information processing capability, enabling an organisation to acquire carbon emission data from SC partners to gain insights into the changing environment and remain competitive through effective decision-making (Zhang et al., 2020).

The existing literature has emphasised the importance of SCV and BDA as capabilities for achieving organizational flexibility, supply chain integration and its impact on performance (Agrawal et al., 2022; Dubey et al., 2021). However, our findings did not conform to the direct path relation between SCV as a capability that impacts Net-Zero. The reason is that SCV provides visibility of upstream and downstream supply chains but does not provide organisations with visualisation and analytics capability. Therefore, our findings confirm that the organisation must implement BDA and visualisation capabilities to analyse and measure the carbon emission data across the SC partners. Our results suggest that BDA mediates the indirect relation between SCV and NZC. The finding implies that access to accurate, timely, trusted and useful information from SCV helps tackle Scope 3 emissions, i.e., across the SC partners. BDA provides information processing capability to analyse the Net-Zero emissions data to meet environmental goals. This empirical evidence is scarce and inconclusive in the earlier research; thus, our findings suggest that SCV alone does not directly contribute to NZC but contributes through the mediation of BDA. This makes sense because Net-Zero requires analysis of various emission sources in SCs which are often complex, and BDA is enhanced by SCV that can help to achieve the Scope 3 targets.

The operations management literature has emphasised the intra and inter-organisational SCI across the SC partners to comply with environmental regulations to remain competitive (Wong et al., 2021). Furthermore, BDA capability is deemed especially relevant to capture and analyse reliable data from SC partners to extract valuable insights, allowing decision-making to increase competitiveness and environmental performance (Dubey et al., 2022; Oliveira & Handfield, 2019). Our research findings conform to those arguments that BDA mediates the indirect relation between SCI and NZC. This supports the view that SCI provides an ability to gain useful access to carbon emission data across the SC partners to swiftly respond to environmental changes with effective analysis and decision-making through BDA capability (Benzidia et al., 2021).

The supply chain operations at various levels are heavily reliant on information, and according to IPV, the SCP is highly dependent on the ability of organisations to process and utilize this information effectively (Zhou et al., 2023). Previous research in SC literature has illustrated that information processing capabilities can enable organisations to swiftly gather, combine, interpret, and analyse concealed patterns within the SC to improve performance (Liu & Chiu, 2021). Our purpose was to measure if NZC positively affects SCP. The findings of our study confirm the significant and positive empirical association between NZC and SCP. The novelty of this finding is important from the organisational point of view as earlier empirical research has just focussed on focal organisation carbon emissions, mainly from its operations, i.e., marketing, logistics, and warehousing (Cadden et al., 2022). Therefore, the goal of achieving Net-Zero could be attained by controlling and managing carbon emission data and practices across the SC (Al-Khatib, 2022) to achieve SCP. This will encourage more SCs to make voluntary Net-Zero pledges and target earlier achievement of Net-Zero goals.

The findings of the study could also extend the literature on green supply chain management. The NZC can help organisations assess their performance level to meet the United Nations 2050 mission (Chaudhuri et al., 2023; Zhang et al., 2022). The effective Net-Zero measurement can help organisations reduce costs by facilitating green product and process innovation (Wong et al., 2020). Acquiring and promoting carbon neutrality is a high priority for circular economies in developed and developing economies (Govindan, 2023). NZC will help them transform their Net-Zero-related approaches to meet the sustainable development goals (SDGs). Dynamic capabilities such as NZC can help organisations sense and measure carbon emissions and transform the organisational structure to achieve sustainability (Chevrollier et al., 2023). Net-Zero carbon practices have been critical for organisations in global warming. Resilience is the key to addressing the challenges. NZC will not only help organisations develop strategies and identify the resources required but also help them implement new techniques to achieve Net-Zero SC (Vimal et al., 2022). NZC could be beneficial for organisations to develop carbon regulatory environmental policies to achieve sustainable performance (Kannan et al., 2022; Sharma et al., 2022).

6.2 Theoretical implications

This study contributes to the operations and supply chain management (OSCM) literature by presenting the relationships between SCI, SCV, BDA, and NZC in Net-zero SC and the influence of these capabilities on enhancing SCP. Conceptually, our research on Net-Zero SC capability (NZC) is a major shift from the earlier research (Al-Khatib, 2022; Behl et al., 2022; Benzidia et al., 2021; Dubey et al., 2021) which has mostly focussed on BDA capability in achieving resilience and green SCP. The current study extends the previous understanding of dynamic capabilities by exploring the role of BDA and Net-Zero SC in facilitating organisations to meet the UN environmental goals of Net-Zero. It accounts for a missing link, i.e. Net-Zero SC measurement and assessment from a SC perspective, through which environmental activities across the SC could be managed, leading to improved SC performance (Kannan et al., 2022; Y. Liu et al., 2017).

The contributions of the study reflect on three critical avenues. First, our study contributes to DCV and the research on Net-Zero by an empirical illustration of how SCV and SCI resources have a significant positive impact on capabilities such as BDA that organisations align into their processes to share, measure and analyse the carbon emissions data from the SC partners to meet the Net-Zero goals. Second, this study extends the existing literature by exploring the mediation role of BDA. Brandon-Jones et al. (2014) have empirically tested that SCV enhances SC resilience. Dubey et al. (2021) extended the argument of Brandon-Jones et al. (2014) and empirically confirmed the role of BDA as an information processing capability for achieving SC resilience. Building on IPV, we explored as how the mediation role of BDA can help and develop NZC, a critical information processing capability to achieve Net-Zero goals of SC. SCV provides visibility of upstream and downstream SC carbon emission data that is analysed by BDA to meet the Net-Zero goals. Hence, our results suggest that BDA mediates the indirect relation between SCV and NZC. This empirical evidence is scarce and inconclusive in the earlier research for the effective measurement of Net-Zero. Finally, the current study extends the SCP research by Al-Khatib (2022), who empirically analysed the impact of BDA capability to achieve green SCP. This study adds to this research stream by showing the positive role of BDA and NZC as dynamic information processing capabilities enabling an organisation to acquire carbon emission data from SC partners (Scope 3) to gain insights into the changing environment and achieve SCP through effective decision-making (Schulman et al., 2021).

6.3 Practical implications

The findings of this study offer several significant implications for OSCM managers. First, the social and environmental campaigns and regulatory pressures are forcing organisations to decarbonise SC operations to combat against climate change. Therefore, managers must build dynamic capabilities to address the changing environment and remain competitive. Four dynamic capabilities (SCI, SCV, BDA, and NZC) are investigated in our research, which organisations need to integrate, measure and analyse the carbon emission data across the SC partners (Scope 3) to meet the Net-Zero goals. Managers are suggested to promote anticipation of these dynamic capabilities to accurately measure and analyse the carbon emission data across the SC in achieving Net-Zero. In this vein, a mechanism must be developed to gather inter and intra organisational carbon data across the SC to enhance SC coordination and integration in decarbonisation process (Scope 3).

Secondly, the large volume of SC data acquired through information processing capabilities facilitates organisations in real-time decision-making to make more informed and responsive decisions in meeting the environmental goals, eventually achieving SCP. Managers in SC can consider the control tower as an option to improve real-time decision-making for decarbonisation decisions. For instance, a control tower can help companies implement BDA and manage transportation routes to reduce carbon emissions. A control tower can identify opportunities to optimize routes, reduce empty miles, and shift to lower carbon emission modes of transportation.

Thirdly, managers should invest in BDA and SCV tools to measure and analyse carbon emission data to identify and respond to environmental changes. These tools can involve a range of technologies that improve data sharing, such as RFID tags, internet of things sensors, and blockchain-based platforms. Sensors and RFID tags can enable automated real-time data sharing, while a blockchain platform provides a platform for more secure and transparent transmission of data. Cloud computing tools can be utilised to store this large dataset, and more advanced data analytics software such as Power BI or SAP Business technology platforms can be used by SC managers to conduct data analytics.

Companies like Asia Paper and Pulp, Nike, Kimberly Clark, Lego and General Mills face regulatory pressure to minimise unsustainable practices to protect the climate. The biggest hurdle these companies face is the availability of carbon emission data across the SC. Some companies have taken inspiring initiatives to minimise emissions, such as Hewlett-Packard, which has designed a carbon reporting tool to audit GHG emissions. Ford, the largest car manufacturer, has made a comprehensive environmental policy to address the environmental challenges and to make well-grounded data-driven decisions. Thus, we contented that BDA and SCV tools provide the visibility and transparency to develop Net-Zero SC in measuring the Scope 3 emissions, responding to changing environments, and enhancing SCP. These efforts to achieve Net-Zero will also help supply chains improve their performance as validated in our results.

The study emphasises the importance of digital transformation to develop *sensing* capability, i.e., through measuring carbon emission data, *seizing,* i.e. integration and collaboration of data through SCI and SCV, and *transforming* through the development of information processing capability such as NZC to reduce carbon emission across the sub-tier suppliers and channel partners (Chevrollier et al., 2023). Leading organisations like Apple, Samsung, BMW and Sony leverage SC data to optimise their SCs and achieve Net-Zero targets (Liu et al., 2022). Net-Zero will be a high priority for organisations to meet the SDGs (Govindan, 2023). The timely reporting of carbon emission data helps top management of organisations to smartly align their resources, strategies and approaches to reduce emissions (Scope 3) across the SC (Chevrollier et al., 2023; Zhang et al., 2022a), which will eventually result in the form of sustainable performance (Patil et al., 2023).

6.4 Societal Implications

The implementation and effective measurement of Net-Zero emissions benefit not just the organisations in adequately identifying the carbon emissions across their sub-tier suppliers but also customers in improving their quality of life (Vimal et al., 2022). Prior studies by Govindan(2023) and (Beske et al., 2014) have emphasised the importance of technology, dynamic capabilities and sustainable SC practices to achieve environmental, economical and societal goals. The findings derived from our study can be applied to SCs that benefit society. Some of these benefits are:

- Implementing dynamic capabilities such as Net-Zero can help organisations measure their carbon emissions and accordingly develop sustainable SC practices to maintain control of carbon emissions. This will help reduce GHG emissions and improve air, water and land quality.
- The pressure from consumers, regulators and stakeholders is increasing to develop sustainable supply chains with less environmental impact. The NZC will help organisations build knowledge-based SCs, considering the barriers that the extended SCs face in implementing Net-Zero. That will help the society, which is one of the key stakeholders of the Net-Zero economy.
- NZC can help organisations develop long-term circular economy strategies to reduce emissions and resource consumption. NZC facilitate acquiring real-time carbon emission data. The data is then evaluated, analysed and validated to set up the circular economy strategies and practices to meet the SDGs of the UN.

7. Limitations and future research

There are a number of limitations that point to opportunities for future research. Firstly, this study only investigated the role of BDA in enhancing Net-Zero SC and its impact on SCP. Future studies could explore the impact of other emerging technologies, such as blockchain and artificial intelligence (AI), for real-time traceability and data transparency across the SC for effective decision-making. Secondly, this study was limited to BDA, SCI, and SCV as dynamic capabilities that lead to Net-Zero as a second-order capability while considering superior SCP. Accordingly, future studies to consider additional capabilities/resources, such as quality of data, trust and traceability that may be linked with BDA for more accurate and reliable decisions (Dubey et al., 2021; Wamba et al., 2017) in meeting the Net-Zero goals. Thirdly, a huge amount of data across the SC partners is collected to measure and pattern-match carbon emissions. Therefore, future research is required to analyse the impact of big data and AI on the pattern-matching of carbon emission data as a competitive advantage tool (Dubey et al., 2022). Further studies can examine moderator effects on Net-Zero SC, such as technological turbulence and environmental factors (Sharma et al., 2022a).

Our SCP measure focuses on the downstream SC elements, such as delivery performance and customer satisfaction. Yet, we acknowledge that SCP could be expanded to a broader context, including other aspects such as sustainability and cost (Delic et al., 2018). The results of our study should be read, considering the focus on downstream SC. Future studies could take a more granulated approach and measure the impact of NZC on different SCP facets, such as the downstream supply chain. Moreover, the survey is conducted on producers of goods (finished, intermediate, and raw materials), and services firms are not surveyed. Further studies can focus on service organisations by utilising different aspects of SCP. While this study discloses the relationship between information processing capabilities and Net-Zero, it does not examine how Net-Zero data collection could be implemented. In order to address this, future research should conduct an in-depth qualitative study to disclose implementation cases and draw a model to illustrate the implementation process.

NZC construct in our research examines supply chain partners' emissions (Scope 3). The impact of BDA, SCI, and SCV on NZC could be different if the construct focused on Scope 1 and Scope 2 emissions by firms. Likewise, the impact of NZC on SCP could also be different. Hence, we invite future studies to test such relationships. Finally, although not hypothesised, we tested the direct link between BDA and SCP in two different ways. First, we included a link between BDA and SCP in the existing model. Both had a positive impact on SCP (BDA→ SCP $p< 0.05$ – Net-Zero → SCP $p<0.001$). Second, we removed the link between BDA and Net-Zero and tested their impact on SCP. This test also led to similar results (BDA→ SCP $p< 0.05$ – Net-Zero → SCP $p<0.001$). This suggests that NZC could play a partial mediating role between BDA and SCP. Future studies can test the mediating role of NZC between different capabilities and SC performance measures.

8. Conclusion

This study was largely motivated by the urgent need to advance understanding of Net-Zero SC and Scope 3 emissions. The existing studies on Net-Zero literature have only focussed on the focal company's direct emissions from its operations (Scope 1) or emissions related to the electricity purchased for operations (Scope 2) (J. Singh et al., 2022). These studies offer limited insight into the Scope 3 emissions as the majority of SC emissions – up to 90% for end products – originate from SC partners in upstream activities (WEF, 2021). Given the novelty and magnitude of challenges arising from Scope 3 emissions, there is a need to understand the relationship between Net-Zero SC, its capabilities and to test the impact of Net-Zero on SCP. In this vein, building on DCV, the current research suggests that SCI, SCV and BDA are dynamic capabilities that lead to Net-Zero as a second-order capability (NZC) while considering superior

SCP. Hence, it is imperative to decarbonise SC operations to combat against climate change.

Furthermore, using IPV, the relationship between Net-Zero and its antecedent capabilities is further rationalised as an information processing capability that positively impacts NZC and SCP. The findings demonstrate that BDA mediates the indirect relation between SCV and SCI on achieving Net-Zero. Our study considers Net-Zero as a SC capability (NZC) and develops a new construct that positively influences the SCP. This result implies that SCs demonstrate that NZC, as a competitive advantage tool that, can facilitate a superior SCP.

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