Dual Pathways Toward Net-Zero–Based Performance Through Responsible Leadership—Mediation of Green HR Practices, Green Innovation, and Moderation of Digital Capabilities

Dual pathways toward net-zero based performance through responsible leadership – mediation of green HR practices, green innovation and moderation of digital capabilities

Abstract

The research pertains to exploring one of the unique relationships, between responsible leadership (RL) and net-zero based performance (NZBP), through two different pathways utilizing the theoretical lens of upper echelons theory. One is a direct pathway through the moderation of digital capabilities and the other is indirect through the sequential mediation of green HR practices and green innovation. Data were collected through a two-wave, time-lagged design from 357 senior officials of large manufacturing firms. Data analysis was also carried out in two stages; firstly through "Partial Least Structural Equation Modeling" (PLS-SEM) and then through "Artificial Neural Networks" (ANN). The PLS-SEM results conveyed positive relationship between RL and NZBP through both pathways. Further, the moderator digital capabilities catalyzed the relationship between RL and NZBP. The ANN analysis while strengthening the PLS-SEM results, predicted the dimension of "Leadership" holding greater importance, followed by "Business" and "Environmental" within the spectrum of RL responsibilities. The findings have deeper insights for the fields of leadership and NZBP, advancing both theoretical understanding and practical applications for sustainable business practices.

Keywords: Responsible leadership; Net-zero based performance; Digital capabilities; Green HRM; Green Innovation;

Introduction

Net-zero-based performance (NZBP) aims to develop an organization's capacity to minimize greenhouse gas (GHG) emissions, offsetting the remaining emissions, to achieve a balance between emissions produced and removed from the atmosphere (Tang et al., 2023). This objective is crucial in the battle against the devastating effects of climate change on our planet. The authors Lee et al. (2023) argue that transitioning to a net-zero emission society may significantly reduce GHG dilution; for instance, CO_2 in the environment, minimizing global warming and climate disruptions. This shift to cleaner energy and sustainable behaviors is essential to preserve biodiversity and environmental balance. Net-zero emissions may also improve Earth's quality of life. Lower pollution and air quality will benefit public health, reducing respiratory ailments and other health issues (Lund et al., 2023). Therefore, in the early 1990s, the net-zero emission policy emerged to link human activities involving fossil fuel use and other energy usages, giving rise to the greenhouse gas levels. The initial global efforts to this end were “The United Nations Framework Convention on Climate Change” in 1992, the 1997 Kyoto Protocol for setting binding emission targets, and then the 2015 Paris Agreement for equilibrium in net-zero emissions (Tang et al., 2023). This strategy shows how collective effort may combat climate change and alter energy sources to solar, wind, hydro, and bioenergy.

Given this background, it is pertinent to mention that the recent data demonstrates the severe GHG emissions in air, soil and water, especially in lower-and middle-income nations, due to rapid industrialization, causing danger to ecosystem, human health as well as financial growth (Shahzad et al., 2020; Huong et al., 2019). Particularly, Pakistan is facing severe challenges, including pollution of urban regions by smog-filled air, carbon emissions, and the poisoning of aquatic bodies with hazardous

contaminants (Shahzad et al., 2020). Moreover, when it comes to air pollution-related mortality, Pakistan is in third place globally; its air-pollution index is among the worst countries of the world. Additionally, being characterized as newly industrialized economy (emerging economy) with limited technological advancements as well as resources, Pakistan is still heavily relying on traditional linear consumption models and fossil fuels for economic growth (Ghani et al., 2024a). The major damaging industrial sectors (for instance textile, auto-parts manufacturing, chemicals and cement) of Pakistan (Abbas et al., 2020) have conventionally prioritized revenue generation over environmental concerns, resulting in disastrous environmental imbalances (Farrukh et al., 2022; Chien et al., 2021).

Considering these reason, the authors posit that the environmental deterioration and threat to human health in metropolitan areas may be considerably reduced, if these industries in developing countries like Pakistan, transition to net-zero emissions (Mehmood et al., 2024; Aftab et al., 2023; Qin et al., 2021). These countries seriously need some mechanism and remedial solution to resolve this environmental catastrophe, emphasizing and highlighting the significance of the enablers of net-zero based performance. Therefore, the authors of this research suggest that by adopting green practices, integrating green innovations and advanced technologies, organizations in these regions can drastically reduce their carbon footprints and accomplish prevalent environmental health (Khan et al., 2024). However, understanding the drivers of NZBP and bringing up such transformation in industries is essential for creating targeted interventions that promote sustainable development.

This research proposes responsible leadership (RL) as the determinant of NZBP. Further, it is proposed that responsible leadership by adopting green human resource (GHR) practices and fostering green innovation (GI), can demonstrate accountability to societal actors who prioritize sustainability, such as environmentally conscious customers, suppliers, investors seeking ESG-compliant businesses and policymakers enforcing stricter environmental regulations (He et al., 2021; Liao & Zhang, 2020). This proactive engagement helps firms reduce their environmental impact, enhance their reputation, and build trust, ultimately leading to competitive advantages in global markets, where sustainability is increasingly valued (Ooi & Memon, 2025a).

Previous studies have explored the potential factors and pathways for attaining net-zero emission profiles due to the increasing recognition of NZBP (Tang et al., 2023; Kumar et al., 2023; Mehmood et al., 2024; Singh et al., 2023; 2024; Vieira et al., 2021). However, these works concentrate on issues such as technological innovations, policies, legal requirements, and financial incentives that serve as enablers. Despite its significant potential, recently very limited studies have explored the direct influence of responsible leadership in achieving environmental performance (Refer studies, Rehman et al., 2023; Javed et al., 2020; Liao & Zhang, 2020) whereas these limited studies are not adequate enough to comprehend the various mechanisms through which responsible leadership may influence organizational environmental performance. Moreover, previous studies are predominantly based on stakeholder theory focusing only on fulfilling the needs, regulations and addressing the pressures of stakeholders (See for example, Voegtlin et al., 2020; Maak & Pless, 2006; Doh & Quigley, 2014). Instead of highlighting leadership behaviors, traits and characteristics, only emphasis was stakeholders' profitability and managing environmental issues for enhancing their financial abilities (See for example,

Maak et al., 2016; Voegtlin et al., 2020). These studies have completely ignored the dominating and inspiring influence, characteristics and behavioral impacts of the responsible leadership. This leads us to another gap with regards to analyzing RL through the lens of any other theoretical lens, such as upper echelons theory that considers leaders' characteristics and behaviors as central to organizational direction and performance (Memon & Ooi, 2023a).

Another gap is concerning the measurement of responsible leadership. Previous studies have measured the limited characteristics and roles of RL, which may not articulate the holistic understanding of RL's attributes and responsibilities (Rehman et al., 2023; Voegtlin et al., 2020). The authors of this research contend that the escalating environmental repercussion of industrial growth demands particular emphasis on studying environment friendly leadership behaviors, i.e. responsible leadership in more detail. Such leadership style cannot be ignored to be studied in-depth, through its various characteristics, responsibilities, behaviors as well through different mechanisms and enablers (Abraham, 2024; Javed et al., 2024).

In addition, while investigating the behavioral characteristics of RL, influencing NZBP under developing country's contextual setting, although ignored previously, yet carries great importance that authors also rank the behavioral characteristics, with regards to their importance. This would allow the organizations to prioritize and develop higher ranked behavioral characteristics of their leaders, resulting in cost efficiency and incurring of limited resources on training & development (Memon et al., 2024).

Moreover, previous studies have overlooked the aspects of green transformation and innovation that can be brought by responsible leadership (See for example, Javed et al., 2020; Voegtlin et al., 2020) leaving behind a huge gap and need to further study, the serial mediation of GHR practices and green innovation, leading to NZBP (Abraham, 2024). There is greater need to propose a comprehensive and clear theoretical mechanism at organizational level, rather fragmented & isolated studies on individual relationships between RL & GHR practices or GHR practices & GI that lead to employee level outcomes through various theoretical frameworks. Therefore, the purpose of this study is to propose, test as well as provide a nuanced understanding of achieving organizational level outcome i.e. NZBP through distinctive mechanisms that may be adopted not only by developing countries but developed nations too.

Considering the needs and gaps, the authors propose and measure RL as a multidimensional construct based on upper echelons theory (Hambrick & Mason., 1984; Hambrick, 2007) encompassing several characteristics, values & responsibilities that RL fulfills (Javed et al, 2024). It is argued that RL not only possesses the business and leadership characteristics but also plays very significant role in societal welfare, stakeholder engagement, relationship building for achieving the NZBP (Rehman et al., 2023). Additionally, the study highlights the role of digital capabilities in enabling organizations to communicate transparency and track progress in their sustainability efforts. By leveraging technologies to measure, report, and reduce their environmental footprint, RL can meet societal expectations for accountability and performance (Javed et al., 2020). RL not only improve NZBP and comply with global standards by adopting GHR practices and GI, but they also address communal expectations and increase engagement in environmental initiatives (Liao & Zhang, 2020). This inclusive approach

highlights GHR practices and green innovation's function as mediators by explaining the influence of RL on NZBP and digital capabilities as moderator, thereby creating value for both the organization and society as a whole (Ahsan & Khawaja, 2024). Further, this research employs artificial neural network (ANN) analysis, to rank the six dimensions of responsible leadership, since ANN is well-known and reliable approach for ranking the latent variables (Memon & Ooi, 2023a).

Accordingly, this study makes four substantial contributions with upper echelons theory serving as its overarching framework. This theoretical approach explores how leaders' attributes and preferences influence the environmental performance of organizations. The study's initial contribution demonstrates the direct impact of multi-dimensional RL in achieving NZBP. Second, the study scrutinizes the boundaries of digital capabilities, examining how these capabilities amplify the impact of RL on NZBP. Third, the research explores the interplay involving responsible leadership, green HR practices and green innovation, emphasizing how these sequential mediators translate leaders' ethical and strategic values into fostering a sustainable culture of net-zero based emission. Fourth, methodologically this research contributes by measuring the specific influence of RL behaviors (dimensions) through ANN analysis, to assess which dimension influences greater (Memon & Ooi, 2023a) on NZBP.

After this introduction section, the paper is organized as follows: First a comprehensive conceptualization of RL is presented discussing its dimensions. Then research hypotheses are formulated. Subsequently, the methodology and design is discussed along with the analysis of data and reporting of results. The findings are discussed; theoretical and practical implications are drawn. Finally, the study's limitations and future research suggestions are provided.

Conceptualizing responsible leadership

Responsible leadership (RL) is a comparatively new concept that is distinctly different from the various leadership styles like transformational (Maak & Pless, 2006), servant (Greenleaf, 2002), ethical (Brown and Trevino, 2006) and authentic leadership (Avolio and Gardner, 2005), with some overlapping characteristics. For instance relational characteristic is common between servant and responsible leadership styles. Relationships are fostered by servant leaders through their service to others, while RL establish amicable relationships by establishing a consensus and protecting the stakes of all stakeholders (Voegtlin et al., 2020). In the same vein, the characteristics of ethics and values are shared by responsible and ethical leadership (Maak & Pless, 2006). RL employs ethics and values to resolve conflicts among stakeholders, while ethical leadership promotes strict adherence to them (Bhatti & Irfan, 2024). The convergence between authentic and RL encompasses individual traits and attributes, including honesty, integrity, and veracity (Walumbwa et al., 2008). Authentic leaders establish a consistent relationship between their personal and professional lives, whereas RL may adopt contrasting perspectives in their personal and professional lives to benefit stakeholders.

Similarly, the characteristics of change and change management are shared by transformational and RL styles (Banks et al., 2016). Transformational leaders are agents for addressing social, business, and ethical issues whereas RL implements change to enhance performance, resolve conflicts, and execute obligations to pertinent stakeholders (Stazyk & Davis, 2020). Thus, RL is considered as a distinct construct, despite its overlap and similarities to the aforementioned common areas and distinctions (Miska and Mendenhall, 2018).

Following some of the recent research on RL, this study also utilizes upper echelons as the relevant theoretical framework (See for example, Liao & Zhang, 2020; Maak et al., 2016).

The upper echelons theory (Hambrick & Mason., 1984; Hambrick, 2007) states that the attributes of a manager highly impact the performance of its organization. Further, upper echelons states that an organization's strategy choices and their implementation are mostly determined by these managers (Hambrick, 2007; Carpenter et al., 2004). The theory asserts that there is a strong association between the leader's tenure, level of education, work experience, relevant abilities and the strategic decisions taken by the company, which in turn have a strong relationship with the firm's future performance (Wang et al., 2016). Thus, leaders' "experiences, values and personalities…….affect their choices" (Hambrick, 2007, p.334) and "through these choices, organizational performance" (Hambrick & Mason, 1984, p. 197).

The research conceptualizes RL as a multi-dimensional construct, whereby the dimensions of RL have been elaborated in the Table 1, aligning with the above reasoning and characteristics, which may influence the NZBP of the organizations and lead to the promotion of sustainable development. The six (6) dimensions are "social", "ethical", "leadership", "business" and "legal". Consistent with the RL responsibilities and characteristics, it is defined as "*Responsible leadership is the type of leadership which places overwhelming emphasis on social and ethical responsibilities and is accountable to internal and external stakeholders for its leadership, business, legal, and environmental obligations" (*Bhatti and Irfan, 2024, *p. 19).*

Thus, this research aspires to unveil the responsibilities and roles of RL that impact NZBP through multiple pathways; however, all these roles of RL underscore the significance of conscious decision-making that is based on preferences and focused areas. As a result, the objective of this research is to identify the roles and attributes of responsible leaders that have an impact on GHRP, GI and, in the end, NZBP. The degree to which a leader incorporates each

characteristic & responsibility may differ based on the circumstances. Therefore, RL is paramount, highlighting its characteristics and responsibilities imperative for today's business leaders, facing greater sustainability challenges and societal demands. The significance of studying RL is increasing due to the transformation required in leader's roles, particularly due to the growing industrial activities causing environmental and sustainability issues (Javed et al., 2024).

Insert Table 1 Right Here

Hypotheses building

Responsible leadership (RL) & net-zero-based performance (NZBP)

Today's organizations are increasingly required to adopt a holistic approach that considers the interests and well-being of various stakeholders, as well as their environmental impacts, rather than concentrating exclusively on financial performance and shareholder returns (Zacher et al., 2023). RL is a critical determinant of organizational environmental performance (Tuan, 2022), especially the reduction of GHG emissions. Recent studies underline the importance of RL in promoting environmental sustainability in manufacturing units (Rehman et al., 2023). Based on upper echelons theory, RL develops a shared vision among external and internal stakeholders of the organization, emphasizing environmental sustainability, fostering mutual trust and collaboration for vision's accomplishment (Wang et al., 2024). Leaders' environmental behaviors are positively correlated with those of their subordinates because leaders lead by example and employees mirror their principles (Robertson and Barling, 2013).

Thus, responsible leaders lead and employees follow through imitating, learning and following their leaders by adopting environmental sustainability practices (Wang et al., 2024).

Centered on upper echelons theory, this research contends that responsible leaders develop internal culture of their organizations that is environmentally sense making and stimulating. Further, RLs promote organizational behavior and strategic decision-making by setting environmental objectives, including reduction in greenhouse gases (GHG) emission (Rehman et al., 2023), trimming down energy consumption (Tuan, 2022), encouraging the use of renewable energy solutions and encouraging sustainable supply chain management practices (Memon & Ooi, 2023b). As a result, when it comes to lowering emissions of GHG and implementing environmental sustainability policies, followers pursue the objectives set by the leaders, adhering to the leaders' behaviors and preferences (Wang et al., 2024). Based on upper echelons theory, responsible leaders' beliefs and goals steer organizational choices that enable net-zero performance. Their sustainable strategies improve environmental effects and lead organization to develop the capacity to achieve net-zero based performance (Javed et al, 2020). Thus, we present:

H1: RL positively influences NZBP.

The moderation of digital capabilities

In today's rapidly evolving technological landscape, RLs must leverage digital capabilities to drive organizational performance, including sustainability goals. Digital capabilities refer to the ability of an organization to effectively use digital technologies to

develop, mobilize and utilize organizational resources in response to changing environment and adding value to organization (de Vasconcellos et al., 2021). These technologies include the use of "artificial intelligence (AI), the Internet of Things (IoT), and big data", to improve efficiency and sustainability outcomes (Teece, 2018). Further, the adoption of digital technologies enhances sustainability by improving operational efficiency and value creation (Hao et al., 2023). Firms utilize digital tools like big data analytics, IoT, and blockchain to optimize supply chains, reduce energy consumption, and increase competitiveness, all of which are integral to NZBP (Neri et al., 2023). These technologies empower companies to track environmental performance more effectively and implement sustainable practices, such as energy management and waste reduction (Yang et al., 2021).

In the context of upper echelons theory, responsible leadership that possesses strong digital capabilities will be better equipped to drive sustainability and achieve net-zero based performance (Harrison et al., 2019). This is because digital capabilities can enhance the leader's ability to interpret and respond to environmental cues, make data-driven decisions, and prioritize sustainability initiatives (Memon & Ooi, 2023b). Digital technologies enable RL to monitor and optimize energy use, reduce waste, and track carbon emissions in real-time, thus helping organizations progress toward net-zero goals (Yang et al., 2021). Moreover, digital tools such as predictive analytics and machine learning can identify inefficiencies in supply chains and production processes, enabling firms to reduce their carbon footprint. RL ensures that digital tools are leveraged ethically to enhance sustainability practices, reduce emissions, and track progress toward NZBP (Kane et al., 2015). The digital capabilities possessed by RL guarantee the involvement and facilitation of all stakeholders through transparency and

trust, thus bolstering sustainable development initiatives (Yang et al., 2021). Thus, the intersection of responsible leadership, digital capabilities, and net-zero performance is increasingly recognized as vital for sustainable organizational practices (Neri et al., 2023; He et al., 2021). Companies that effectively leverage digital capabilities tend to outperform others in achieving environmental and sustainability targets and achieve NZBP (Neri et al., 2023; Kane et al., 2015; Zhou & Wu, 2010). Therefore, our next hypothesis is:

Hypothesis 2: Digital capabilities positively moderate the relationship between RL and NZBP.

Responsible Leadership and Green HR Practices

The relationship between RL and GHR practices has received growing interest in recent years (Tuan, 2022). RL, characterized by the capacity to influence and motivate others towards sustainable organizational objectives, is recognized as a significant determinant in the implementation of green HRM practices (Shah & Soomro, 2023).

Green HR practices, which include environmentally sustainable policies and initiatives in the HR field, are acknowledged as a significant facilitator of corporate sustainability (Zhou et al., 2024). Practices including green recruitment and selection, green training, compensation and rewards, and employee involvement are essential for promoting environmentally-conscious norms and behaviors within organizations (Saeed et al., 2019). Additionally, GHR practices involves policies and procedures that encourage sustainability, such as reducing energy consumption, promoting recycling, and developing environmentally conscious talent management practices (Ghani et al., 2024a).

Based on upper echelons theory, responsible leadership drives the adoption of GHR practices due to their environment friendliness and sustainability orientation. Responsible leadership uses a values-driven approach that puts sustainability and environmental stewardship at the top of their list of objectives. This leads to strategic initiatives that support GHR practices (Renwick et al., 2013). In high-pollution industrial organizations which significantly contribute to environmental degradation, responsible leaders steer their organizations by setting environment related goals and objectives in performance appraisals. RLs motivate their employees by rewarding employees based on their achievement of environmental objectives (Ghani et al., 2024b). Thus, responsible leaders can exemplify environmental stewardship and can motivate employees to embrace pro-environmental behaviors and participate in green HRM initiatives (Shah & Soomro, 2023).

Research indicates that responsible leaders, by leveraging their vision, communication skills, and employee empowerment, nurture a culture of environmental responsibility and support the implementation of GHR practices. GHR practices instill a culture of sustainability within organizations, making employees more aware of their role in reducing environmental harm (Aftab and Veneziani, 2024). Thus, by aligning GHR practices with sustainability goals, RLs foster employee engagement in green initiatives and enhance overall organizational commitment to reducing carbon emissions (He et al., 2021). Therefore, we hypothesize:

Hypothesis 3: Responsible leadership positively influences Green HR practices.

Green HR Practices and Green Innovation

Green HR practices promote employees to engage in environmental sustainability activities, which can lead to green innovation (GI) within organizations (Khan et al., 2024). GI refers to innovations that trim down environmental harms, improve resource efficiency, and encourage sustainability (Chen, 2008). Further, GI is considered as the "development of new products, processes, and technologies" that minimizes environmental impacts and reduces GHG emissions (Chen et al., 2006). A fundamental aspect of GHR practices is its capacity to encourage pro-environmental behaviors among employees. This is accomplished through practices including green recruitment, green training, green performance management, green compensation and green engagement (Saeed et al., 2019). From upper echelons perspective, these GHR practices driven by responsible leadership can enhance employees' knowledge and skills related to sustainability and environmental stewardship, enabling them to develop and implement green innovations. For instance, green training and development programs can equip employees with the necessary knowledge and skills to design and implement sustainable products and services (Ghani et al., 2024a). Moreover, employee engagement initiatives that promote sustainability and environmental stewardship can motivate employees to contribute to green innovation, leading to increased creativity and idea generation. The impact of GHR practices on green innovation can be seen in various areas, including product innovation, process innovation, and business model innovation. Green HR practices can enable the development of sustainable products and services that reduce environmental impact (Rana & Arya, 2024; Khan et al., 2024).

Further, GHR practices can instill a culture of sustainability that persuades employees to propose and implement environmentally friendly innovations (Ghani et al., 2024a). Similarly, green performance management system remunerates sustainability initiatives that can lead to increased innovation aimed at achieving NZBP (Longoni et al., 2018). Recent studies have shown that organizations with strong GHR practices are more likely to achieve higher levels of green innovation because employees feel empowered to develop solutions to environmental challenges (Rana & Arya, 2024; Khan et al., 2024; Shah & Soomro, 2023). In the manufacturing sector, where GHG emissions are a major concern, GHR practices encourages employees to engage in innovative practices that improve resource efficiency and reduce waste (Rana & Arya, 2024; Aftab et al., 2023). Therefore, we hypothesize:

Hypothesis 4: Green HR practices positively influence green innovation.

Green Innovation and Net-Zero Based Performance

Green innovation performs a pivotal role in accomplishing NZBP since it serves as a strategic instrument that advances sustainable practices and enhances employee responsiveness and commitment to sustainability concerns (Rana & Arya, 2024). By investing in GI, firms can reduce energy consumption, improve resource efficiency, and minimize waste, which are critical steps toward achieving NZBP (Albort-Morant et al., 2018).

Green innovation is crucial for large manufacturing firms in achieving NZBP, particularly in polluted environments like the cities of Lahore and Karachi in Pakistan (developing country). GI enables firms to reduce their environmental impact by adopting cleaner technologies, enhancing resource efficiency, and developing eco-friendly products (Mehmood et

al., 2024). Studies have shown that organizations that spend in GI are better positioned to attain NZBP because they can implement solutions that directly address emissions reduction (Rana & Arya, 2024). From upper echelons perspective, GI emphasized by responsible leadership can also enable the development of sustainable business models that prioritize environmental sustainability and social responsibility. Upper echelons theory asserts that RLs have several characteristics, for instance, creativity, commitment, and willingness to reconsider conventional business models, develop circular goods and services, and integrate sustainability into the very fabric of their operations (Boffa et al., 2023; Regmi et al., 2023). By adopting sustainable business models, organizations can reduce their environmental impact while also improving their social responsibility and reputation. This can provide a competitive advantage, enabling organizations to differentiate themselves and improve their reputation (Memon & Ooi, 2023b). Thus, in manufacturing industries, GI enabled by RLs, not only reduces operational emissions but also improves competitiveness by aligning with global sustainability standards (Zhou et al., 2024). Given the significant environmental challenges faced by industries in the metropolitan cities of Pakistan i.e. Lahore and Karachi, green innovation becomes an indispensable tool for achieving long-term sustainability and net-zero based performance (Khan et al., 2024; Aftab et al., 2023). Our next hypothesis is:

Hypothesis 5: Green innovation positively influences net-zero-based performance.

Responsible leadership, green HR practices, green innovation and net-zero based performance

Literature review suggests that RL goes beyond the traditional focus on the leader-follower dynamics, expanding its domain to include the interests and welfare of society and the environment (Wang et al., 2024). Based on upper echelons theory, responsible leaders' values, personalities, and experiences shape organizational outcomes. In the context of sustainability and environmental stewardship, responsible leaders play a crucial role in driving organizational decisions that prioritize green HR practices and green innovation. This, in turn, can lead to improved net-zero based performance (Abraham, 2024). To improve the company's NZBP, RL encourages the adoption of GHR practices, spur green innovation, and incorporate sustainable values into the organization's core strategy and aim. Firstly, GHR practices implemented by RL are vital for integrating sustainability throughout the employee lifecycle (He et al., 2021). GHR activities engage employees in proactive pro-environmental behavior (Ghani et al., 2024a) whereas RL augments the effects of green behavioral development through various interventions. RL influences these pro-environmental behaviors via informal leader-member relationships and personal relationships, resulting in greater employee motivation towards adoption of green behaviors and concern for environmental sustainability (He et al., 2021).

Similarly, for companies to promote and drive GI, RL is crucial. This is because RL affects the policies, practices, and strategic direction that determine how a company performs and impacts the environment (Liao & Zhang, 2020). It's the RL that enhances the benefits of the adoption of GHR practices and leads employees through personal exemplification, providing

resources as well as support to nurture GI activities (Tuan, 2022). It is very obvious, if leader do not value environmental protection through personal behavior, employees' green behavior may get diminished. Therefore, it is essential for leaders to prioritize ethical decision-making and environmental stewardship in order to foster a culture of sustainability inside their organizations (He et al., 2021). Their endeavor is to ensure that the company's goals and activities are in line with sustainable practices by interacting with actors both within and outside the company (Rana & Arya, 2024). Thus, we present the following:

Hypothesis 6: RL influences NZBP through the mediation of GHR practices and GI.

Research method

Procedure and participants

The research was based on large manufacturing organizations of a developing country Pakistan having > 250 employees. The manufacturing sector was focused since it is considered as a key economic engine (Ghani et al., 2024a). Moreover, in Pakistan, the manufacturing industry is the 3rd largest, contributing 12.79% annually to the country's GDP (Pakistan Ministry of Finance, 2021) and driving significant technological advancement. Rapid urbanization and industrialization have highlighted the necessity for sustainable production & consumption (Farrukh et al., 2022). Further, the industry is known for its environmental impact (Aftab et al., 2023) and faces significant institutional and environmental pressure locally as well as globally (Shah & Soomro, 2023). Additionally, manufacturing firms' carbon footprints raise threats to public health and the environment (Farrukh et al., 2022). To decrease manufacturing enterprises' environmental impact in Pakistan, it is crucial to explore the impact of RL on NZBP including GHRM practices, GI, and moderator digital capabilities.

The purposive non-probability sampling strategy was employed to select the sample from a variety of sectors, such as textile, food & beverage, pharmaceutical, electrical and electronics, steel, cement & auto parts manufacturing. The purposive criteria for organizations selected for the research includes being established for more than 5 years so as to exclude start-ups, demonstrating role in strategic approach towards environment (Memon et al., 2024). Further, the firms should have implemented and certified environmental management system (for instance, ISO-14000). Moreover, firms should have implemented green practices. The respondents included key members of the management team, including directors, CEOs, general managers, senior managers and managers. The respondents were selected because of their in-depth knowledge regarding firm's policies, strategies and performance (Aftab et al., 2023).

A list of randomly selected 148 large manufacturing firms was prepared by researchers, by contacting relevant chamber of commerce. Accordingly, the research team contacted the HR managers of these manufacturing firms prior to data collection, soliciting their consent to initiate the survey. Upon the consent and collecting basic information as per our selection criteria, the surveys were sent through emails to 99 agreeing firms via Google Forms. The data were collected in a two-wave, time-lagged manner, with two months apart, from multiple respondents of these firms to reduce the single response bias (Kock et al., 2021). In the initial wave (time 1), six hundred survey questionnaires regarding the mediating variables and demographic data were disseminated to the participating organizations. Of these, 469 responses (78.16%) were received. In the second phase (time 2), questionnaires were distributed to the organizations that responded in time 1 and data were collected for the independent, dependent and moderating variables. After second phase (time 2), 357 responses from the senior management were matched using identification codes excluding the incomplete questionnaires. Therefore, the final sample size

was 357, with a response rate of 76%. In accordance with previous research (Aftab et al., 2024), this rate was achieved by employing a variety of response-enhancing strategies, such as guaranteeing confidentiality and issuing numerous reminders. Additionally, following the methodology employed in other social science investigations (Ghani et al., 2024 a, b), the requisite minimum sample size was estimated using the G*Power software. The 357 collected responses were considerably reliable (Hair et al., 2017) since the usable sample size exceeded the minimum required sample of 129 to achieve 85% statistical power for this model.

The participating firms consisted of electrical and electronic sector (22%). Moreover, 24% of the firms belonged to textile sector, 20% were manufacturing auto parts, 14% firms belonged to cement manufacturing, 10% of the organizations were engaged in the food & beverage sector, 6% in the pharmaceutical sector whereas only 4%, belonged to steel divisions. With regards to workforce, 44% of the organizations had <250 to 500 employees, 38% had 500 to 750 employees while 18% had more than 750 employees. In terms of the firms' age, 45% were within the 10–15 year range, 30% were 16 – 20 years, and 15% had been in operation for more than 20 years. Lahore (38%), Faisalabad (22%) and Karachi (40%), comprised the plurality of enterprises in terms of geography. Respondents of the study comprised of management positions like general managers (42%), senior managers/managers (36%), directors (12%) and CEOs (10%). Their experience in higher or leadership roles was diverse; having experience of 6–10 years (46%), 11–20 years (23%) and 13% having 21–30 years. Furthermore, twelve (12) percent and 6 percent of the respondents had 3–5 years and < 3 years of experience, respectively.

Instrument & Tools

The research instrument, a questionnaire was carefully analyzed by two experienced management specialists and they found no serious flaws, confirming content validity. The questionnaire was also pre-tested at smaller-scale with industry executives to ensure clarity and comprehension before data collection (Ooi & Memon, 2023b).

The operationalisation of the constructs was based on prior studies with established validity and reliability. Accordingly, the construct of responsible leadership was considered as reflective-formative type 2 construct with six (6) dimensions, each having 4 items (24 items in total), through a scale adapted from Bhatti and Irfan (2024), as per our conceptualization. The sample items consist of "Leaders in our organization emphasize minimizing solid waste" and "Leaders in our organization seek sustainable development and creation of a better life for future generations". The moderator, digital capabilities was measured through a scale adapted from Zhou & Wu (2010) having 5 items; sample items include "Our organization effectively acquires important digital technologies" and "Our organization masters advanced digital technologies". The construct of green HRM policies was measured through a 6-item measure adopted from Aftab and Veneziani (2024); sample items include "Our organization sets green goals for its employees" and "Our organization provides employees with green training to promote green values". The measure for green innovation for net-zero and net-zero based performance were adopted from Mehmood et al., 2023 having 9-items and six items respectively. The sample items for green innovation include "Our organization is using less or non-polluting/toxic materials" and "Our organization recycles, reuses, and remanufactures material" and the sample items for NZBP are "Our organization's environmental activities drop CO2 emissions" and "Our organization's environmental activities decrease consumption of poisonous materials". All items

were assessed using a 5-point Likert scale with "Strongly agree" being highest and "Strongly disagree", the lowest.

Common method bias (CMB)

Although several procedural measures were adopted to avoid CMB including data gathering from multiple sources & in two-waves with two months' time interval. We also tested the data statistically. The Harmain Test revealed 38% of the variance i.e. < 50% threshold value (Podsakoff et al., 2012). Further, as per methodology suggested by Kock (2015), a full collinearity test was performed to confirm that all VIF values were lower than the limit (< 5) (Sarstedt et al., 2016). Additionally, the marker variable assessment using the social desirability scale (Memon & Ooi, 2023a) revealed no significant impact on the change in the coefficient of determination (R^2) of the endogenous constructs. These post-hoc tests confirmed that common method bias was not an issue of this study.

Endogeneity and robustness test

In order to confirm the main results were without estimation bias, sample-selection bias, missing variables, and reversed causality, robustness tests were performed. For instance, to test for potential endogeneity in our model, firstly, we conducted the Durbin-Wu-Hausman (DWH) test. The DWH test is a statistical test used to determine whether a variable is endogenous or exogenous in a regression model. Endogeneity occurs when a variable is correlated with the error term, which can lead to biased and inconsistent estimates (Bianco et al., 2023). This test compares the estimates of ordinary least square (OLS) model and instrumental variables (IV) model. OLS assume that all variables are exogenous. IVs are used to identify the causal effect

of the endogenous variable on the dependent variable. The authors conducted this test and results of the DWH test indicated that the null hypothesis of exogeneity could not be rejected. Please note that the null hypothesis of the DWH test assumes that the variable (responsible leadership) is exogenous. For each regression equation in these tests, p values >0.05 were found (RL and NZBP, $\chi^2 = 1.21$, $p = 0.27$; for RL and GHR practices, $\chi^2 = 0.85$, $p = 0.36$ and for RL and GI, $\chi^2 = 1.53$, $p = 0.22$), concluding that the results are safe from endogeneity bias. This suggests that our model estimates are consistent, and that responsible leadership can be treated as an exogenous variable.

Secondly, to test for potential specification errors in our model (e.g. omitted variables, interaction terms and incorrect functional form), we conducted "Ramsey's Regression Specification Error Test" (RESET) (Whittaker & Schumacker, 2022). It checks whether the model is correctly specified by testing for non-linear relationships between the independent variables and the dependent variable. The results of the RESET test indicated that the model is correctly specified, as the test values were not statistically significant (RL and NZBP, $\chi^2 = 2.13$, $p = 0.15$; GHR practices and NZBP, $\chi^2 = 1.46$, $p = 0.23$ and GI and NZBP, $\chi^2 = 0.97$, $p = 0.38$). This suggests that our model accurately captured the relationship between the exogenous and endogenous variables, and that there is no evidence of omitted variables or non-linear relationships that would bias our results (Bianco et al., 2023).

Data analysis

The analysis consisted of two phases. Initially, PLS-SEM was utilized to examine the data. PLS-SEM is ideal for assessing the multifaceted models with latent variables, consisting

moderation and mediation (Hair et al., 2017). PLS-SEM has stronger statistical power and efficiency in parameter estimation and is more predictive than covariance-based SEM for our model (Hair et al., 2017; 2019). PLS-SEM was chosen since the model had higher-order construct and a moderator and two mediators, making covariance-based SEM inappropriate for such analysis (Sarstedt et al., 2019; Hair et al., 2019). PLS-SEM has also been shown to be effective for assessing non-probability sample data. Further, PLS-SEM is used as a popular regression method for hypothesis testing that addresses data normality issues (Ooi et al., 2020; Memon et al., 2024).

However, SEM is not appropriate for ranking dimensions of responsible leadership that impact net-zero based performance since it assesses linear connections between constructs (Memon & Ooi, 2023a). One well-known artificial intelligence approach to perform this task accurately is artificial neural networks (ANN). Complex non-linear correlations as well as linear ones can be detected by ANN. According to Leong et al. (2019), ANN improves prediction accuracy when distribution assumptions are not made. ANN is more effective than traditional statistical methods and works well with structural equation modeling (SEM) to identify linear and non-linear associations between constructs (Wong et al., 2022). Liébana-Cabanillas et al. (2017), Memon et al. (2024), and Memon & Ooi (2023a) are only a few of the many studies that have integrated SEM and ANN techniques. By employing this hybrid approach, one can verify hypotheses, reveal both linear and non-linear relationships within the model, and prioritize variables according to their significance/importance.

Therefore, as discussed above, the study's analysis has two parts. First, the relationships between various variables were assessed through PLS-SEM using SMART PLS software. The

second part of the study involved employing neural networks to rank and assess the independent variables in relation to dependent variable that were significantly represented by SEM analysis (Asadi et al., 2021). According to Memon & Ooi (2023a), the artificial neural network (ANN) input was PLS-SEM output. The ANN study used multilayer perceptron (MLP) method through IBM SPSS Statistics 26. Both output and hidden layers were activated using sigmoid function. We used a tenfold technique to determine predictor significance. 90% of the data was used for training, 10% for testing (Memon et al., 2024). On both training and testing datasets, the root mean square error (RMSE) assessed the ANN model's prediction accuracy. Model errors were assessed using standard deviations. The normalized relative significance (NRI) of each dimension of independent variables in predicting net-zero based performance was examined in the sensitivity analysis. In order to predict the NZBP, the ANN evaluated the influential dimensions of independent variables resulted from SEM (Wong et al., 2022).

Lower-order constructs level

In an endeavor to reduce the model's complication and improve its theoretical parsimony, higher-order constructs (HOC) were employed (Sarstedt et al., 2019). As suggested by Becker et al. (2012), the disjoint two-stage method was implemented in the analysis. This method implements a measurement mode that corresponds with the operationalization of the HOC in the second phase. This HOC method has the ability to improve discriminant validity and reduce collinearity (Hair et al., 2017; 2019). We conducted the multi-collinearity test and that did not reveal any concerns, as all items' values were less than 5 (Hair et al., 2019).

Additionally, the measurement model was assessed for reliability & validity. Table 2a indicates that all constructs have composite reliability values > 0.70 (Hair et al., 2017), which is

indicative of their internal consistency. Then, the convergent validity was determined through "average variance extracted" (AVE) and outer loadings. All AVEs were greater than 0.50 indicating that each construct accounted for at least 50% of its indicator variance (Hair et al., 2017; 2019). Further as suggested by Hair et al. (2017; 2019), the items that have relatively lower outer-loadings were deleted; all other outer loadings were > 0.708, indicating that all reflective constructs had sufficient convergent validity (Hair et al., 2017; 2019).

Insert Table 2a Right Here

Discriminant validity was analyzed utilizing the "HTMT ratio of correlations". Table 2b shows that all the LOC and HOC of responsible leadership, had HTMT ratios below 0.90 (Henseler et al., 2015), indicating their considerable differences. Thus, discriminant validity was established via the measurement model. Additionally, Henseler (2017) suggested using the "Standardized Root Mean Square Residual" (SRMR) as one of the PLS method for modeling approximation, model fit criterion. The measurement model utilized in this study had an SRMR of 0.075, below the criterion of 0.08 (Hu & Bentler, 1999). The SRMR result implies this investigation's measurement model is fit.

Insert Table 2b Right Here

Higher-order constructs level

Responsible leadership was conceived as reflective-formative HOC and was evaluated using the disjoint-two stage method (Becker et al., 2012). It was deemed crucial to have VIF values (<5) and significant outer weights ($p<0.05$) in order to validate the HOC (Hair et al., 2017; 2019). The VIFs ranged from 1.294 to 3.209 whereas one of the formative measures was

insignificant; yet it was retained due to content validity (Hair et al., 2019). The assessment values of the HOC are displayed in Table 2c that were obtained through bootstrapping re-sampling.

Insert Table 2c Right Here

Structural model

The structural model was evaluated after PLS-SEM confirmed the measurement model following the directions of Hair et al. (2017; 2019). The estimated hypothesized model can be visualized through Figure 1. The results conveyed that multi-collinearity was not a problem in this research since all exogenous variables were significantly less than the limit of 3 (Hair et al., 2019). Further, we used bootstrapping with 10,000 re-sampling iterations to evaluate path relationships. Four direct, one indirect (sequential mediation) and one moderation hypothesis are presented through Table 3a.

Insert Table 3a Right Here

The results conveyed that RL had positive direct effect on net-zero based performance (β= 0.431, $p<0.001$). Further RL positively leads to GHR practices (β= 0.382, $p<0.001$) and GHR practices further lead to green innovation (β= 0.446, $p<0.001$) whereas green innovation leads to net-zero based performance (β= 0.278, $p<0.05$). Additionally, RL had significant indirect influence (Sequential mediation) on net-zero based performance (β= 0.094, $p<0.05$) through GHR practices and green innovation. Finally, the moderator "digital capabilities" between RL and NZBP influenced positively and significantly (β= 0.0182, $p<0.05$). The moderation results can also be visualized through sloping effects presented through figure 2.

Insert Figure 1 Right Here

Afterwards, the R^2 values were examined. As presented in Figure 1, the R^2 values symbolized that RL explained 64.7% of the variance in NZBP whereas the value of R^2 from RL to GHR practices was 57.6% considering them as having substantial explanatory power (Hair et al., 2019) and GHR practices to green innovation was 29.9%. In order to determine the effect sizes (F square, F^2 computes the relative impact of a predictor construct on the endogenous construct) of the constructs were evaluated. According to our findings, RL had substantial effect on net-zero based performance with the F^2 values of 0.525. Further, RL had moderate to substantial effect on GHR practices (f^2=0.325), GHR practices had moderate effect on green innovation (f^2= 0.23) and green innovation had moderate effect on net-zero based performance (f^2=0.278) (Cohen et al, 2013).

Insert Figure 2 Right Here

Predictive power

In order to estimate the out-of-sample predictive power, a PLSpredict examination was conducted. The prediction assessments for the endogenous construct (net-zero based performance) are presented in Table 3b. All indicators of NZBP in the PLS model exhibit lower RMSE values compared to the benchmark "linear regression model" (LM), indicating strong predictive accuracy (Hair et al., 2019; Shmueli et al., 2019).

Insert Table 3b Right Here

Artificial Neural Network

The PLS-SEM analysis specified important factors that were used as neurons in the ANN model (Wong et al., 2022). The resultant ANN model included an input layer consisting of six roles of responsible leadership and an output layer that represented the variable of interest i.e. net-zero based performance. Table 4a displays the RMSE values for both the training and testing stages, offering vital information on the accuracy of the model's predictions.

Network model efficiency was assessed using RMSE. ANN models with stronger predictive power have RMSE values near to 0 (Wong et al., 2022). Table 4a indicates that ANN models reliably detected linear-nonlinear correlations (Liébana-Cabanillas et al., 2017). The mean RMSE values were 0.2995 and 0.3500 for training and testing respectively. ANN models are vastly regarded for their reasonable standard deviations and low mean RMSE values during the training and testing phases, which are used to evaluate the relationships.

Insert Table 4a Right Here

Afterwards, the important dimensions were ranked, considering their normalized relative importance, as demonstrated through Table 4b. Amongst the several dimensions of responsible leadership, the "leadership responsibility" (LDR) emerged as the most significant predictor of net-zero based performance, with a normalized relative value of 100%. It was immediately succeeded by "business responsibility" (BUSN), "environmental responsibility" (ENV) and “Social responsibility” (SCR). Interestingly, the results acquired from the ANN align closely with the results shown in Table 3a from the partial least squares (PLS) analysis. The analyzed ANN model is presented in Figure 3.

Insert Table 4b Right Here

Insert Figure 3 Right Here

Discussion

In order to better understand the link between responsible leadership and net-zero performance, this study used GHR practices and GI as a mediating mechanism and digital capabilities as a moderator. Using a two-wave, time-lagged data from environmentally conscious firms in Pakistan, the study provides vital insights into how companies can strategically deploy responsible leadership behavior to improve net-zero based performance in a developing country's context.

This research conceptualized and empirically investigated two distinctive mechanisms that combine the processes of moderation and mediation. The pathways were both direct and indirect. Overall six hypotheses were investigated; four of them were direct, one sequential while one was moderator. This study employed a unique methodology to evaluate these relationships. Responsible leadership was defined and assessed as multifaceted construct with six dimensions whereas no previous study has measured RL in such a holistic way (see previous studies e.g. Wang et al., 2024; Rehman et al., 2023; Voegtlin et al., 2020). RL was measured as reflective-formative type 2 construct, as per the guidelines of Hair et al. (2019). In addition, the research used artificial neural network (ANN) to support and strengthen the results of PLS-SEM. This is one of the robust methods that have also been used by previous studies to rank the dimensions of multi-dimensional constructs (Memon & Ooi, 2023a). Thus, the

findings of this study enhance our understanding of how RL decreases greenhouse gas emissions and accomplishes NZBP through two different pathways.

Grounded on upper echelons theory, the results underscore the critical role that RL plays in enhancing the organization's environmental performance via the implementation of green interventions and innovations thereby reducing harmful emissions and CO2. Businesses are better able to address sustainability demands when they inculcate responsible leadership behaviors into their strategic direction. This study extends the upper echelons theory, offering a comprehensive explanation of how leaders strategize their internal practices in ways that support long-term sustainable competitiveness (Wang et al., 2024, Tuan, 2022). This is in line with previous studies that highlight that RL possesses characteristics that enable sustainable practices and accomplish greater environmental performance (Liao & Zhang, 2020).The results of this study have provided evidence of practical applicability of responsible leadership in a developing country's context. For instance, the first hypothesis (H1) with direct effect (β= 0.431, $p<0.001$) clearly conveys the dominating effect of the priorities and preferences of the responsible leadership, based on upper echelons theory, resulting in the 64% of the variance in net-zero based performance. This is done through its digital capabilities, which allows RL to tackle the hazardous environmental materials and monitor the operational efficiency in real time to accomplish NZBP. Thus, H2 is accepted at β= 0.0182, $p<0.05$. The use of digital capabilities as moderating effect is unique and need of today's digital age. Previous studies lack in theorizing and

investigating the effects of responsible leader's digital capabilities for improving the deteriorating environmental performance (Javed et al., 2020; Voegtlin et al., 2020).

Moreover, the study's hypothesis H3 is accepted at β= 0.382, p<0.001 portraying the delineating effects of RL on organizational green practices. RL provokes green practices and inculcates in organizational culture to foster the innovation. Thus, the organizations are bestowed with green innovation which results in the acceptance of H4 (β= 0.278, p<0.05). Such remarkably inspired organizational practices and green innovation inculcated in each and every target of organizations, allow firms to accomplish goals like waste management, resource efficiency, and GHG emission reduction (Wang et al., 2024; Rehman et al., 2023). This is how organizations accomplish net-zero based performance confirming our fifth and sixth hypothesis at β= 0.094, p<0.05 and β= 0.094, p<0.05 respectively.

The results of PLS-SEM were supported and strengthened by ANN analysis. As per ANN, leadership, business and environmental characteristics of responsible leadership were most important whereas PLS-SEM analysis provided the values of 0.427, 0.371 and 0.301 respectively. Interestingly, ANN and PLS-SEM findings portray similar results with regards to the importance of the dimensions of the responsible leadership. This is in line with several previous studies whereby PLS-SEM and ANN results were ranked similarly (Refer, Memon et al., 2024; Yadegaridehkordi et al., 2023; Wong et al., 2022; Memon & Ooi, 2023a). Here, it is important to consider the purpose

of the ranking of the dimensions of RL. The ranking emphasize the need to focus and prioritize these high-ranked characteristics of RL and include these training & development areas in management development & succession planning programs.

In addition, these results portray the increasing efforts made by the organizations of the developing countries and accomplishment of improved environmental performance. In response to growing concerns about these threats' potentially devastating long-term consequences (Shah & Soomro, 2023), there has been an upsurge in the efforts to combat environmental degradation and climate change recently (Zacher et al., 2023). Overall, this research contends that the concept of RL is a significant addition to the current research frameworks on leadership characteristics and leadership theories. It has the potential to solve problems at the individual, organizational, and system levels, as well as ethical and environmental concerns that are a result of new social and environmental crises (Abraham, 2024). Responsible leadership cannot only work for stakeholders' profitability rather may comprise of several other characteristics and functionalities. Accordingly, the following sub-sections explain how our study findings can augment theory and practice.

Theoretical implications

By examining Pakistani large manufacturing organizations and confirming their relationship with GHR practices, GI, and NZBP within this context, this study improves comprehension of RL roles and responsibilities. This study, which is grounded in the "upper echelons theory", offers a theoretical perspective on a comparatively under explored field (Javed

et al., 2024). It emphasizes the major role of RL impacting NZBP and underscores the frequently unnoticed ethical & environmental aspects of large manufacturing organizations in today's modern era. Moreover, it accentuates the critical function of digital capabilities in fortifying the beneficial relationship between RL and NZBP. As a result, this investigation adds to the "upper echelons theory" by integrating RL as a fundamental component whereas the stakeholder theory has been the focus of previous studies. Nevertheless, this research integrates responsible leadership, a fairly new aspect, into the model, acknowledging that modern-day leadership styles in the technological era considerably impact organizational dynamics. Furthermore, the study broadens the "upper echelons theory" to include ethical, environmental and socially responsible components by measuring RL as multidimensional construct (Bhatti and Irfan, 2024). In today's world, businesses are being scrutinized for their social responsibility, which is why this is extremely important. This research expands the influence of the upper echelons theory beyond their sole strategic and financial implications (Memon & Ooi, 2023a).

This research explores the interplay between RL, GHR practices, and GI, leading to NZBP, adding complexity to "upper echelons theory" by documenting that these elements are not isolated. The interplay between these variables is vital for developing organizational strategy and results. Limited studies have measured the relationship between RL and GHR practices using only stakeholder theory (See for example, Tuan, 2022) but not through upper echelons theory. Moreover, rarely studies have examined RL as a higher-order construct (Bhatti & Irfan, 2024; Liao & Zhang, 2020) and RL as a possible source of NZBP (See for example, Rehman et al., 2023). Thus, the study enhances upper echelons theory for strategic decision-making. Elevated leadership's focus on environmental and responsible practices greatly affects the organization's strategic direction and firm performance.

This study adds to "upper echelons theory" by analyzing the dimensions of leadership, environment, and social responsibility in the digital age (Javed et al., 2020). Examining senior executives' characteristics and orientations is crucial for understanding organizational performance and NZBP in the ever-changing business world. Such assessments may pave the way for the organizational development plans required to meet the upcoming challenges due to the changing external environment (Aftab et al., 2023). Finally, this research has expanded the purview of responsibility and underscored the intricacies of leadership within modern organizations. Rather than merely serving as effective change agents or relationship-oriented leaders, responsible leaders must embody a comprehensive range of characteristics to a significant degree. The application of these principles possesses the potential to transform not only the perception of leaders regarding their responsibilities within organizations but also to reshape research methodologies in the field of sustainability leadership and other pertinent domains (Memon et al., 2024).

Practical implications

This research contends that the significance of NZBP is particularly vital for developing countries, which endure a comparatively higher rate of loss due to climate change impacts, including natural disasters and diminished biodiversity (Rana & Arya, 2024). Consequently, through policies aligned with net-zero objectives, organizations can enhance both their environmental accountability and their resilience to climate threats (Lou & Hsieh, 2024). This method significantly mitigates ecological degradation, which consistently presents a complex challenge to development and, consequently, limited resources. Moreover, declaring a net-zero economy is an opportunity to advance the growth of green sectors and create employment within

the climate sector (Tang et al., 2023). NZBP is thus not merely an environmental necessity but a determinant of competitiveness in global marketplaces.

In this context, RL, characterized by the active engagement and support of societal actors, has the potential to cultivate a culture of responsibility and to elucidate the proposed ramifications of significant transformations within their respective industries, as well as for employees and all pertinent stakeholders (Cao et al., 2024). In the quest for a responsibility-oriented trajectory, it is essential to establish a clearly articulated strategy that prioritizes social welfare and environmental sustainability while simultaneously ensuring production & operational efficiency. This alignment is indispensable to meet the objectives of sustainable development. It is progressively more apparent that environmental alteration is resulting in detrimental consequences such as infection, mortality, and economic desolation, all of which can profoundly disturb a nation's developmental route (Memon & Ooi, 2023b). RLs play a critical role in mitigating GHG emissions & facilitating the implementation of a novel, sustainable mechanized paradigm that underpins a nation's sustainable growth (He et al., 2021). During this transition, renewable energy solutions and substitute recycling means have the potential to supersede environmentally harmful yield such as carbon, methane, and nitrous oxide.

Furthermore, this research indicates the imperative for robust association connecting the communal and private sectors to develop a novel, ecologically sustainable manufacturing model that emphasizes performance based on net-zero principles (Kumar et al., 2023). It is very important that organizations, and more specifically, RL, actively participate in societal initiatives. The study deduces that RL can appreciably contribute to collective makeover by engaging diverse actors and providing support to community workers, who possess expertise in digital technologies. RLs not only foster a sense of belonging and social identity but also

engender trust among personnel through their responsible actions. Ultimately, organizations may attain a higher performance, enhance their sales, and augment their profits (Ahsan & Khawaja, 2024).

Additionally, GHR practices introduced by RL have been found to promote business sustainability. They encourage staff to develop and execute green solutions, which improve the company's environmental and financial performance (Zhou et al., 2024). HR strategies that support environmental objectives may promote sustainability and innovation. This involves hiring environmentally conscious people, educating them in green practices, and giving them performance management and reward incentives (Aftab & Veneziani, 2024). Environmentally conscientious personnel are more likely to develop and execute creative ways to lessen the organization's environmental effect when empowered and rewarded. Moreover, smart GHRP may help organizations meet their sustainability goals and boost competitiveness and profitability (Ghani et al., 2024a).

Finally, with regards to the organizations sustainable consumption and production initiatives to achieve NZBP, the organizations will have to make several changes to their existing routines and procedures (Kumar et al., 2023). This research suggests green innovation i.e. to handle all garbage and chemicals sustainably; waste reduction through repair, reuse, upcycling, and recycling at the end of the life cycle; promoting energy efficiency, water efficiency, wastewater reduction, climate emission reduction, clean product design through the adoption of responsibly innovative ways and methods; encourage sustainable procurement techniques like sustainability criteria in procurement and purchase and last but not the least, educating people about sustainable consumerism (Hao et al., 2023; Ooi and Memon, 2025b).

Limitations and future research

This research has also some potential limitation that could be focused in future studies. First, in this study, we adopted a two-wave time-lagged data. Although two-wave time-lagged data provide some information about sequential relationships, future research could use an experimental or quasi-experimental research design to thoroughly investigate the causal relationship between all variables. Second, this study specifically gathered data from the large manufacturing firms, which limits the practical significance of the findings to small & medium enterprises. To improve the practicality of these findings, future research should strive to get data from smaller manufacturing firms. This will enable us to get an in-depth understanding of the two distinct types of organizations and their influences. Further, the veracity of the findings may be influenced by the use of subjective measures for NZBP, rather than objective measures. Despite several common method bias checks, this phenomenon reflects the dependence of data collection primarily through the perceptual judgments of senior officials of organizations. In future, researchers should gather the secondary (actual) data, portraying the exact impact of study variables.

Third, this study looked specifically at two sequential mediating variables through which RL can achieve NZBP; however, future research could look for other mechanisms for instance, we suggest that circular economy practices adopted by RL could be a valid mechanism to achieve NZBP. Similarly, the concept of responsible innovation is very well known; it could be another pathway towards NZBP. Future research may investigate these pathways and interplay between these variables in SMEs and large manufacturing firms. Fourth, the study used upper echelons theory which provides a solid framework for assessing these relationships, future research could use other theories, such as trait theory, dynamic capability theory, LMX and

social identity theory to better understand the mechanism through which employees develop their capabilities and adopt responsible behaviors. This would allow for a more detailed explanation of the phenomenon and its implications.

Finally, this research may be susceptible to omitted variable bias, as it did not evaluate the digital capabilities of senior officials (leaders). These aspects should be evaluated in future research, and recommendations for training and development requirements should be made. Additionally, examining the influence of leaders' development programs on digital capabilities may possibly offer valuable insights into topics that require refinement. Further, it is proposed that future research may investigate the effects of particular digital technologies, including block-chain, artificial intelligence and robotics on the NZBP.

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Figure 1: Hypothesized Research Model

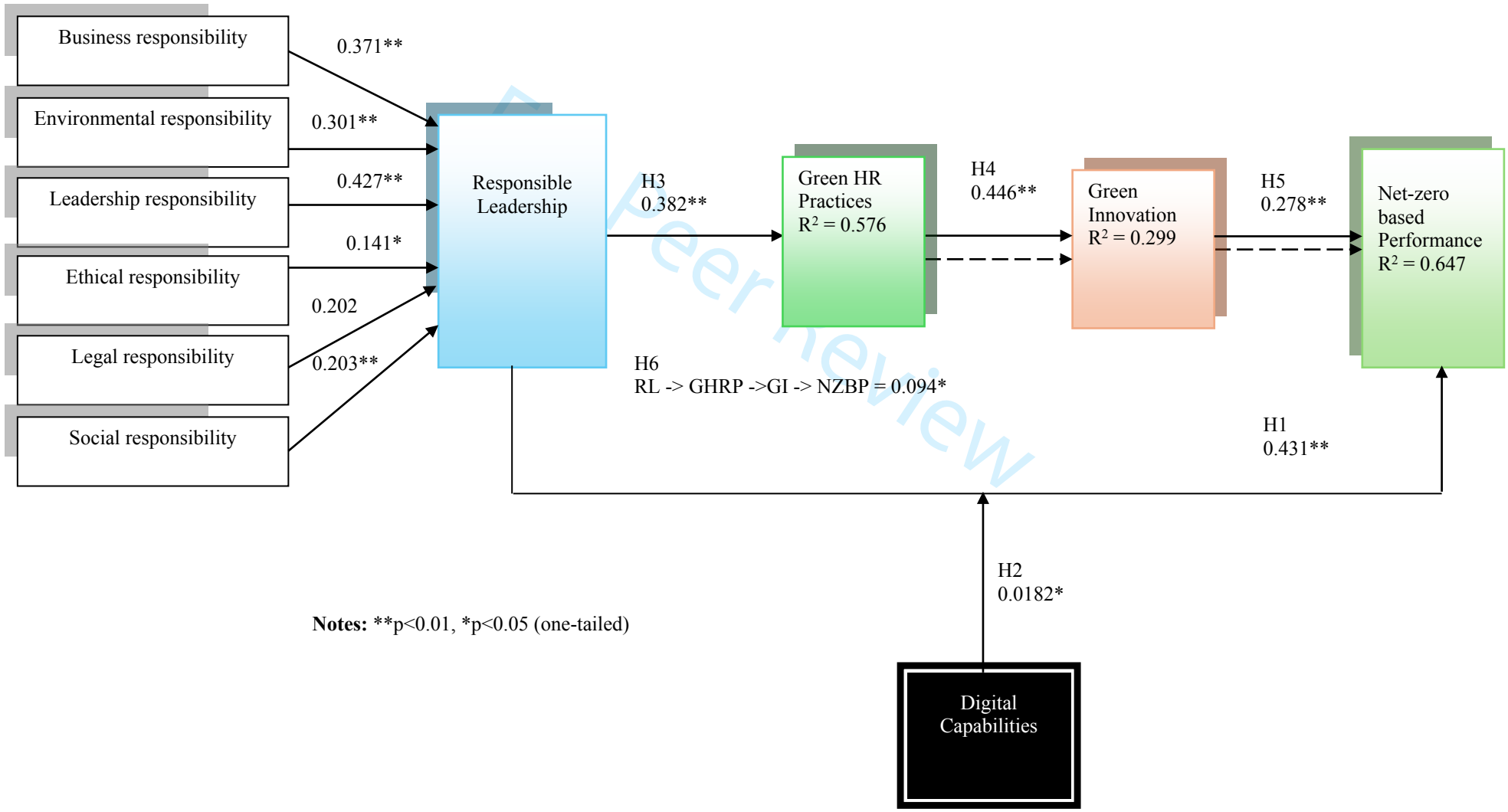


Figure2: Moderating effect of digital capabilities

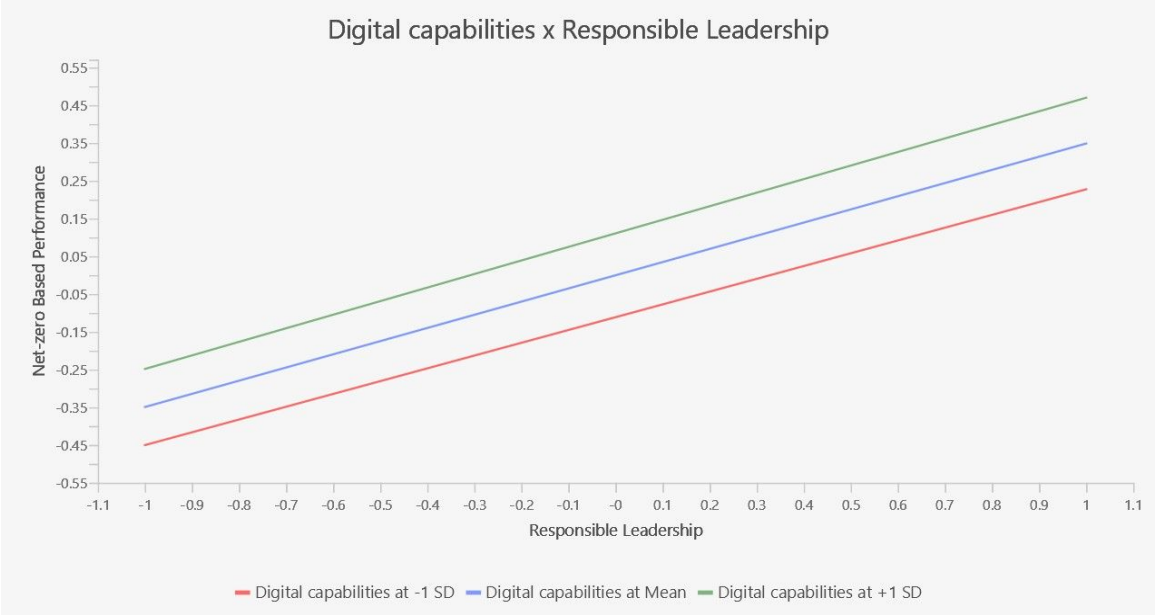
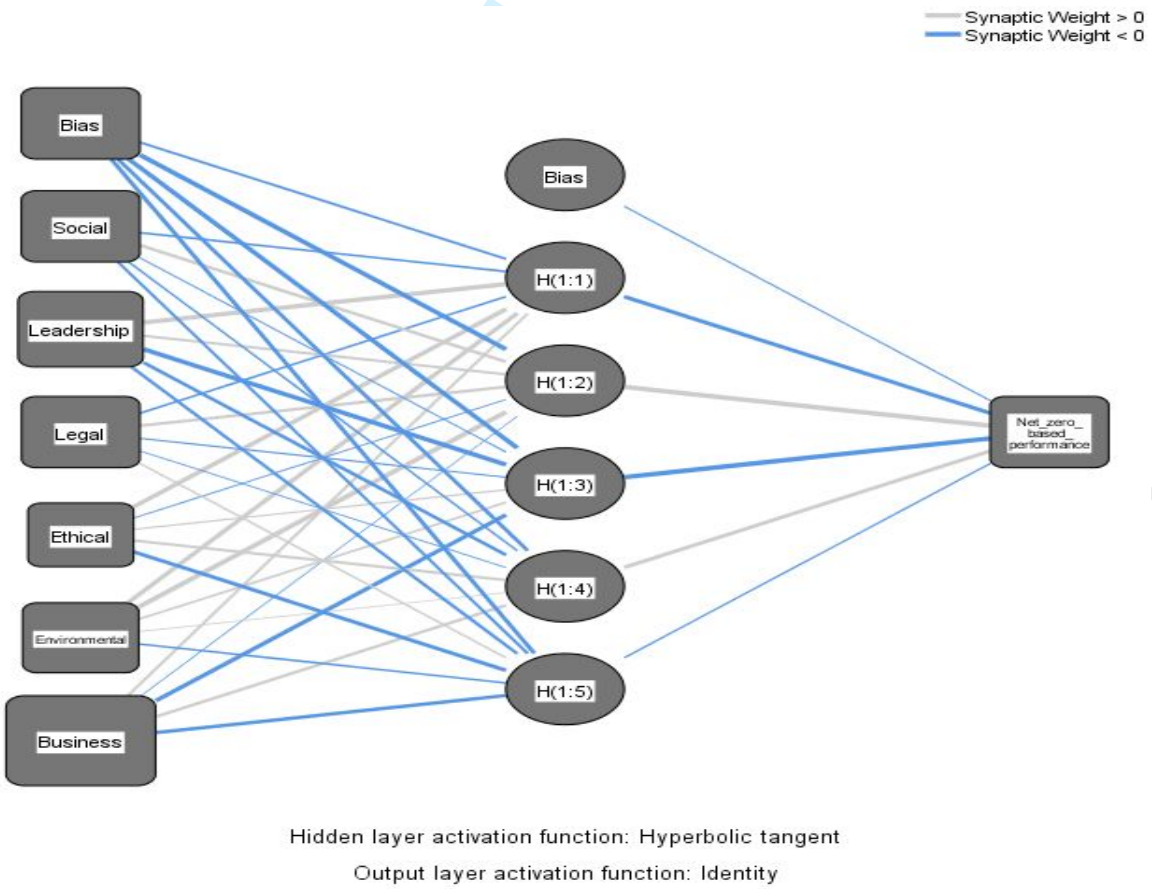


Figure 3: ANN Model of responsible leadership



Tables

Table 1

Dimensions and responsibilities of responsible leadership

#	Responsibilities / Dimensions	Descriptions and characteristics
1	Social	Social responsibility pertains to CSR including citizenship behavior as well as commitment with the social welfare. Responsible leaders develop the good-will of the organizations through their society-oriented behaviors. They donate for society, seek sustainable development and contribute to the common good.
2	Ethical	It includes ethics, values, and respect for the diversity. Responsible leaders present themselves for accountability to all stakeholders. They respect and give value to every stakeholder and consider them important.
3	Leadership	Leadership responsibility includes relational intelligence, self-awareness, and the aggregates of virtue. This includes the leadership characteristics of motivation, integration and care for all stakeholders specially employees.
4	Business	It covers the stakeholder orientation, collaboration, and participative decision making whereby stakeholder orientation is considered as the essential part of the responsible leadership.
5	Legal	This responsibility is constituted by legal compliance and transparency. They keep record of every transaction, never support unfair means, regularly pay all taxes and practice the law without any discrimination.
6	Environmental	This responsibility includes environmental friendliness and pollution control. Responsible leaders do not only set personal examples but also involve other stakeholders by setting environmental goals, targets as well as set long-term vision to meet these performances.

Table 2a: Results of Measurement Model (Lower-order constructs)

Constructs	Items	VIF Values	Loadings	CR	AVE
Business responsibility	RL-1	2.139	0.746	0.840	0.569
	RL-2	2.182	0.824		
	RL-3	2.152	0.806		
	RL-4	1.821	0.820		
Environmental responsibility	RL-5	2.262	0.930	0.830	0.546
	RL-6	2.150	0.872		
	RL-7	2.332	0.822		
Ethical responsibility	RL-9	2.199	0.824	0.823	0.516
	RL-10	2.117	0.815		
	RL-12	2.629	0.863		
Leadership responsibility	RL-13	1.962	0.873	0.915	0.573
	RL-14	2.891	0.851		
	RL-15	2.426	0.865		
	RL-16	2.698	0.887		
Legal responsibility	RL-17	1.863	0.797	0.763	0.602
	RL-19	1.952	0.780		
	RL-20	1.786	0.799		
Social responsibility	RL-21	1.842	0.875	0.764	0.595
	RL-22	1.708	0.897		
Digital capabilities	DC-1	2.183	0.718	0.792	0.573
	DC-2	2.349	0.826		
	DC-3	2.595	0.844		
	DC-4	2.663	0.782		
	DC-5	2.865	0.822		
Green Innovation	GI-1	2.711	0.845	0.797	0.568
	GI-2	2.613	0.833		
	GI-3	1.993	0.785		
	GI-4	2.720	0.821		
	GI-5	2.454	0.825		
	GI-6	2.045	0.842		
	GI-8	2.687	0.862		
	GI-9	2.096	0.887		
Green HR Practices	GHRP-1	2.197	0.810	0.758	0.643
	GHRP-2	2.572	0.826		
	GHRP-3	2.605	0.849		
	GHRP-4	2.749	0.765		
	GHRP-5	2.307	0.791		
Net-zero based performance	NZBP-1	2.795	0.857	0.812	0.567
	NZBP-2	2.679	0.806		
	NZBP-3	2.488	0.865		
	NZBP-4	2.593	0.876		
	NZBP-6	2.631	0.838		

Note: CR: Composite Reliability; AVE: Average Variance Extracted

Table 2b: Discriminant validity (HTMT Criterion)

	1	2	3	4	5	6	7	8	9	10
1.Business responsibility										
2.Digital capabilities	0.339									
3.Environmental responsibility	0.346	0.371								
4.Ethical responsibility	0.642	0.655	0.686							
5.Green HR practices	0.844	0.371	0.692	0.678						
6.Green innovation	0.681	0.376	0.502	0.435	0.657					
7.Leadership responsibility	0.813	0.365	0.589	0.832	0.846	0.617				
8.Legal responsibility	0.574	0.445	0.849	0.380	0.564	0.848	0.366			
9.Net-zero based performance	0.504	0.441	0.662	0.503	0.575	0.780	0.592	0.685		
10.Social responsibility	0.463	0.605	0.576	0.555	0.326	0.284	0.234	0.164	0.625	

Table 2c: Measurement properties for higher-order constructs

Second-order construct	First-order	Measure	Weight	t-value	VIF
Responsible leadership	Business responsibility	Formative	0.371	2.746**	2.209
	Environmental responsibility		0.301	3.255**	1.435
	Ethical responsibility		0.141	2.477*	1.723
	Leadership responsibility		0.427	3.021**	2.053
	Legal responsibility		0.202	1.631	1.423
	Social responsibility		0.203	2.261**	1.294

Note: VIF=Variance inflation factor; **p<0.01; *p<0.05 (one-tailed)

Table 3a: Results of Structural Model

Relationship	Path coefficient	Std. error	t-value	95% confidence interval	R^2
Direct effects					
H1: RL -> NZBP	0.431	0.119	3.614**	[0.191, 0.589]	0.647
H3: RL -> GHRP	0.382	0.044	7.085**	[0.448, 0.692]	0.576
H4: GHRP -> GI	0.446	0.085	5.269**	[0.265, 0.555]	0.299
H5: GI -> NZBP	0.278	0.123	2.254*	[0.103, 0.516]	
Moderation effect					
H2: RL * DC -> NZBP	0.0182	0.142	2.342*	[0.049, 0.276]	
Sequential Mediation effect	0.094	0.083	3.122*	[0.030, 0.176]	
H6: RL -> GHRP ->GI -> NZBP					

Note: **p<0.01, *p<0.05 (one-tailed)

Table 3b: $PLS_{predict}$ Assessment

PLS-SEM				
Indicators	**RMSE**	**Q^2_predict**	**LM-RMSE**	**(PLS-SEM) – (LM-RMSE)**
NZBP-1	0.764	0.359	0.816	-0.052
NZBP-2	0.829	0.314	0.853	-0.024
NZBP-3	0.818	0.411	0.836	-0.018
NZBP-4	0.814	0.385	0.801	0.013
NZBP-6	0.788	0.431	0.824	-0.036

Table 4a: RMSE values for the ANN models

Inputs: BUSN, LDR, LGR, SCR, ENV, ETH;				Output: NZBP			
	Training			Testing			Total (N)
Network	N	SSE	RMSE	N	SSE	RMSE	
ANN1	342	25.172	0.304	15	2.254	0.388	357
ANN2	348	21.583	0.279	9	1.353	0.388	357
ANN3	336	22.230	0.289	21	2.100	0.316	357
ANN4	338	22.427	0.289	19	2.184	0.339	357
ANN5	337	26.133	0.313	20	2.412	0.347	357
ANN6	340	24.138	0.299	17	2.378	0.374	357
ANN7	336	22.957	0.294	21	1.453	0.263	357
ANN8	342	21.513	0.281	15	1.053	0.265	357
ANN9	343	30.120	0.332	14	2.248	0.401	357
ANN10	347	27.518	0.315	10	1.756	0.419	357
Mean		24.3791	0.2995		1.9191	0.3500	
SD		2.8491	0.0168		0.4820	0.0546	

Notes: BUSN=Business; LDR=Leadership; LGR=Legal; SCR=Social; ENV=Environmental; ETH=Ethical; NZBP=Net-zero based performance

Table 4b: Sensitivity analysis

	Model (Output: NZBP)					
	Responsible leadership					
Neural Network	**BUSN**	**ETH**	**SCR**	**LDR**	**LGR**	**ENV**
ANN1	0.161	0.152	0.122	0.183	0.095	0.131
ANN2	0.165	0.148	0.157	0.164	0.069	0.151
ANN3	0.182	0.149	0.178	0.189	0.048	0.133
ANN4	0.128	0.161	0.114	0.196	0.084	0.189
ANN5	0.164	0.127	0.108	0.204	0.104	0.195
ANN6	0.196	0.115	0.098	0.167	0.125	0.137
ANN7	0.195	0.108	0.136	0.194	0.097	0.141
ANN8	0.165	0.095	0.122	0.198	0.087	0.214
ANN9	0.15	0.084	0.145	0.208	0.079	0.221
ANN10	0.198	0.061	0.115	0.224	0.098	0.146
Average relative importance	0.170	0.120	0.130	0.193	0.089	0.166
Normalised relative importance (%)	88.43	62.27	67.20	100.00	45.98	86.04
Ranking	**2**	**5**	**4**	**1**	**6**	**3**

Notes: BUSN=Business; LDR=Leadership; LGR=Legal; SCR=Social; ENV=Environmental; ETH=Ethical; NZBP=Net-zero based performance

Appendix A – Questionnaire items

Responsible leadership ((Likert Scale: 1-5; Strongly Disagree – Strongly Agree)

Social

1. Leaders in our organization actively contribute to the common good.
2. Leaders in our organization contribute for social welfare even during recession and low profits.
3. Leaders in our organization believe they have responsibilities to the society.
4. Leaders in our organization seek sustainable development and creation of a better life for future generations.

Ethical

5. Leaders in our organization follow the principles of honesty, integrity and fairness.
6. Leaders in our organization consider rights of customers and other stakeholders as top priority.
7. Leaders in our organization have "zero" tolerance for discrimination.
8. Leaders in our organization have diverse representation at all levels.

Leadership

9. Leaders in our organization believe in self-analysis.
10. Leaders in our organization know their biases and inclinations.
11. Leaders in our organization respect the sensitivities of every individual.
12. Leaders in our organization consider emotions while taking any decision.

Business

13. Leaders in our organization frequently interact with relevant stakeholders.
14. Leaders in our organization believe in fulfillment of needs of stakeholders for getting their cooperation.
15. Leaders in our organization get relevant expertise through collaboration with stakeholders.
16. Leaders in our organization involve relevant stakeholders in decision making.

Legal

17. Leaders in our organization do not support any unfair means for benefiting the organization.
18. Leaders in our organization always pay taxes and official dues regularly and completely.
19. Leaders in our organization follow transparent contracting procedures.
20. Leaders in our organization explicitly indicate criteria for decisions.

Environmental

21. Leaders in our organization emphasize minimizing solid waste.
22. Leaders in our organization support environment-friendly initiatives.
23. Leaders in our organization emphasize to recycle water and treat appropriately.
24. Leaders in our organization leaders emphasize conservation of energy.

Green HR practices (Likert Scale: 1-5; Strongly Disagree – Strongly Agree)

1. Our organization sets green goals (environment friendly goals) for its employees.
2. Our organization provides employees with green training (environment friendly) to promote green values.
3. Our organization provides employees with green training to develop employee knowledge and skills required for green management (environment friendly management).
4. Our organization considers employees' workplace green behaviors (environment friendly behaviors) in the promotion.
5. Our organization relates employees' workplace green behaviors (environment friendly behaviors) to rewards and compensation.
6. Our organization considers employees' workplace green behavior (environment friendly behavior) in performance appraisals.

Green innovation (Likert Scale: 1-5; Strongly Disagree – Strongly Agree)

1. Our organization uses less or non-polluting/toxic materials
2. Our organization has improved and designed environmentally friendly packaging
3. Our organization has recovered organization's end-of-life products and uses recycling processes.

4. Our organization uses eco-labeling.
5. Our organization has low energy consumption for net-zero goals such as electricity, gas, and petrol during production/use/disposal of material.
6. Our organization recycles, reuses, and remanufactures material.
7. Our organization uses cleaner technology to make savings and prevent pollution for net-zero goals (such as energy, water, and waste).
8. Our organization has redefined operation and production processes to ensure internal efficiency that can help to implement environment friendly supply chain management..
9. Our organization has re-designed and improved products or services to obtain new environmental criteria or directives such as low carbon and hazardous gas emissions.

Net-zero based performance (Likert Scale: 1-5; Strongly Disagree – Strongly Agree)

Our organization's environmental activities:

1. Drop air emissions.
2. Drop CO2 emissions.
3. Drop excess water.
4. Drop solid wastes.
5. Decrease consumption of poisonous materials.
6. Improve ecological conditions.

Digital Capabilities ((Likert Scale: 1-5; Strongly Disagree – Strongly Agree)

1. Our organization effectively acquires important digital technologies.
2. Our organization masters advanced digital technologies.
3. Our organization responds proactively to digital transformation.
4. Our organization masters advanced digital technologies.
5. Our organization develops innovative products, services and processes using digital technology.