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Achieving the sustainable development goals through net zero emissions: Innovation-driven strategies for transitioning from incremental to radical lean, green and digital technologies

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ABSTRACT

This work adopts a resource-based view for strategically managing firms' tangible and intangible resources based on lean and green philosophies to explore the role of digital technologies in achieving NZE and the SDGs.This research outlines three contemporary issues. First, it assesses the theory-driven approaches and real-world datasets from conference of parties (COP) meetings. Second, adopting the VRIO (Valuable, Rare, Inimitable, Organized) framework, 25 identified digital technology-based values are obtained by digitalization-based integrated lean-green approaches that may enable manufacturing firms to pursue SDGs via net-zero emissions. Four scenarios of digital technology adoption and integration level of lean and green manufacturing pathways are proposed, differentiated by the degree of radical/ incremental interests in innovation and sustainable advantage types. Third, the study highlights that the achievement of NZE by SDGs may be possible only by adopting digital technologies and high-level integration of lean and green.

1. Introduction

The United Nations Climate Change Conference,i.e., Conference of Parties 26 (COP26) took place in Glasgow, United Kingdom, in November 2021. The purpose of the summit was to enforce the Paris Agreement and the United Nations Framework Convention on Climate Change (UNFCCC) obligations to sustainable development, which established a restriction on the global temperature increase to 1.5 °Celsius above pre-industrial levels (Dwivedi et al., 2022). This planet seriously needs to cut half of the greenhouse gaseous (GHG) emissions within the next ten years and accomplish net-zero carbon dioxide (CO_2) emission levels by the middle of the century in order to accomplish the aforementioned objectives (COP26, 2021). Following a year, the COP27 summit was held during November 6–18, 2022, in Egypt. The Paris Agreement, Glasgow Climate Pact, and additional initiatives to combat global warming were all reviewed during COP27 (Arora and Arora, 2023). As a result, the focus of the session in Egypt was on improving the timeliness of effective climate policy, which had lagged behind in past conferences (Stanczyket al., 2022). Execution, reduction, adaption, and partnership were the four main interrelated objectives that COP 27 developed for the conference. The top priority for COP 27 execution was using cutting-edge technologies and eco-friendly (green) methods to maintain the 1.5 °C objective under range (Arora and Arora, 2023). Additionally, chronic illnesses caused by air pollution account for 4.2 million deaths worldwide due to GHG production (Duan et al., 2020).

Additionally, the UK and the European Union (EU) have reviewed their net zero strategies to advance their net zero goals and are presently focusing more on attaining energy and economic security as a result of the energy crisis brought on by Russia's invasion of Ukraine (Okorie et al., al.,2023). As a result, sharing the responsibility for decreasing emissions across regions, nations, and people has emerged as one of the most crucial international agreements (Kovacikovaet al., 2021). With a contribution to yearly GHG emissions of around 24.2%, the global

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Table 1
Previous research in the field of NZE and SDGs.

Studies	Research type	Industry Type	Theoretical approach	Resource/ Process management strategies	Innovative approach	Achieving NZE	Achieving SDGs	Findings	Research gaps
Jabbour et al. (2015)	Qualitative (case study)	Brazilian manufacturing industries	Not adopted	Human resource management	Low carbon Eco-innovation	✓	✓	As businesses adapt to new methods of reducing their carbon footprint, the importance of the human critical success factor (HCSF) in creating such goods has been shown to grow.	There is a lack of information regarding the particular implications of HCSF for the establishment of corporate eco-innovative initiatives to mitigate climate disruption and promote a low-carbon economy.
King and Linox (2001)	Quantitative (survey-based)	USA manufacturing firms	Not adopted	Lean and green philosophies	Not adopted	✓	✓	This study provides conclusive proof that ISO 9000 adoption and small chemical inventories, two indicators of lean manufacturing, are synergistic with efforts to reduce waste and pollution.	Only a few researchers have examined the relationship between lean and green practices using questionnaire surveys. The majority of research rejects additional firms' characteristics which might be the fundamental source of both environmental enhancement and lean manufacturing.
Inman and Green (2018)	Quantitative (survey-based)	USA manufacturing plants	Not adopted	Lean and green philosophies	Not adopted		✓	Green supply chain management strategies were also shown to have a good correlation with environmental performance, while lean manufacturing practices were found to have a positive correlation with both ecological and functional performance.	There is a scarcity of investigations that explore the causal relationship between lean and green practices along with the integrated effect of lean and green behaviours on both operational and environment performances.
Vimal et al. (2022)	Quantitative (MCDM based)	Manufacturing industries	Not adopted	–	Not adopted	✓		One of the study's main findings was the identification of hurdles, with "lack of management willingness" being the most important and "lack of consumer awareness" being the least important.	To reach net zero emissions objectives, which call for significant cuts in global emissions while also addressing disruptions, it is necessary to investigate ways to achieve SC's sustainable goals and flexibility.
Thekkoote et al. (2022)	Quantitative (cross-sectional survey based)	Manufacturing firms	Not adopted	Lean and green philosophies	Not adopted	–	✓	As the study's findings show, lean methods have a direct impact on sustainability, and green manufacturing is a crucial moderating factor.	The linkages between several facilitating variables that offer an organised approach to carry out and conduct the lean, green, and sustainability programmes have not been extensively explored in the existing literature.
Mishra et al. (2022)	Systematic literature review	–	Not adopted	Supply chain management	Digital technologies	✓	–	The results stress the favourable correlation between digitalization, the circular economy, and resource efficiency with the pursuit of net-zero economic growth.	There is a dearth of SC research in the net-zero field and no comprehensive evaluation is available in this area based on digital technologies, circular economy and other sustainability factors.
Zhang et al. (2022)	Bibliometric analysis	–	Not adopted	Circular supply chain	Not adopted	✓	–	The objective of carbon neutrality is not achievable from a single vantage point; rather, it calls for a thorough and methodical examination of the interplay between "technology, the economy, and society".	Most nations' carbon neutrality goals remained politically motivated because they lack adequate technological assistance from legislative frameworks, policies, and legal mechanisms.
Acampora et al. (2023)	Survey	Agri-food sector of developed countries	Not adopted	Carbon neutral strategies	Not adopted	✓	✓	Together with a dearth of a clear and comprehensive legislative framework and distrust in carbon sequestration, the high costs associated with achieving carbon neutrality have been	The academic research did not emphasize the carbon neutrality strategies from a commercial and managerial point of view.

(*continued on next page*)

Table 1 (*continued*)

Studies	Research type	Industry Type	Theoretical approach	Resource/ Process management strategies	Innovative approach	Achieving NZE	Achieving SDGs	Findings	Research gaps
								identified as one of the key impediments.	
Song et al. (2023)	Qualitative (case study)	Machinery manufacturing firms	Not adopted	Lean production & low carbon manufacturing	Not adopted	✓		The function of green technology expenditure in mitigating carbon emissions is comparable to that of process management. Carbon gains may be increased sustainably if equipment manufacturers regulate their carbon emissions over the product's entire life cycle and include their carbon resources in their production prices.	Insufficient immediate revenue from investments in carbon reduction measures has increased expenses for manufacturing firms and reduced their capacity to compete. Investments in reducing emissions and controlling overall corporate costs are in disagreement with one another.
SagnakandKazancoglu (2016)	Quantitative	Turkish manufacturing industries	Not adopted	Lean, green and six sigma approach	Not adopted	✓		Any inaccuracies or fluctuations in ecological pollution assessments need a combination of measuring system analysis and gage control methods with a green lean strategy.	Investigations on the viable limitations of combined green and lean strategies are lacking. Also, less emphasis was placed on the available tools and methods to get beyond this restriction.
Sheng et al. (2022)	Quantitative (survey-based)	Chinese manufacturing Firms	Not adopted	Low-carbon operations management practices (LOMP)	Digital technologies	✓		The effects of digitalization on carbon efficiency are mitigated by the presence of low-carbon goods, low-carbon operations, and low-carbon transportation, whereas the effects of digitalization on financial outlook are mitigated by the presence of low-carbon goods.	To comprehend how LOMP mitigates the effects of digitization on economic and low- carbon achievement, a conceptual model has not been designed.
Okorie et al. (2023)	Qualitative (case study)	UK Manufacturing firms	The resource-based view (RBV)	Circular supply chain	Digital technologies	✓	✓	In order to achieve NZE via the SDGs, businesses must prioritize the oversight and growth of intangible assets, such as labour and supply chain connections, as a component of their digital transition strategy.	Past researchers have completely ignored RBV-based firms' resource utilization or combination to achieve firm competitiveness. Further, they ignored the institutional pressures to guide NZE and SDGs.
Present study	Qualitative	Indian manufacturing firms	Resource-based view (RBV)	Lean and green philosophy	Digital technologies	✓	✓	Recent studies have shown that using digital technology and a thorough blending of lean and green strategies may be the only ways to reach NZE by the SDGs.	Most of the previous studies did not consider the combination of digital technology, lean production, and green manufacturing to handle their scarce resources to achieve SDGs via NZE.

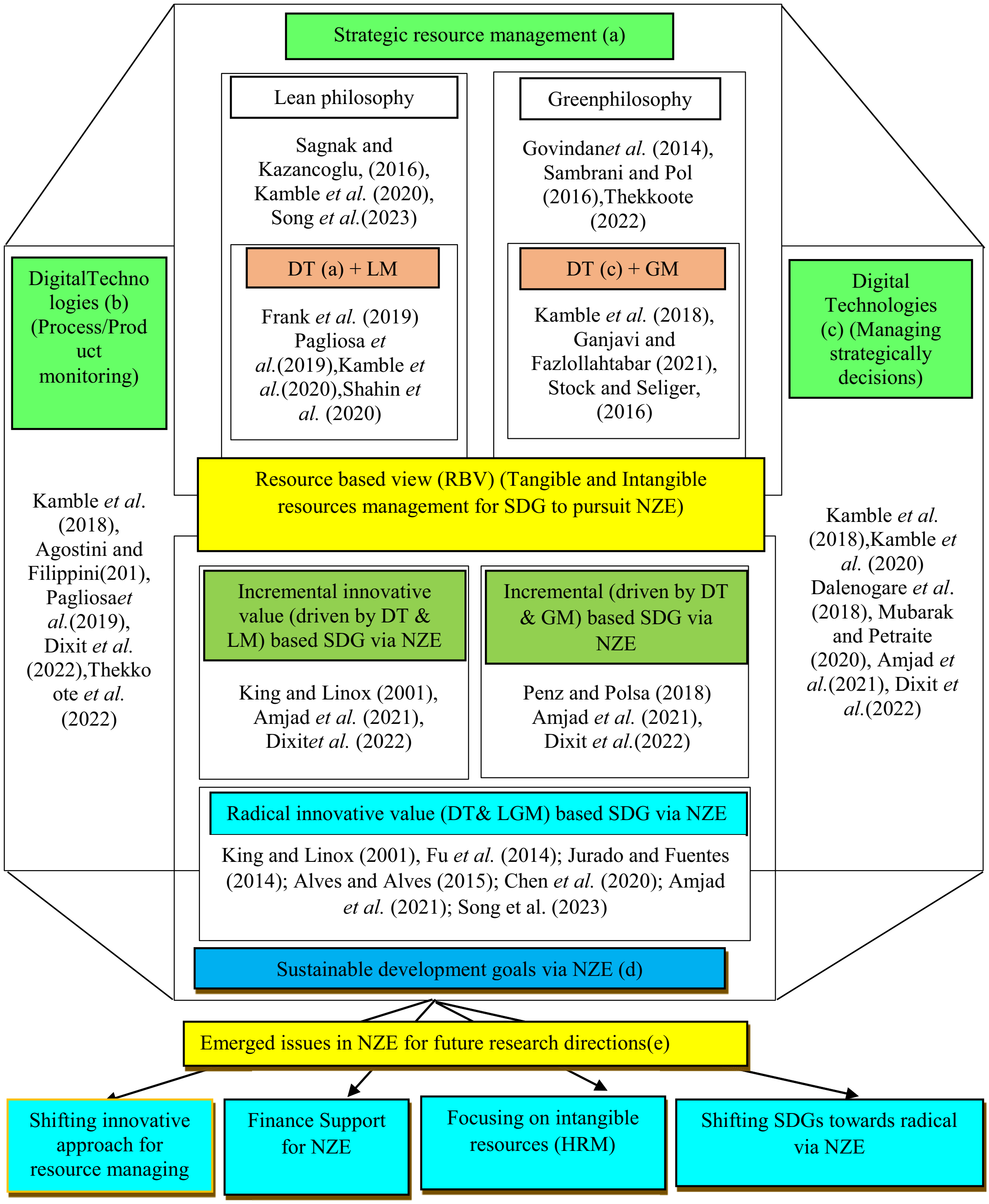


Fig. 1. Literature map for overlapping context.

manufacturing sector is one of the biggest sources of emissions (Ritchie and Roser, 2021). The energy demand of manufacturing industries in China, which is the largest in the world, is projected to be 57% of the country's overall energy consumption, contributing directly or indirectly to nearly 80% of carbon emissions (Yang et al., 2020). Additionally, there is a growing understanding that achieving a sustained competitive edge depends on mitigating and reducing GHG emissions linked to industrial activities (Morioka et al., 2017; Olatunji et al., 2019). As a result, goals for addressing climate change through NZE might be considered a chance to gain competitiveness. In the extant literature, a connection has been made between a company's sustainable advantages and NZE (emissions reductions), which can pave the way for SDGs (Hasan et al., 2020). The SDGs provide a common framework for individuals, the planet, wealth, harmony, and collaboration (Okorie et al., 2023). History warns us that this shift and broader technical progress would not necessarily result in inclusive growth (Rydge et al., 2018). In this context, lean manufacturing places emphasis on a new managerial approach that aims to increase system performance while lowering carbon emissions via designing a uniform procedure of operation. Although sticking to the philosophy of achieving total benefits, green manufacturing tries to cut carbon emissions over the entire manufacturing value chain and minimize environmental expenses.

Hence, it is not only reasonable to combine lean production with green manufacturing, but it can also enhance the possibility of emission reduction and efficiency improvement in production operations (Souza Farias et al., 2019; Chen et al., 2020). To the extent that lean and green techniques are implemented, they have the ability to lessen environmental impacts and eliminate road blocks to doing so. In contrast, Garza-Reyes (2015) suggested that the integrated lean-green method may have certain restrictions. Similar to the shortcomings of either lean or green alone, the combined green lean strategy lacks a systematic and organised approach for tracking operations or for resolving the associated difficulties (Souza Farias et al., 2019).

From the vantage point of environmental management systems and the green paradigm, its limits might be seen as having to do with strategic issues, such as how to deploy green interventions to fulfil both the business objectives of revenue generation and ecological protection (Thekkoote et al., 2022). Incorporating digital technology into corporate procedures can lead to enhanced interaction between stakeholders, more accurate data analysis, more efficient production flows, and various process improvement initiatives. As a result, digital technology may be seen as a catalyst for lean, productive processes that also foster more opportunities for innovation (Frank et al., 2019); second, digitalization can facilitate better energy tracking and administration, boosted the development of renewable energy technologies, decrease the price of renewable power, and speed up the rate of power shift (Lange et al., 2020); third, the digital trade can boost low-carbon consciousness, expedite the spread of green information technology, and increase business' green innovation degree (Li et al., 2021). Therefore, there is a need for digital technologies to avoid the shortcomings of the lean and green approach. Furthermore, recent research has shown that the net-zero target may be efficiently approached via the use of digital technology, sustainable techniques, and smart resource management (Stock and Seliger, 2016; Sehnem and Olveira, 2017; Rehman et al., 2020). Based on the discussion and Table 1 i.e., previous research in the field of NZE and SDGs, the following research gaps are formulated:

- Emerging economies that have not yet committed to net zero emissions by 2050 still have enough room to manoeuvre. This is despite the fact that consciousness of the need for carbon neutrality has increased over the last five years. Existing research has mostly examined how to reduce carbon, and GHG emissions (Lewandowski and Ullrich, 2023) and GHG released as a result of using various energy sources (Deng et al., 2014). Still, the measures adopted to reach net zero by 2050 remain mostly unproven.
- Indications of sustainable production are beginning to emerge from lean and green production methods. Although evidence suggests that lean and green practices might affect sustainability, the exact nature of the relationships between these concepts remains unclear (Inman and Green, 2018).
- Nonetheless, most businesses now use a combination of digital technology, lean production, and green manufacturing to handle their scarce resources better.
- Manufacturing companies have recognized the mutual challenge-opportunity that may be inferred from incorporating technological progression for the administration of their resources as a result of the wide variety of opportunities presented by digitalization and digital technologies like the Internet of Things (IoT), additive manufacturing, artificial intelligence (AI), big data, and cloud-computing (Frank et al., 2019; Elia et al., 2021; Shakoret al., 2022).
- In addition, prior studies have not used an RBV perspective, therefore, they have not taken into account how businesses' strategic fusions of resources and competencies might enhance their competitive advantages (Patnaik et al., 2022).

Thus, based on the research gaps established above and Table 1, the following research questions have been developed for proposing and advancing a future research agenda:

RQ1: How the available firms' resources (tangible or intangible) can be strategically managed (based on digital technologies)?
RQ2: How the firms' strategically managed resource-based innovative values will drive NZE?
RQ3: How NZE drive the managers to achieve sustainable development goals (SDGs) by adopting RBV?

In view of the above research gaps and discussion, this research adopts the RBV theory to strategically manage firms' resources. In this context, this research combines digital technologies and lean-green philosophies without tinkering with existing equipment (tangible resources) but by changing strategic resource management policies (intangible resources) to explore effective management of firms' resources. Furthermore, this research also emphasizes the attainment of NZEs based on incremental innovative values (integrating lean approach and digital technologies; integrating green approach and digital technologies) and radical, innovative values (integrating green, lean approaches and digital technologies), and the ultimate achievement of sustainable competitive advantage. Taking the SDGs as the guiding principles, this research analyzes the innovative values based on the "VRIO" framework proposed by the RBV theory, which results in the level of sustainable competitive goals driven by innovative values.

2. Literature review

Our strategy makes the use of two significant techniques as a portion of an analysis framework: (1) a literature review to illustrate the extant crossover among crucial themes and concepts; and (2) a committed scholarship strategy that pertains perspectives from the literature assessment to actual-world, functional obstacles of perceiving how RBV theory can play a vital role to net-zero strategic plan and accomplishment within the UK manufacturing industry. Both of these methods are referred to as "key methods." Fig. 1 presents a flowchart that illustrates the data, methodology, and overall structure of this investigation.

2.1. Review of extant literature

Academic literature was reviewed to answer the research questions posed in the introduction, clarify the theoretical underpinnings (Tranfieldet al., 2003), and provide the groundwork for future knowledge expansion and theory formation (Dubois and Gadde, 2002; Okorie et al., 2023). Keywords such as "resource-based view", "RBV", "sustainable competitive advantage", "digital transformation", "Industry 4.0″, "sustainable manufacturing", "lean manufacturing", "green manufacturing", "net zero emission", and "conference of parties" were employed to ascertain how thoroughly mentioned topics were discussed. SCOPUS, ScienceDirect, and Web of Science databases were utilized to pull together relevant publications. The results are shown in Table 1 and Fig. 1. Table 1 represents past studies in the field of NZE and SDGs based on strategic resources management. Fig. 1 is a diagram of the reviewed literature adapted from (Hegde and Tumlinson, 2021), compiled and organized by key thematic area: (a) Strategic resources management; (b) Digital Technologies based Process/Product monitoring;(c) Digital technologies-based managing strategic decisions; (d) Sustainable development goals via NZE (e) Emerged issues in NZE for future research directions.

2.2. Engaged scholarship and systematic combining

At this point in our research procedure, we combine components of engaged scholarship (Bansal and Corley, 2011; Okorie et al., 2023) with a previously established technique of systematic combining (Dubois and Gadde, 2002). Engaged scholarship is a kind of action research that involves the participation of the people most affected by the issue being studied (in this case, top manufacturing executives) in order to better understand and address the issue at hand. According to Easter et al. (2021), complex multidisciplinary topics like sustainability issues are ideal for active study. While engaged scholarship has been criticized for being one-sided and focusing on the applicability of academic research to practice, this effort was motivated by global engagement and real-world concerns (Van de Ven, 2007; McIsaac and Riley, 2020). It was anticipated that by the time of the 27 Conference of Parties (COP 27) in November 2022, all of the digital technologies discussed at COP 26 would have been completely implemented in the various industrial businesses as part of the CE implementation strategy. Outcomes from the existing literature were employed to identify the industry and vital approaches that were subsequently investigated using insights from COP #26 and COP#27, which were more centred on the overarching discussion of NZE in the digital age. This was done with an eye towards the questions and discussions that emerged from this approach, which is a characteristic of engaged scholarship (Benyamet al., 2018; McIsaac and Riley, 2020), which may be discussed in the next COP (i.e. COP# 28) as outlined below:

1) Where do we stand now with respect to achieving and practising NZE, and what obstacles must we overcome to get NZE?
2) How can digital technology be integrated with firms' resources (tangible or intangible) to achieve 'net zero' emissions and SDGs by 2050?
3) When it comes to manufacturing, what pre-existing policies, programmes, and support have proven most helpful in facilitating a transition from incremental to radical innovation values?
4) What type of action must a firm take while reporting any emission to achieve the SDGs?
5) How will the government or top managers provide financial support to the projects related to sustainability or processes related to NZE?

2.3. Resource-based view (RBV)

The resource-based view (RBV) is an important theory in the field of strategic management (Maket and Korir, 2017), and it is often used to justify the success of competitive advantage (CA) (Barney and Mackey, 2018). Several fields, including industrial strategy, ecological sustainability, and digital technology transformation, have benefited from resource-based theories of competitive advantage (Wiengartenet al., 2013; Elia et al., 2021). RBV theory implies that under these settings, businesses might gain a sustainable competitive advantage by focusing their efforts on developing a small number of core skills (Barney, 1991). Robust manufacturing performance requires a company's "know-what" (i.e., where to get relevant cross-functional information) and "know-how" (i.e., how to run specialized technology and operations seamlessly) (Paiva et al., 2008). Moreover, a competitive advantage may be attained by combining resources for boosting operational skills, exposure to and employing predictive analytics from big data, and connecting to a skilled labour force that enables enhanced cost and operational performance (Dubey et al., 2019). RBV is used in part to reveal how businesses are using internal assets to gain a market advantage (Barrales-Molina et al., 2013). Addressing the notion of resources, Barney (2014) notes that the physical and intangible commodities that organizations hold or have access to are categorized into three capitals.

- Human: education, expertise, insight, and foresight of the company's management and workers.
- Organizational: business strategy, organizational structure, management and control systems, and the informal connections between departments inside an organization and the outside world.
- Physical: raw resources, physical technologies, machinery, and infrastructure. According to the RBV, a resource may help the CA succeed if it satisfies the four criteria of being valued, uncommon, unique, and organized (Barney, 2014). All of these features come together to form the VRIO ((Valuable, Rare, Inimitable, Organized) structure (Table 1). The four characteristics of the VRIO framework are shown in Table 1 and are explained as follows (Barney and Hesterly, 2019):

1 Valuable (V): capabilities that help the business succeed.
2 Rare (R): assets that set apart competitors.
3 Inimitable (I): materials that are scarce and difficult for competitors to get.
4 Organised(O): resources that the business may use effectively.

2.4. Integration of lean, green and digital technologies for developing innovative values in NZE

Value stream maps, the foundation of a lean implementation, are made much more effective with the help of digital technologies that give up-to-the-second data (Chen and Chen 2014; Meudt et al., 2017). A value stream map is a tool for visualising the steps involved in bringing a product or service to market. To better understand the issues at hand and to plan for a more efficient future, these maps are studied and utilised (Dixit et al., 2022). On the other side, it encourages exploitative innovation since it helps fix the issue by increasing the efficiency with which resources are used (Birkinshaw and Gibson, 2004). Hence, it's also known as gradual innovation or continuous innovation. Stephan and Schlick (2015) suggested adopting GUIs in Kanban to facilitate better information flow and less labour-intensive manufacturing. Wong and Wong (2014) emphasized the need for lean automation for sustainable operations output. One of the most popular types of lean tools, value stream mapping, has been linked to better environmental sustainability by tracking resource use in terms of resources, power, and water (Vinodhet al., 2011).To be more specific, 5S, an acronym for "order, straighten, standardize, polish, and sustain," is a lean tool that is often embraced as the initial step approaching lean manufacturing by most businesses (Chiarini, 2014). In addition, 5S prioritizes the labelling and organization of material warehousing and inventory administration; it can swiftly detect spills, and harmful leaks, thereby decreasing air pollution (Francis and Thomas, 2020). From this vantage point, the lean approach might identify "energy waste," which encompasses underuse, depreciation, dispersion, and unprofitable energy consumption and transition operations, taking into account its potential for saving money while minimizing harmful emissions (Baysan et al., 2019). In addition, the value-stream mapping (VSM) lean tool is utilized to analyse the manufacturing cycle and identify areas of waste and value. Simultaneously, ecological evaluation approaches, such as life cycle evaluation, may be used to learn about the effects on the planet.

Similarly, organisations may better distribute resources, energy, water, and finished goods by using real-time data collected from various value chain partners to support green manufacturing (Stock and Seliger, 2016; de Sousa Jabbour et al., 2018). Digital technologies also aid in lower GHG emissions (Peukertet al., 2015), energy use (Herrmann et al., 2014), raw material stockpiles; productive use of available capacity (Wang et al., 2016); improvements in transportation and logistics resulting in lower fuel use; and the implementation of cutting-edge monitoring and tracking systems (Müller et al., 2017). On the other side, it encourages exploitative innovation since it helps fix the issue by increasing the efficiency with which resources are used (Birkinshaw and Gibson, 2004).

The marginal costs of pollution control, the spread of dangerous substances, and energy and resource savings are all reduced when digital technologies are used with lean and green production (Belhadiet al., 2018). This encourages the kind of invention known as "exploratory innovation," which entails trying out new things in order to find ones that work better than others and, in turn, help the world save money and progress sustainably. It is also known as radical innovation (Birkinshaw and Gibson, 2004; Cheng et al., 2021). It might very well give rise to a whole new market for consumer goods. Yet, the idea of lean and green manufacturing is still relatively new, and there is little information available on how it should be implemented in practice (Abualfaraaet al., 2020). Cheung et al. (2017) provided a novel technique to assess the ecological effect of Lean manufacturing enhancements by integrating a cradle-to-gate LCA with Value Stream Mapping (VSM) (minimized

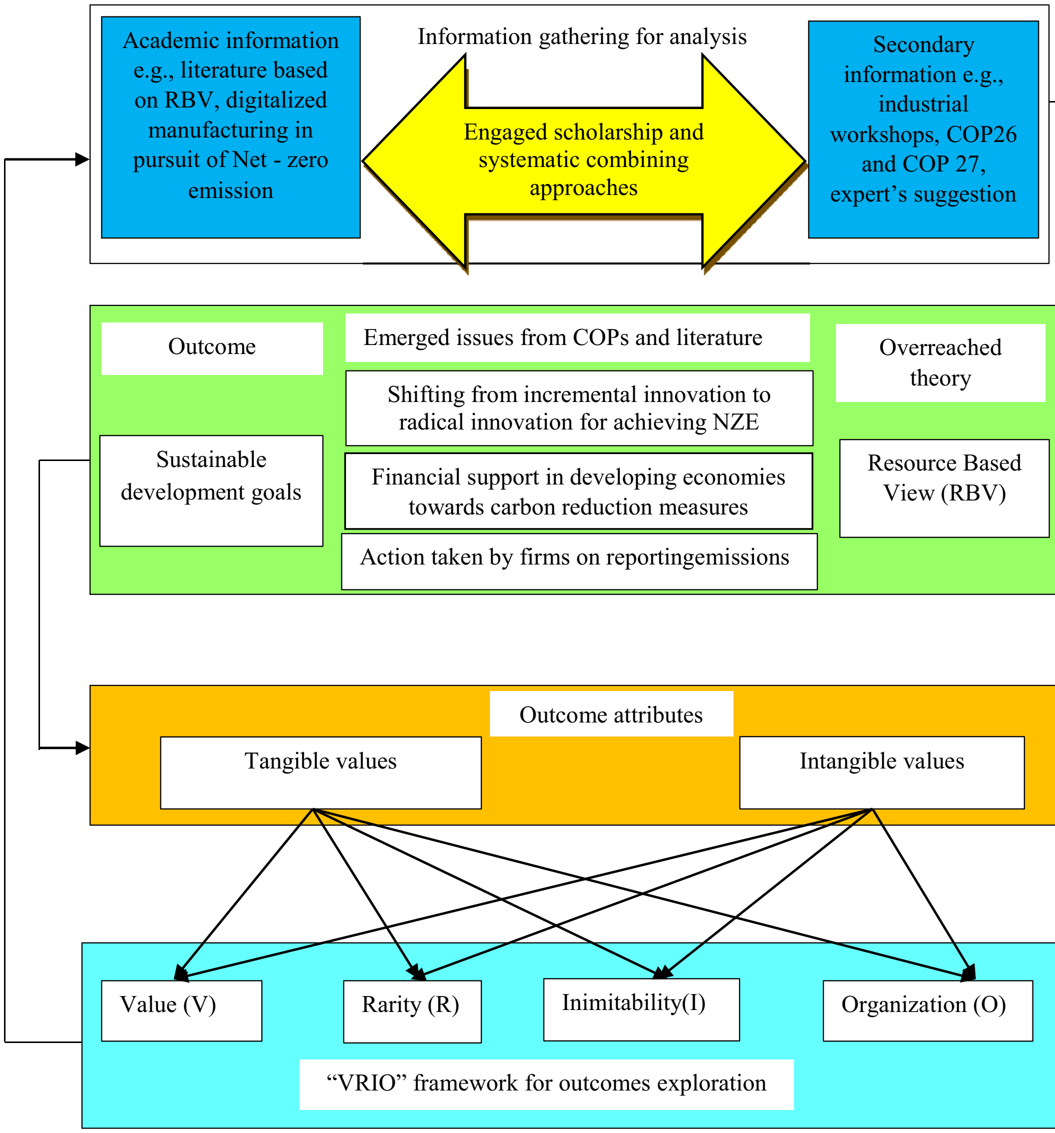


Fig. 2. Research flow diagram.

wasteful expenditures in areas such as time, resources, and energy).

Sustainable Value Stream Mapping (Sus-VSM), developed by Faulkner and Badurdeen (2014), and Green Integrated Value Stream Mapping (GIVSM), suggested by Choudhary et al. (2019), both extend the traditional VSM visualization and evaluation approach to include sustainability measures. These techniques supplement conventional ways of productivity by illuminating the interplay between Lean, green, and other considerations (such as safety and health).

3. Research methodology

Lessons from the previous research and COP results were examined and grouped to determine whether and how traditional sustainable competitive advantage and the accomplishment of net-zero performance are obtained from these digital technologies (in the context of production, digital transformation, a lean and environmentally friendly method of resource management, and a goal of zero waste all play key roles), and "Value (V), rarity (R), inimitability (I), and organization (O)" with VRIO framework as shown in Fig. 2, were used to identify physical and intangible assets (Barney, 1991, 2001; Lopes et al., 2018). Gains may be broken down into their component parts using VRIO analysis. If a company has access to a resource that generates two VRIO characteristics, it can compete on an even playing field with its rivals; if it has access to three VRIO characteristics, it can gain a temporary advantage over its rivals; and if it has access to four VRIO characteristics, it can gain a sustainable advantage over its rivals (Barney, 1991, 2001). Although the VRIO concept has since been applied to other settings, its initial context was businesses (Barney, 1991; Lopez et al., 2019) and has been modified with RBV to identify competitive tactics and governmental initiatives in businesses (Mudambi and Puck, 2016). Typically, a company's organizational qualities are assessed to see whether it possesses the internal organizational processes and structures needed to exploit a possible competitive advantage properly. In this situation, however, we assess how well digital technology (rather than the company) helps with the cross-functional information exchange and coordination inside an organization that is so frequently necessary to capitalize on a competitive advantage fully.

4. Analysis

4.1. "VRIO" frameworks for analyzing the application of digital technologies (innovative values) in carbon reduction measures

Businesses may do nine groups of actions to cut their GHG emissions:

Table 2
Innovative value analysis based on “VRIO”.

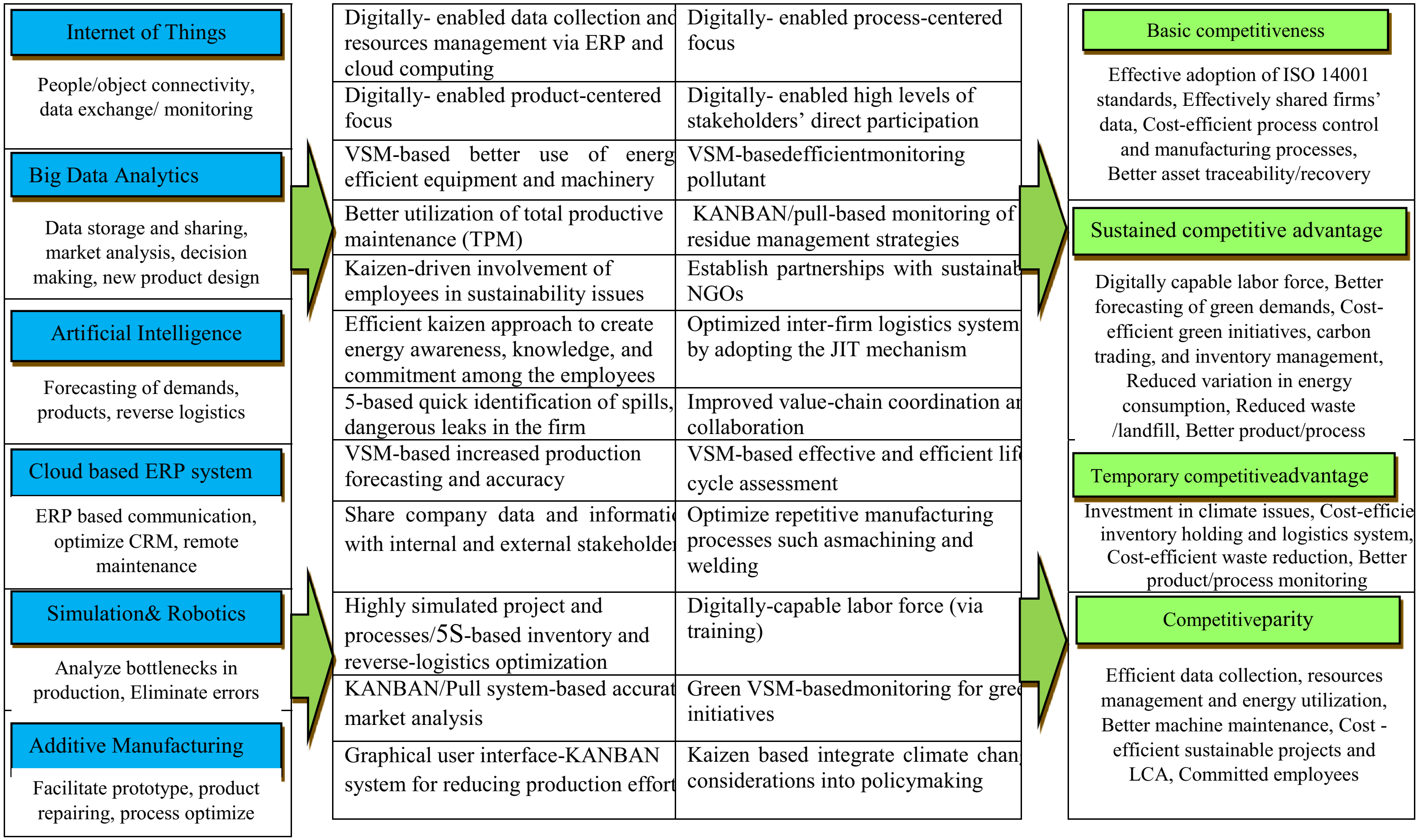
Tangible innovative value derived from combinations of lean, green and digital technologies	V	R	I	O	Influenced NZE measures	References
Digitally- enabled data collection and resources management via ERP and cloud computing	*			*	–	Okorie et al. (2023)
Digitally- enabled process-centred focus	*		*	*	Process redesign, Machine updating	Shahin et al. (2020)
Digitally- enabled product-centred focus	*		*	*	Product adaptations	Zangiacomi et al. (2020)
Digitally- enabled high levels of stakeholders’ participation	*			*	Energy awareness, Disclosure	Kambleet al. (2018)
Intangible innovative value derived from combinations of integrating lean, green and digital technologies	V	R	I	O	Influenced NZE measures	Reference
VSM-based better use of energy-efficient equipment and machinery by operators	*			*	Energy efficiency	Biro and Csete, (2021)
VSM-based efficient monitoring of pollutants or any hazardous substances in air or water			*		Self-regulation	Ganjavi and Fazlollahtabar et al.(2021)
Better utilization of total productive maintenance (TPM)for machine monitoring/ upgradation				*	Energy efficiency, Machine updating	Amjad et al. (2021)
Efficient monitoring of residue management strategies based on KANBAN/pull system	*	*		*	6Rs-principle, Waste reduction,	Metta et al. (2020)
Kaizen-driven effective involvement of employees in sustainability issues	*	*	*	*	Self - regulation	Centobelli et al. (2020)
Establish partnerships with sustainable NGOs	*	*			Offsetting	Laing et al. (2019)
Efficient kaizen approach to create energy awareness, knowledge, and commitment amongst the employees	*	*	*	*	Energy awareness	Biro and Csete (2021)
Optimized inter-firm logistics system by adopting the JIT mechanism	*		*	*	–	Okorie et al. (2023)
5S-based quick identification of spills, dangerous leaks in the firm	*				Reporting system	Ganjavi and Fazlollahtabar et al.(2021)

Table 2 (*continued*)

Tangible innovative value derived from combinations of lean, green and digital technologies	V	R	I	O	Influenced NZE measures	References
Improved value-chain coordination and collaboration based on effective horizontal/vertical integration	*			*	–	Kambleet al. (2018)
VSM-based increased production forecasting and accuracy	*	*		*	–	Pagliosa et al. (2019)
VSM-based effective and efficient life cycle assessment	*	*	*	*	Reporting system	Ganjavi and Fazlollahtabar et al.(2021)
Share company data and information with internal and external stakeholders	*				Disclosure	Pagliosa et al. (2019)
Optimize repetitive manufacturing processes such as machining and welding				*	Energy efficiency	Pagliosa et al. (2019)
Highly simulated projects and processes for monitoring energy utilization		*	*	*	Energy efficiency, Waste reduction, Process redesign	Pagliosa et al. (2019)
Digitally-capable labour force (via training)	*	*	*	*	–	Okorie et al. (2023)
5S-based inventory and reverse-logistics system optimization	*	*	*	*	6Rs-principle	Pagliosa et al. (2019)
Performing accurate market analysis for green demands based on KANBAN/ Pull system	*	*	*	*	Emission credits trading	Thekkoote et al. (2022)
GreenVSM-based monitoring for green initiatives (design green processes/ products)	*	*	*	*	Process redesign, Product adaption	Thekkoote et al. (2022)
Integrated graphical user interface-KANBAN system for reducing production effort	*	*	*	*	Process redesign	Dixit et al. (2022)
Kaizen based integrate climate change considerations into policymaking	*	*	*	*	Investment, Incentives, Emission credits trading	Ferreira et al. (2019)

“energy, product, process, carbon capture, 6R & waste management, management, reporting & disclosure, and compensation”.As described in Table 2, a few novel value-based carbon reduction initiatives result in a lasting competitive advantage and satisfy all four VRIO criteria. Key digital application-based six carbon reduction strategies are outlined below:

1 Energy categories raise workers’ energy-related awareness, expertise, and dedication. It focuses on lowering total energy use and ensuring sustainability throughout the energy life cycle. Deployment instances for energy consciousness initiatives include training



(b) Radical/Incremental innovative values (tangible/intangible) driven by strategically managing firms resources

(c) Sustainable competitive advantages based on "VIRO"

Fig. 3. Synthesis of the pathways to pursuit SDGs via NZE.

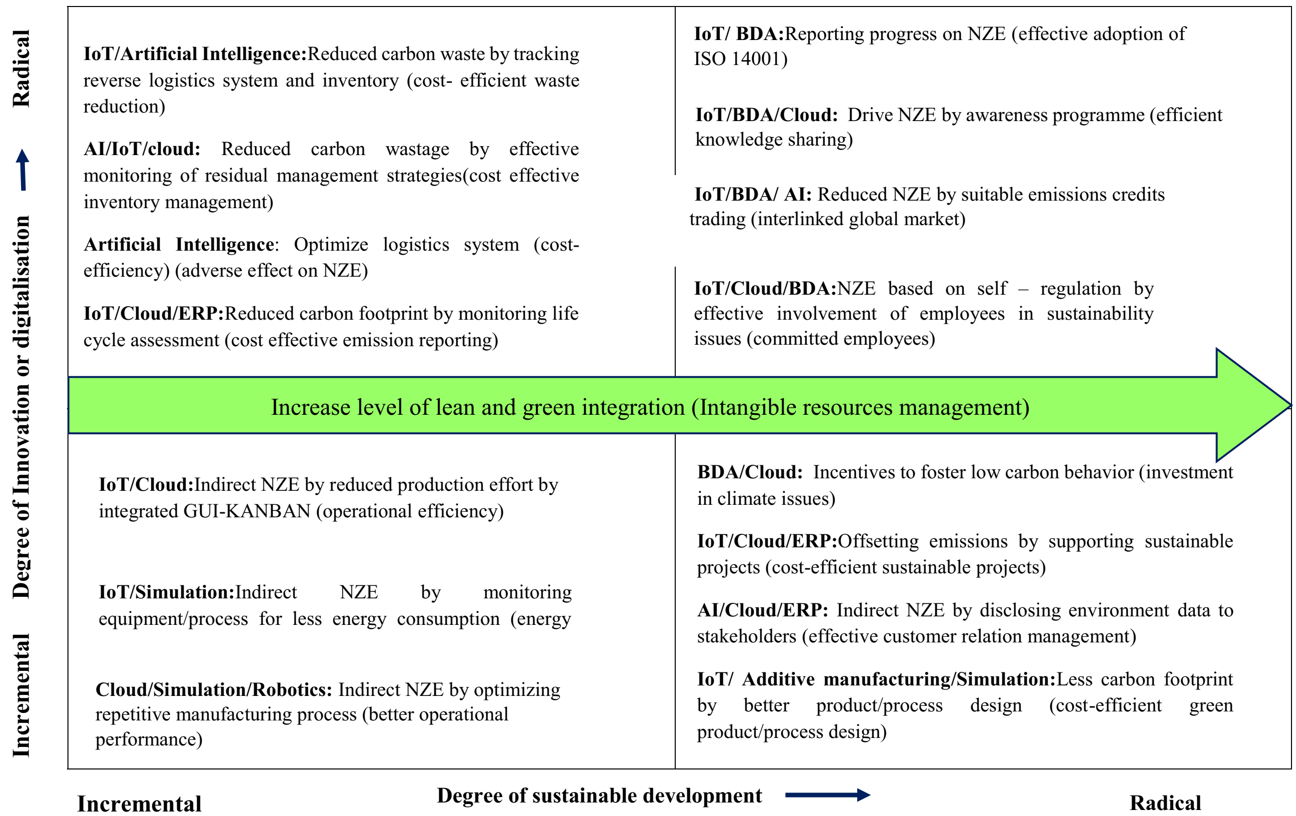


Fig. 4. Achievement of NZE via progressing towards SDGs.

workers on energy-saving practices like shutting off laptops at night (Biro and Csete, 2021). Interconnecting manufacturing workers and top managers can achieve this in view of the kaizen philosophy (awareness programmer) with the help of Cloud and Cyber Physical System (CPS) systems (Wang et al., 2016).

2 The product category investigates ways to lessen the environmental impact of produced items. These factors directly impact the time, money, and effort that goes into developing a product. Redesigning items is one approach to lowering their environmental impact. This may be accomplished by adjusting the product into consideration (green product/ recycled or renewable material) based on additive manufacturing in view of the green VSM approach (Cadez and Czerny, 2016; Kamble et al., 2018).

3 Process-related reductions focus on increasing process efficiency. Redesigning the manufacturing processes to include more automation is one way to boost process efficiency (Penz and Polsa, 2018; Zhang et al., 2021). Modern equipment, which often has lower energy requirements, produces less waste, and employs cleaner technologies, may also improve process efficiency and cut down on emissions (Britton and Petrovskis, 2020). Machine monitoring and upgrading can be achieved based on the integration of Total Productive Maintenance (TPM), Internet of Things (IoT) and cloud-based ERP system (Pagliosa et al., 2019). Furthermore, efficient repetitive operations such as welding and machining based on additive manufacturing and TPM leads to less carbon emission.

4 6R & waste management-related reduction goals to deploy the 6R principles and appropriate waste release. However, throughout the published works, recycling has been the central topic. Water filtration at a factory or office recycling and disposal systems are only two examples of the kinds of waste management practices that result in adequate waste discharge (Biro and Csete, 2021). Thus, less carbon discharge in different sources is achieved by monitoring residual management strategies based on an AI-based kanban/pull system.

5 The management category consists of measures and reduction activities initiated at the strategic level. The first step is to provide staff with internal incentives to promote low-carbon behaviour. Consider rewarding people financially for fewer work trips (Chu and Schroeder, 2010). The second strategy for reducing GHG emissions is known as "knowledge management," and it involves holding seminars and other forms of information exchange. The last three metrics—investments, project, and stakeholder management—are centred on adjusting to changing rules and regulations, funding initiatives that promote sustainability, and working directly with legislators (Wittneben and Kiyar, 2009). Financially, businesses may restrict pollutants from new projects by including GHG emission objectives in investment choices and investing in sustainable R&D advancements like carbon capture (Kouloukoui et al., 2019). Policymakers must be consulted for responses to carbon legislation as a part of stakeholder management (Hoang Duc and Do Ba, 2017). Ecological or targeted emission-lowering objectives are the first step towards a self-regulated system. To what extent and in what formats should data on the environment be made accessible to the public is governed by disclosure measures. A corporate report or outside programmes like CDP are also viable options for this (Ferreira et al., 2019).

6 Compensation entails charging businesses for their GHG emissions, and indirect emission levels are reduced. Trading in emission credits is the first measure. Companies must get EUAs (EU-Allowances) in the European Union, which set a company's maximum GHG emission ceiling. Depending on a company's requirements, these permits may be exchanged (for example, bought or sold) (Damert et al., 2017). A business might also make up for its emissions by aiding initiatives that cut down on emissions. The compensation-based carbon reduction measured achieved by integrating intangible resources (intra-firm non-stakeholders, market data) and digital technologies (Cloud/ERP system, AI, BDA) in view of kanban/kaizen

(lean philosophies) and green information system (green philosophies).

4.2. Achievement of SDGs via NZE

The ideas and trends from Table 2 are summarized in Fig. 3 to provide a clear framework for thinking about the function and capabilities of digital technologies within net-zero plans as a source of long-term competitive advantage. Literature has recognized six key digital technologies for net-zero manufacturing, including the IoT, automation and autonomous robots and simulation, big data analytics, artificial intelligence (AI), cloud-based enterprise resource planning (ERP) and additive manufacturing (Fig. (3a)). RBV was used to divide the various digital resources/values and/or their advantages into categories for tangible and intangible assets (Fig. (3b)). The conclusions of the VRIO study are then used to demonstrate the various levels of sustainable competitive advantage that may result from the adoption and suitable implementation of digital technology (Fig. (3c)).

4.3. Strategic use of firms' innovative capabilities to achieve SDGs via NZE

The level of digitalization achieved by the firm can be incremental or radical depending on the exploratory and exploitative nature of innovation (Dixit et al., 2022). SDGs can also be incremental (improvements to the existing performance) or radical (novel improvements to sustainable value creation and capture) (Foss and Saebi, 2016). Based on these findings, four scenarios have been propounded in Fig. 4 and also explained below:

1) Incremental digitalization of the firms' resources and incremental SDGs via NZE: In this scenario, firms strategically managed their resources by integrating digital technologies and lean manufacturing philosophies to improve their existing performance and achieve NZE. There is a small sustainable competitive advantage achieved from the reduction of emissions, for example, in all lower-left scenarios i.e., indirect NZE by reduced production effort (operational efficiency) and NZE by less energy consumption (energy efficiency).
2) Incremental digitalization of the firms' resources and radical SDGs via NZE: In this scenario, firms strategically managed their resources by integrating digital technologies and green manufacturing philosophies for novel improvements in sustainable value creation and capture to achieve NZE. There is a long-term sustainable competitive advantage achieved from the reduction of emissions for example all lower-right scenarios i.e., Less carbon footprint by better product/process design (Cost-efficient green product/process design) and the other three scenarios.
3) Radical digitalization of firms' resources but incremental SDGs via NZE: In this scenario, firms strategically managed their resources through a high level of integration of digital technologies, and lean and green manufacturing philosophies to improve their existing performance and achieve NZE. There is also a small sustainable competitive advantage achieved from the reduction of emissions, for example, all upper-left scenarios i.e., reduced carbon waste by tracking reverse logistics system and inventory (cost-efficient waste reduction) and the other three scenarios.
4) Radical digitalization of firms' resources and radical SDGs via NZE: In this scenario, firms strategically managed their resources through a high level of integrating digital technologies, and lean and green manufacturing philosophies for their novel improvements to sustainable value creation and capture and achieve NZE. There is a long-term sustainable competitive advantage achieved from the reduction of emissions, for example, all upper-right scenarios i.e., NZE based on self–regulation by effective involvement of employees in sustainability issues (committed employees) and the other three scenarios.

5. Discussion

The results show that digitizing lean production and manufacturing processes in several sectors may lower GHG emissions. The low carbon emission problem could be solved via digitization (Stock and Seliger, 2016). There may be more recycling and reuse options with greater resource use, equipment maintenance, and end-product utilization (Carvalho et al., 2018). In addition, digital technologies are crucial for green production since they allow for more adaptable approaches to planning, data management, and organizational structure (Zangiacomi et al., 2020). As such, previous research has shown that lean production and environmentally friendly production go hand in hand (King and Lenox, 2001). When taken as a whole, these influential theories of business management represent approaches to production that minimize their environmental impact (Alves and Alves, 2015; Johansson and Osterman, 2017). Sustainable competitive aims are pursued by both production types (Fu et al., 2015). Current findings suggest that the primary benefit of incorporating digital technologies, lean and green manufacturing is considered to be largely affiliated with expected or realized improved efficiency, increases in productivity, and cost savings facilitated by general digitalization but were not affiliated with net-zero manufacturing emissions. When compared to the published research, however, the advantages of digitalization in reaching net-zero emissions may be more conceptual than real (Okorie et al., 2023).

To put it in another way, digital technology often allows for the optimization and enhancement of manufacturing procedures and other activities throughout the value chain that cannot be measured or compensated monetarily (Dixit et al., 2022). Instead, a lasting competitive edge comes from data sets that are unique to a company or a particular product, the free flow of information across departments, and a lean, environmentally conscious approach to the management of human resources. These results are consistent with RBV because they highlight the "know-what" (i.e., where to find necessary cross-functional information) through the use of digital technologies and the "know-how" (i.e., how to operate specialized technologies and processes smoothly) through the use of lean and green philosophies, both of which are crucial to the success of a manufacturing company (Amjad et al., 2021). Thus, the following research proposition is developed to guide future researchers:

> P1: The integration of lean, green and digital technologies leads to firms' effective resource utilization

However, it is essential to remember that digital technologies that may result in SDGs (such as an optimized inter-firm logistics system via the adoption of the JIT method) are not always those that result in NZE, especially when it comes to the actual resources being used. Studies that have shown discrepancies between lean and green may provide weight to this idea (Baumer-Cardoso et al., 2020). Skornowicz et al. (2017) found that without specialized measurements like the ones they created, environmental progress might be missed. A number of other studies have shown that some lean solutions have negative effects on the environment (Choudhary et al., 2019; Baumer-Cardoso et al., 2020); e.g. Just-in-time production may have greater effects since it involves more frequent travel (which produces more carbon emissions), more packaging, and smaller batches. Flexibility might demand more resources when moving between production configurations. Thus, the following research proposition may be reflected upon by future researchers:

> P2: The stand-alone implementation of either digital technologies or lean manufacturing does not always lead to the attainment of NZE goals

The majority of the strategies for carbon reduction that the current study has discovered and that are motivated by radical creative ideals are connected to management categories (Lewandowski and Ullrich,

Table 3
Potential research questions and exploration to advance the field of NZE via SDGs.

Present research questions	Present research exploration with propositions (P)	Major themes (Future opportunity/ TMC approach)	Future research questions for further exploration
RQ1: How the available firms' resources (tangible or intangible) can be strategically managed (based on digital technologies)?	The present research has proposed an integrated approach of lean and green philosophies and digital technologies for strategically managing both tangible and intangible firms' resources, as given in Figs. 1 and 2. (P1)	Need to focus on theory-driven research (T, M)	• What are the various resources management theories such as RBV, Natural-RBV and stakeholder theories which may be adopted for firms' resources management? • How may empirical studies contribute to theory development in the direction of interlinking digital technologies and firms' strategies for the management of their resources? • What are the various qualitative pieces of research which may identify different challenges for adopting digital technologies in firms' resources management?
		Need to focus on intangible firms' resources (C)	• How to focus on human resource management in view of digital capabilities and data exchange? • How to handle huge amounts of information from different organizations based on cloud/ ERP systems? • How to achieve traceability of assets for their management and increased recovery rate?
RQ2: How the firms' strategically managed resource-based innovative values will drive NZE?	The innovative values generated from strategically managed resources are classified into tangible and intangible values, which are further classified into radical and incremental innovative values. Further, innovative values were linked with various carbon reduction measures (CRM) to explore the impact of digital technologies on the NZE as given in Table 2. (P2)	Need to shift from incremental to radical innovation to achieve NZE (C)	• How digitalized factories and products based on incremental innovation will impact managers' decisions towards radical innovative values to achieve NZE? • What is the impact of digital manufacturing vertical/horizontal integration, reverse logistics, production planning, and control of product recycling and remanufacturing to drive radical innovation, which leads NZE?
		Need to focus on developing countries (C)	• How can social and cultural aspects of developing economies, such as age, gender, educational level, income level, and experience influence users' behaviour towards digital NZE practices? • How could different political, institutional and cultural environments influence the implementation of plans for achieving digitalized NZE? • How do uncertainties in addressing global climate change affect the integration of digital technologies and carbon reduction measures in developing economies? • How the firm managers' of developing countries will disclose their emission information to the local community?
		Need to focus on secondary data-based studies (T, M)	• How can primary data support, extend and corroborate studies done using secondary data (COP meetings, industrial workshops) to improve the rigour of the studies done in the digitalized-based net-zero economy? • How does data triangulation (data from different sources, persons at different times) help to capture a more comprehensive understanding and

(continued on next page)

Table 3 (*continued*)

Present research questions	Present research exploration with propositions (P)	Major themes (Future opportunity/ TMC approach)	Future research questions for further exploration
			increase the validity of the research results in the field of NZE?
		Need to focus on the under-presented sector/ industry (M, C)	• What are the suitable approaches for minimizing carbon emissions by strategic resource management in the freight transport and services sector? • What are the driving forces/ challenges/ enabling factors encountered by firms working in the service sector? • How empirical comparative studies from different sectors will provide a more generalized solution to NZE by effective resource management?
RQ3: How NZE drive the managers to achieve sustainable development goals (SDGs) by adopting RBV?	The present research has analysed the innovative values based on the "VRIO" framework proposed by the RBV theory to explore the sustainable goals via NZE. Based on these four modes of sustainable competitive goals have achieved i.e., basic competitiveness, sustained competitive advantage, temporary competitive advantage and competitive parity as given in Table 2, Figs. 3 and 4 (P3, P4, P5, P6, P7, P8 and P9)	Need to focus on developing countries (C)	• How does financing associated with the net-zero economy (NZE) goal lead to sustainable development goals (SDGs)? • What are the technological and behavioural changes in developing countries' stakeholders needed to make the transition towards SDGs via NZE? • How the firms' managers in developing economies will take follow-up action (resources management policies) when reporting any emission to achieve SDGs?
		Need to shift from incremental to radical SDGs via NZE (C)	• What is the impact of digitized products and factories on managing customer relationships to develop new channels of information to create new sustainable value creation? • How will firms manage huge data of marketing communication related to the integration of the NZE goals and SDGs? • How to achieve a high level of digital technologies connectivity to the integrated resources management strategies to achieve SDGs (e.g., lean and green integration)? • How to make effective stakeholder management in sustainable projects and climate issues?

2023). This conclusion may be supported by the fact that research has concentrated more on the use of new technologies and energy for the industrial sector's low-carbon transition. Long-term emission reduction practices, however, have shown that management makes up 70% of the elements affecting the emission reduction impact while technology makes up 30% (Song et al., 2023). Table 3 also reveals two more noteworthy facts: To begin with, a sustained competitive advantage (showing four VRIO characteristics) is not necessarily achieved through the simple integration of green, lean, and digital technologies; effectively, digital technologies can facilitate a short-term competitive edge (showing three VRIO characteristics) or competitive parity (having two VRIO characteristics) (Barney, 1991; Barney et al., 2001). This conclusion may be supported by RBV since it does not suggest that the advantage gained by a corporation is permanent (Barney and Mackey, 2018), nor does it provide a timeframe (Barney et al., 2021). As stated above, this strategy is doomed to failure since it relies only on the ability of rivals to replicate the innovations (Barney and Hesterly, 2019). Thus, the following research proposition may be propounded for further deliberation:

P3: Sustained competitive advantage is simply not achieved by the mere integration of lean, green and digital technologies to pursue NZE.

Sustaining competitive advantage via NZE is enabled by digital technologies when they are used correctly and optimally ("IoT, cloud computing/ERP, AI, and BDA"), and when intangible resources are managed in accordance with lean and green principles (Amjad et al., 2021). Businesses that invest in a thorough analysis of the market for green demands using the Kanban/Pull system and an effective kaizen approach to raise employee energy consciousness and buy-in to the company's zero-waste goals will have a long-term competitive advantage as a result of the ties to other like-minded businesses that they have developed through their net-zero approach (Farias et al., 2019). This finding is corroborated by research on the return on investment, which has shown that spending money on things like cross-functional orientation, training, and information-sharing within a company can increase its internal capabilities and organizational knowledge, which in turn can improve its performance (as opposed to spending money on things like generic technology and employees with generic skills) (Paiva et al., 2008; Okorie et al., 2023). Thus, the following research proposition needs further attention:

P4: Sustained competitive advantage is only achieved by the suitable and optimal integration of lean, green and digital technologies.

In this research, we found that the degree to which digitalization, lean, and green manufacturing are integrated was correlated with the potential for achieving a sustained competitive advantage (via advancements towards NZE). Lean-green principles advocate for the integration of various digital technologies and, also, human resources in order to strategically maximize the use of digital transformation (radical innovation) to reach SDGs (radical sustainability) and attain net-zero manufacturing emissions (Fig. 4, upper-right scenario). It is anticipated that the widespread use of digital technology may reduce carbon dioxide emissions by 2.07 gigatons in Europe alone by 2030 (Bitkom and Accenture, 2022). For this reason, the following research proposition should be investigated by future researchers:

P5: To reach radical sustainability goals via NZE, a firm needs to effectively manage its human resources and other resources by integrating innovative digital technologies, lean and green practices

Also, the upper-right scenario emphasizes indirect NZE via carbon trading in a globally interconnected market. Building a worldwide interconnected carbon market is receiving more and more attention in light of the new bottom-up system for independent national emissions reductions after the Paris Agreement (Weng et al., 2020). Efficient carbon trading can help us get to indirect NZE more quickly if we have a single carbon market (Zhang et al., 2020). Therefore, the following research proposition may be developed to guide future researchers:

P6: Collaboration-based carbon trading by integrating innovative digital technologies, lean and green practices can be an effective carbon reduction measure for achieving radical sustainability goals

Since the Sustainable Europe Research Institute (SERI) estimates that 21 billion of the raw resources used in manufacturing do not become a part of the end product, the upper left scenario largely focuses on the recycling and residual management of the discarded raw goods to reach NZE (Mishra et al., 2022). MacArthur Foundation (2013) concurs with the fact that most raw materials that are not used properly result in greenhouse gas emissions. Thus, the following research proposition needs greater attention from future researchers:

P7: To reach radical sustainability goals via NZE, a firm needs to shift its practices towards a circular supply chain by integrating innovative digital technologies, lean and green practices

However, as no business in the sector completely reveals its emission levels, the lower-right scenario (Fig. 4) implies an indirect NZE via the disclosure of environmental data to stakeholders. In addition, there is a lack of public education on the climate problem and what can be done about it, which suggests that efforts to reach net zero by 2050 will be slow (Ayloret al., 2020).

Thus, the following research proposition should be explored by future researchers:

P8: To reach radical sustainability goals via NZE, a firm needs the effective participation of each internal and external stakeholder by integrating innovative digital technologies, lean and green practices.

Finally, the lower left scenario (Fig. 4) mapped that digital technologies mainly drive operational-related practices with an indirect effect on emission control. Thus, shifting to a low-carbon economy requires energy-efficient machinery, efficient manufacturing processes and trained workers which are addressed by the bottom left scenario (Deberdt and Billon, 2021). Thus, the following research proposition may be proposed to guide future researchers:

P9: To reach incremental sustainability goals via NZE, a firm can integrate digital technologies and lean practices without much emphasis on green practices

5.1. Managerial, practitioners and social implications

Managers will decrease the amount of garbage treated on-site and boost efforts to minimize waste throughout the manufacturing process (also known as source reduction or pollution prevention). Managers may be persuaded by evidence from lean manufacturing to prioritize process improvement over retrofitting at the end of the line. As a result of saving money on the time and effort required to find viable pollution prevention possibilities, lean manufacturing might also help bring down the price of decreasing pollution. Managers may never look into the true benefit of pollution reduction if they anticipate it to be expensive, and it is impossible to undertake the measurement and analysis to evaluate this assumption. The outcome might be a missed chance to reduce pollution while making a profit. Lean production may help managers adjust their expectations for the costs and benefits of pollution reduction operations by shedding light on the significance of indirect and dispersed costs and benefits. Managers must grasp the idea and value of carbon assets, as well as how to maximize that value for maximum return. A company with limited means should obtain training in low-carbon production and carbon pricing that incorporates diverse and heterogeneous information to enable it to adapt to the changing demands of the market and government policy.

The policies are serving as a roadmap for the implementation of pilot and demonstration projects on national, local, community, industrial parks, and other scales in a variety of nations. Further studies on institutional change in the social sciences are coming. As a result, this will inspire professionals to include pressing and timely NZE concerns in strategy development. Second, the manufacturing industry should not be the primary focus of research towards a net-zero economy. Given the importance of the service industry to the world's economy, experts advise pushing towards net-zero ambitions in the service sector. Current research findings should be put into practice to reduce GHG emissions and advance SDG progress. As a result, the quality of our air, water, and land would all increase. This has far-reaching implications, including improved health, prosperity, food safety, and water quality. As manufacturing moves from incremental to radical value-based, a net-zero carbon model has emerged, necessitating new ways of thinking about operations, as well as reassessing the role of various nodes within manufacturing companies and recruiting and training employees with expertise in putting sustainable operational practices into practice. Given the scope of the transformation, it is imperative that the NZE facility be staffed with appropriately qualified individuals. Accordingly, practitioners will learn to recognize the difficulties related to achieving the net-zero goal in manufacturing organizations so that preventive measures can be taken. By examining potential paths of digitization, sustainability and resource handling, practitioners can figure out industry-specific characteristics (e.g., different aspects of lean and green techniques) that impact emission regulation in the manufacturing sector.

Table 4
Future research themes that need to be discussed in the COP 28 conference based on hits and misses of COP 27 and present research.

Main agenda of COP 27 driven by four inter-connected visions (i.e., Implementation, Mitigation, Adaptation, and Collaboration) (Adapted from Arora and Arora, 2023)	Missed agenda in COP 27	Research propositions for achieving SDGs via NZE in manufacturing firms	Future research themes need to be discussed in COP 28
• The most important agenda for implementation is keeping the target of 1.5 °C within reach through the implementation of green and advanced technologies	• Did not consider radical climate change in developing and underdeveloped economies. Lack of climate action, finance and social inequalities to achieve SDGs	P2: Stand-alone implementation of either digital technologies or lean manufacturing does not always lead to the attainment of NZE goals P3: Sustained competitive advantage is simply not achieved by the mere integration of lean, green and digital technologies to pursue NZE. P4: Sustained competitive advantage is only achieved by the suitable and optimal integration of lean, green and digital technologies. P8: To reach radical sustainability goals via NZE, a firm needs the effective participation of each internal and external stakeholder by integrating innovative digital technologies, and lean and green practices.	• Adapting products to use recycled, environmentally friendly, or less carbon-intensive elements • Green recycling strategies • Adopting green practises • Development of concurrent lean and green methodologies • Assessing lean-green strategies • Measures to encourage less-carbon-intensive travelling habits (such as fewer trips, electric vehicles, and bicycles);) • Implementation of sustainable value stream mapping • Integration of lean, green and six sigma approaches for reducing flue gas emission • Technology-based and natural capture of GHG • Conducting SWOT analysis (risk management, recognizing new markets driven by climate influence) • Implementing lean and green practices in the manufacturing supply chain for reducing waste
• Mitigating the rising temperatures of oceans, forests and cryosphere may act as a nature-based solution to preventing temperatures and climate disasters	• Lack of planning for reducing temperature rise or carbon dioxide (CO_2) emission in the oceansss	P9: To reach incremental sustainability goals via NZE, a firm can integrate digital technologies and lean practices without much emphasis on green practices	• Strategies for periodically enhancing process effectiveness via redesigning the process or innovative machinery • Using waste heat recovery, heat pumps, or IGCCs (Integrated Gasification Combined Cycles). • Water savings and reduction of wastewater discharge • Information sharing of mitigation activities, raising awareness of internal and external stakeholders
• Energy and its transition towards renewable and green methods was another major agenda at COP27 under adaptation	• No phase-out of fossil fuels to achieve SDGs based on green technologies and proper resource utilization	P1: Integration of lean, green and digital technologies leads to firms' effective resource utilization P7: To reach radical sustainability goals via NZE, a firm needs to shift its practices towards a circular supply chain by integrating innovative digital technologies, lean and green practices	• Application of 6Rs-principle throughout the whole organization (reuse, recycle, reduce, redesign, recover, remanufacture) • Improve the performance of carbon-derived power plants in the fossil fuel industries (for instance, by switching to gas from coal). • Using machines and equipment that utilise less energy. • Appropriate use of energy recovery techniques (such as reusing blast furnace gas and recovering thermal energy from landfills).
• Collaboration to set up a loss and damage fund for countries that are most vulnerable to climate change disasters	• Loss and damage fund introduced but no defined structure to achieve SDGs, especially for underdeveloped economies	P5: To reach radical sustainability goals via NZE, a firm needs to effectively manage its human resources and other resources by integrating innovative digital technologies, lean and green practices P6: Collaboration-based carbon trading by integrating innovative digital technologies, and lean and green practices can be an effective carbon reduction measure for achieving radical sustainability goals	• Financial rewards encourage low-carbon behaviour inside the organization. • Public-private partnerships (PPPs) for investing in the conservation of energy. • Discuss potential carbon mitigation measures, such as taxes, regulation, and carbon trading, with decision-makers. • Consider emissions objectives during funding considerations for upcoming projects. • Adopting Carbon Emissions Trading Scheme (ETS). • Disclosure of the firms' sustainable activities officially in a business report.

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Table 4 (*continued*)

Main agenda of COP 27 driven by four inter-connected visions (i.e., Implementation, Mitigation, Adaptation, and Collaboration) (Adapted from Arora and Arora, 2023)	Missed agenda in COP 27	Research propositions for achieving SDGs via NZE in manufacturing firms	Future research themes need to be discussed in COP 28
			• Establishment of partnerships with sustainable NGOs to support sustainable projects. • Active participation of manufacturing firms in the Global Reporting Initiative (GRI).

5.2. Agenda for future research based on discussion

In accordance with the standards established by previous studies (Paul and Singh, 2017; Mishra et al., 2021), suggestions for future study are made within the concept, technique, and setting (TMC) framework as shown in Table 3. From a review of the literature, we can identify three major settings that have been previously employed. The first is that most of the research has been done in the context of developed economies (Table 1); the second is that the only context that can be evaluated is the one that pertains to the specific business sector. The adoption of net-zero procedures is also affected by sector-specific factors (Giannakis and Zittis, 2021).

In our study, we observed that the manufacturing sector is the focus of the majority of the articles on lean and green philosophies. Despite this, the broad acceptance of lean manufacturing is in vogue in many other industries, including healthcare and construction. In addition, green management is extensively spread (Souza Farias et al., 2019), and environmental awareness is a prevalent concern across many business domains. As a result, researching how lean and green may be used in different industries is just as crucial as researching the combination of lean and green. It has already been mentioned that several researchers concentrated on logistics (Ahmad and Xu, 2021), oil, gas, and energy (Jenniches et al., 2019) sectors. However, there have been no studies that compare enterprises in developing economies to determine whether or not they have net-zero aims within a certain industry. Likewise, there is a dearth of research that compares industries.

There were found to be two key gaps in the research technique of net-zero economy and manufacturing companies. Firstly, most research employed quantitative data-gathering techniques, including modelling and survey methodologies (Table 1), which begs the issue of how long the net-zero objective would last and what real practices would be used to get there. Due to their underrepresentation in the current body of research, qualitative methods of data collecting including the Delphi methodology, focus groups, and semi-structured interviews, would be crucial. Secondly, we were unable to discover any publications that used longitudinal data, and all of the articles included in this analysis relied on cross-sectional data instead. In terms of theory, it is obvious that standard business and management theories, including strategic management, information system, transitional, and behavioral theories have not been used to research net zero. As emerging nations increasingly absorb wealthier ones' industrial infrastructure (Meng et al., 2018), emissions are typically discarded in countries with weak environmental laws, like under developed nations (Michalek and Schwarze, 2015). Increased emissions in developing nations may result from the GHG reduction policies of developed countries. For nations with less rigorous climate policies, the introduction of tight climate rules might have a large distorting influence on the replacement and growth of carbon-intensive businesses (Antimiani et al., 2013). As developing nations are responsible for carrying out the bulk of actual measures to lower emissions, they will feel the full force of these repercussions in their economies and ecosystems. Business, society, politics, law, and culture all have a role in whether or not we can make the shift to a low-carbon economy (Dou, 2013) and calls for a sea shift in our technological capacities, our social structures, our economic methods, and our patterns of consumption. Due to the emergence of new incentives and constraints to corporate activities, businesses will undoubtedly confront new governance difficulties, particularly in regard to the engagement of various players (Foxon, 2013). The implementation of many types of low-carbon technology and shifts in current methods of innovating are needed to avoid this outcome (Lewandowski and Ullrich, 2023), and the management of several supply chains also have to have a long-term sustainable perspective (Seuring, 2013; Mishra et al., 2022).

6. Conclusions

In recent years, energy-related (power and heating) emissions accounted for 43%, transportation-related emissions contributed for 26%, and the combined manufacturing and construction sectors accounted for 17% of global emissions. The potential for the greatest increase in carbon emission in both sectors lies with the manufacturers, who are intrinsically linked to the production of both electricity and heat. Higher pollution costs and lower SDGs are unavoidable in the manufacturing sector, which is also under more pressure to undergo a change aimed at lowering emissions. Findings from this research highlight the significance of intangible resources (mostly those related to human resources and information management) and imply that extra investment and development are necessary to achieve NZE in line with the SDGs. This study also highlights the need to adopt digital technology and implement lean and green practices at a high level in order to reach radical revolutionary values. It is possible that digitalized lean-green techniques might help lessen environmental damage, smooth the way for more precise measurements of that damage, and highlight the need to do away with pollution altogether. Using lean-green manufacturing may also lower the relative cost of lowering pollution by making people more aware of the importance of pollution prevention or by decreasing the expense of implementing ecological development. Policy initiatives that emphasize emissions lessening can assist in promoting the transition (from incremental to radical) to digital alternatives that may endorse the attainment of SDGs and net-zero aspirations and a more universal strategy. This was determined based on the outcomes of literature and COP agendas. And as RBV states confirm, there is room for improvement in value-chain cooperation and optimization with the right policy backing.

Although studies in the net-zero domain have increased significantly since the 2015 Paris agreement, this research has performed a detailed literature review based on selected studies that have focused on both NZE and SDGs. Furthermore, this research does not involve the collection of primary data from industries directly involved in manufacturing; rather it follows the findings and shortcomings of the previously held COP summits. Also, there is another limitation of this research as it does not involve any experts for analyzing innovative values based on the "VRIO" framework. In spite of these caveats, our research is one of the first theoretical underpinnings to examine the overlap between RBV, digital technologies, lean and green philosophies, and the building of a sustainable competitive advantage via the pursuit of NZE. Therefore, the present research has identified possible topics for further inquiry utilizing the TMC framework, which may be considered at the next COP28 meeting, as shown in Table 4. Furthermore, some carbon reduction measures that were not identified or missing in the literature, e.g., sustainability constitution, need to be further researched to evaluate their influence on the firms in the context of NZE and achieving SDGs.

Author credit statement

Sanjeev Yadav: Ideas, Conceptualization, Writing- Original Draft Preparation, Data Collation and Curation, Methodology. Ashutosh Samadhiya: Ideas, Conceptualization, Writing- Original Draft Preparation, Data Collation and Curation, Methodology. Anil Kumar: Ideas, Writing – Original Draft Preparation, Conceptualization, Methodology, Project Supervision and Administration. Abhijit Majumdar: Revision of formal analysis, Conceptualization, Revision Administration. Jose Arturo Garza-Reyes: Revision of formal analysis, Conceptualization, Revision Administration. Sunil Luthra: Reviewing and Editing: Critical Review, Commentary and Revision

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.

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