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Green Transformational Leadership As A Driver Of Green Technological Innovations: The Mediating Roles Of Green Strategic Capability, Organizational Green Management, And R&D Green Innovation Capability In The Manufacturing Industry Of Oman

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Abstract

Through Resource-Based View (RBV) this research examines how green transformational leadership (GTL) impacts green technological innovations (GTI) in Oman's manufacturing industry. Our research analyses mediating roles of organizational green strategic capability (OGSC), organizational green management (OGM), and R&D green innovation capability as they link GTL to GTI. This research used 400 survey results to examine GTL's impact on GTI through PLS-SEM. Our research shows that GTL leads to GTI through effective mediators. Strategic planning through OGSC and systematic OGM helps companies reach green targets just as R&D Green Innovation Capability drives sustainable product development through new scientific research. The research shows that green leadership helps organizations develop the right capabilities to support innovative work. Our study connects leadership and innovation research with environmental practice to grow our knowledge base. This study shows that organizations need to build leadership and operational abilities to reach their sustainability targets successfully. Green leadership development helps organizations build better capabilities which help drive innovation to tackle environmental challenges.

Keywords: Green transformational leadership, Resource-Based View, green technological innovations, organizational green management, organizational green strategic capability

Introduction

Manufacturing companies make green innovation their focus to improve their sustainable industrial practices. Organizations need to adopt new ways to protect the environment and meet worldwide sustainability requirements to compete successfully in a challenging market (Dangelico et al., 2017). Green Transformational Leadership helps organizations achieve sustainable results through its power to drive innovation and motivate employees to follow green targets (Ahsan, 2024; Rizal et al., 2024). Through its focus on championing goals, raising staff enthusiasm, and arranging resources GTL helps businesses combine sustainability with their business approach and results (Alrowwad et al., 2017). Although GTL drives GTI progress today researchers have not analyzed enough how this leadership model works in emerging economies.

Under Vision 2040 guidelines the Omani government supports manufacturing growth to strengthen the national economy (Aggarwal et al.,2024; Louis and Saleh, 2024). Our analysis reveals that this sector confronts growing difficulties in adopting green operations because of rising environmental rules plus customer preferences and market pressures (Gulvady & Jyotirmayee, 2023; Alqassabi, 2020). The move towards sustainability brings forward new market possibilities but organizations need to build their capacity to deliver sustainable product innovations. Based on Resource-Based View principles the analysis demonstrates how GTL uses its internal resources to create successful sustainable innovation solutions. RBV asserts that companies achieve better economic performance when they control exclusive resources that help their business thrive environmentally (El Nemar et al. 2022; Iswan & Kihara. 2022).
Green innovation performance connects GTL with GTI through the power of Organizational Green Strategic Capability (OGSC), Organizational Green Management (OGM) and Research and Development for Environmental Excellence. Organizations use environmental strategies to align their business goals with sustainability interests while OGM helps top managers implement environmental performance solutions (Mingyi & Hong, 2023; Florida & Davison, 2001; Bhatia, 2021). Through R&D Green Innovation Capability companies develop new eco- friendly technologies that help them compete effectively by lowering environmental impacts (Abbas, 2024). These internal capabilities support

executive decisions by translating them into practical results according to RBV principles which recommend using company assets to manage external issues.
Research on GTL has mostly measured organization impact directly but rarely studies the methods through which innovation happens (Waqas et al., 2024; Begum et al., 2022). Research studies on green innovation recognize that effective organizational capabilities help drive results, but more research must explore how resource-based perspectives link with leadership structures. The slow growth of sustainable practices shows clearly in Oman's emerging market setting. This research explores the relationship between GTL and GTI of Omani manufacturing companies with a focus on how OGSC, OGM, and R&D Green Innovation Capability moderate this connection.
Our research brings together GTL theory and RBV to show how leadership uses company assets to develop sustainable innovation. The study will deepen knowledge about sustainable leadership and innovation theories while showing organizations how to better protect the environment. This study is significant for several reasons. Our research applies the Resource- Based View model beyond traditional innovation studies to show how firm resources link leadership styles to green innovation results. Our findings use real-world examples from developing economies to fill a missing link in research about sustainable practices in these regions. Our study offers specific ways to build GTL leadership with sustainable capabilities, so companies achieve both environmental targets and market success. Through this research we seek to help companies across the globe reach their sustainable production goals and show them how to succeed in their green innovation efforts.

Theory and Hypotheses Development

Companies exploring sustainable innovation benefit greatly from research into Green Transformational Leadership as a leading factor (Li et al. 2023). Leaders under GTL lead by inspiring and empowering their workforce to meet both survival targets and environmental duties over the long haul (Le et al., 2024; Xu et al., 2024). Under GTL leadership style organizations develop joint environmental plans alongside their workforce to build dedication and create sustainable solutions to environmental problems (Chen et al. 2023, Rizal et al. 2024). Through clear guidelines and positive demonstrations GTL motivates teams to direct their resources toward successful environmental innovation projects.

The Resource-Based View (RBV) creates a powerful foundation to study how GTL enables GTI development. Organizations achieve competitive advantages according to RBV through assets that stand apart, bring value, and resist duplication (Ferreira et al., 2022). Companies use specific organizational abilities to reach their environmental objectives (Khanra et al., 2022) which include organizational green strategic capability, organizational green management and R&D green innovation capability. Leadership capabilities help GTL and GTI work together by bringing the vision to life as practical actions.

Through its strategic resource role OGSC helps organizations link their long-term targets to environmental objectives and make sustainability part of business strategies (Onwuzulike et al. 2024; Liuet al. 2017). Leaders with transformational mindset about green practices help organizations develop their strategic abilities by showing how sustainability benefits overall success (Ahsan, 2024; Khaddage-Soboh et al., 2024; Singh et al., 2020). When organizations use OGSC they integrate sustainability into all their business choices and performance standards which gives them better ways to develop green solutions.

Organizations use OGM to develop operational systems and procedures that support environmental objectives (Mingyi & Hong, 2023). Organizations achieve better environmental management through green policies and employee education about sustainability combined with process optimization. GTL helps OGM succeed by creating an organization that cares about protecting the environment and teaches managers how to work more sustainably. Companies that put green management rules at the heart of their work routines become better at dealing with environmental problems while improving the way they invent new things (Mathews, 2018).

Organizations need strong R&D functions to create sustainable products and processes through new technology development. GTL creates spaces that let R&D teams search for sustainable answers while supporting green technology investments and working together on novel projects (Rizal et al., 2024; Begum et al., 2022). By developing unique resources that competitors struggle to match our company confirms Resource-Based View's theory that strategic assets matter most in business today. Improved research and development in environmental innovation helps businesses find better ways to protect the environment while keeping up with their competitors.

GTL helps organizations improve their innovation skills, but OGSC OGM and R&D Green Innovation Capability make GTL's results stronger. These organizational skills turn leadership plans into real results by making the connection

between what leaders want and what employees deliver. Organizations with advanced green capabilities can meet environmental needs faster while responding to market shifts and making effective use of internal resources to create sustainable solutions (Agyapong et al., 2024; Antoni et al., 2020).

Our research combines GTL with RBV to explain how organizational capabilities support leadership roles in creating green technology innovation. This research about Oman's manufacturing sector shows how emerging markets use leadership and resource strategies to meet sustainability targets. This research explores how resources within organizations help connect leadership to innovation as it examines sustainable industrial practices using resource- based view framework.

Hypotheses Development

1. Green Transformational Leadership and Green Technological Innovation. Through GTL employees find a supportive space to develop sustainable technological solutions that solve environmental problems (Sangadji & Islami; 2024, Chen et al. 2023; Sun et al. 2022). According to Boeske (2023) transformational leaders design sustainability plans for their teams while boosting employee drive and supplying financing to solve tough environmental challenges. Leaders who use this style inspire unique teamwork while looking ahead to help companies master green tech innovation problems (Abbas 2024). According to Afsar et al. (2018) transformational leaders empower workers with direct motivation to use new technologies that lower operating expenses and protect the environment. Through their leadership transformational leaders encourage their teams to test new ideas which propel technological development. Leaders who adopt sustainable methods help companies move past habitual patterns and motivate employees to research unusual environmentally friendly approaches (Cui et al., 2023). GTL supports organizational flexibility to adjust effectively with advanced technologies while meeting environmental challenges (Fatin & Mazlan, 2023). Leadership in manufacturing companies makes sustainable breakthroughs happen according to research data. According to Waqas et al. (2024) leaders whose practices center on green transformation strengthen sustainable target alignment between employees and facilitate fast implementation of advanced environmental technologies. These leaders incorporate environmental considerations in their major choices and connect teams across functions to bring new technology into line with eco-friendly intentions (Ahsan, 2024). Ongoing knowledge sharing and skill development create better organizational learning which leads to green technology innovation (Chen et al., 2023). Businesses with transformational leadership achieve better adoption of green technology results in higher market success and stronger business performance.

H1: Green Transformational Leadership has a positive impact on Green Technological Innovation

2. Green Transformational Leadership and Organizational Green Strategic Capability An organization's capacity to put green strategies into its future plans makes up Organizational Green Strategic Capability (also known as OGSC). Through GTL companies learn how to merge their environmental goals with business targets and establish a sustainable corporate mindset. Through inspiring leadership transformational leaders build a convincing argument that proves environmental initiatives should become a core part of every strategic plan for the organization (Joel & Oguanobi, 2024). Under transformational leadership employees become engaged in building strategic green targets through an environment that supports innovative teamwork (Yi et al., 2019). Leaders promote sustainability through purposeful resource distribution and sustainable goal setting plus their dedicated action plans. Studies by Rizvi and Garg (2021) verify that transformational leaders guide organizations to build an effective green strategy for all departments through green decision-making within every level. GTL helps organizations develop their ability to keep getting better and stay flexible in what they do. Through team collaboration and knowledge sharing transformational leaders help their teams create novel green strategies that overcome difficult environmental problems (Malik et al., 2024). Teamwork within the organization helps build capabilities and partnership work with outside stakeholders brings more strength to their green strategy. Leaders serve as drivers of new green practices by helping organizations adjust to advanced ecological strategies such as circular economy concepts and renewable energy systems. Effective leadership helps organizations stay ahead of environmental laws and competitive pressures (Mittal & Dhar, 2016). Studies in today's manufacturing sector confirm that GTL helps companies better link their business strategies to sustainability for better environmental results and financial performance.

H2: Green Transformational Leadership has a positive impact on Organizational Green Strategic Capability.

3. Green Transformational Leadership has a positive impact on Organizational Green Management.
Organizational Green Management works through actions and rules to integrate sustainability into operational processes (Abbas & Khan, 2023). GTL is established at OGM by building a company culture that puts environmental stewardship

first and promotes eco-friendly ways to work throughout all roles. Leaders create environmental behavior changes in staff through their leadership example and continuous promotion of green principles (Robertson & Barling, 2013). Under transformational leadership OGM experiences better operational process performance through accountable sustainable solutions. According to Avolio et al. (2004) transformational leaders stimulate organizational members to integrate sustainability into their regular job performances by building a common mission. Leaders who make transformation take action to develop HRM systems that reduction the impact on the planet. They build environmental awareness through employee training while offering rewards and add environment-focused performance rating criteria to company standards (Huo et al. 2022). GTL connects team and employee progress to environmental targets, so everyone works consistently toward both company aims and sustainable outcomes. Leadership approaches that transform thinking drive better ways to work which supports OGM efforts. Leaders help their teams find ways to reduce environmental impact by supporting them during their search for new resource use methods and sustainable recycling solutions

H3: Green Transformational Leadership has a positive impact on Organizational Green Management.

4. Green Transformational Leadership and R&D Green Innovation Capability Research and development efforts help organizations develop and put into practice environmentally friendly technology (Amui et al., 2017). GTL supports this strength by building a business model that promotes environmental stewardship along with innovation in its research and development programs. Leaders encourage R&D teams to find eco-friendly solutions by showing how sustainability drives business strategy while giving them the needed resources to solve problems creatively (Ahsan, 2024; Singh et al., 2020). When leaders display transformational qualities, they spark their R&D team's passion for environmental challenges leading to innovative solutions. Under transformational leadership R&D teams enhance their creativity while strengthening their ability to produce next-level green technology (Hu et al., 2013). When leaders prioritize team interaction, they bring together multiple perspectives and professional knowledge to strengthen their organization's R&D process (Chung et al., 2021). Leaders direct their teams to consider sustainability in their R&D work while working to match company targets and follow environmental standards. As transformational leaders they guide R&D projects and assist teams to create products that enhance both environmental protection and business performance (Cortes and Herrmann, 2021). Leaders help bring in outside partner organizations through collaborations like academic institutions and government groups to support their sustainability research. GTL builds better ways for organizations to learn and share useful information which are needed to progress their environmental research-based innovation platform. Top executives promote professional growth and best practice adoption to keep their R&D workforce up to date in using green technology advancements. According to studies by Amui et al. (2017) businesses benefit from transformational leadership when it enhances research and development productivity alongside innovation outputs. These practices create lasting successful market positions.

H4. Green Transformational Leadership has a positive impact on R&D Green Innovation Capability.

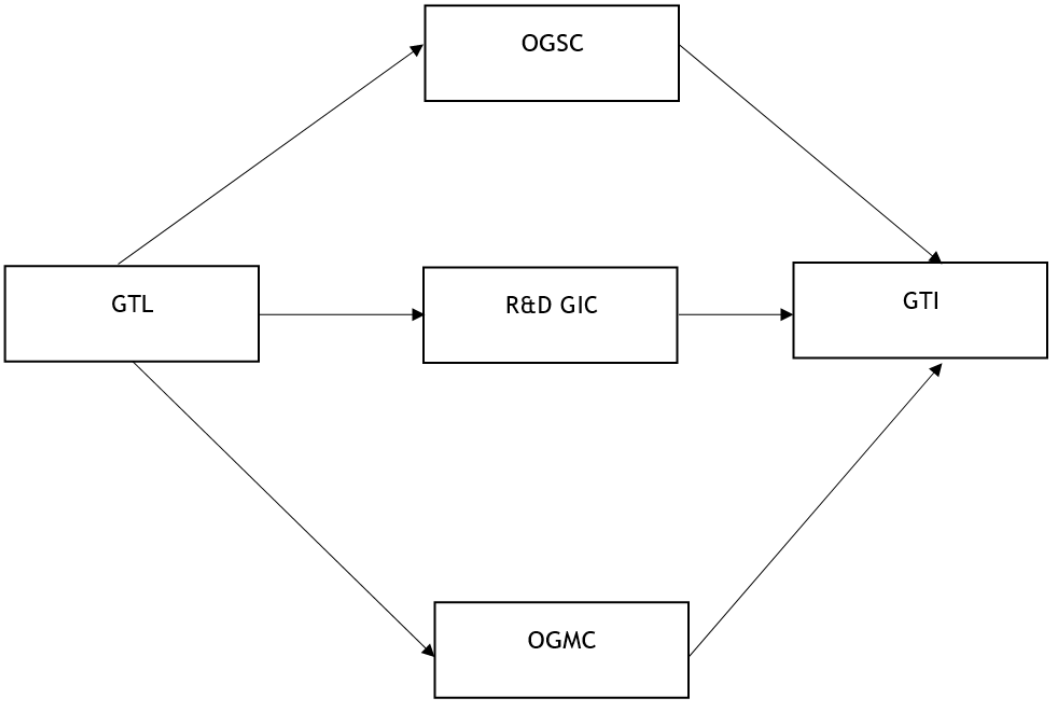
OGSC also plays a role of connecting leadership and innovation by bringing into practice what GTL wants to bring into life. GTL promotes OGSC by giving priority to long-term planning and aligning organizational resources with sustainability goals that allow organizations to gain effective adaptation of green technological advances (Abrudan et al., 2024). According to Joel and Oguanobi (2024), leadership's effects on organizational performance are intermediated by strategic capabilities since these assure the use of organisational resources to accomplish green objectives. Furthermore, organizations with greater OGSC are more capable to align their strategic vision of the market and enhance the organisational application of green advancements to give them a competitive edge (Rizvi & Garg, 2021). Literature has shown that organisations with strong strategic capacities perform better in using green technologies since the capacities help them ensure organisational leadership vision is implemented to innovation (Dangelico et al., 2017).

Through its operations, OGM translates the strategic direction given by GTL into adopting sustainable practices as the basis for green technological development. thus, GTL fosters OGM through the implementation of an environmental friendly outlook, reinforcement, and encouragement of sound environmental resource management as well as the backing of environmentally friendly operation activities (Abbas and Khan, 2023). Strategic leaders with a transformational perspective make sure that all those green practices within the organization remain relevant and consistent in achieving the overall goals of the organization leading to effective management of technological amendments for green projects. Moreover, OGM facilitates the abilities of organisations to incorporate sustainability in their working environment and improve their capability to adapt to the environmental concerns as they are innovative (Leonidou et al., 2013). For instance, firms that have engaged in green supply chain practices as part of OGM are more inclined to experience technological developments that enhance both environmental and organizational results (Samad et al., 2021).

R&D Green Innovation Capability is an important mediating factor that explains the impact of GTL on green technological results. Based on the insights of Begum et al., (2023), transformational leaders help to organize and support R & D teams to ensure the creation and implementation of sustainable innovations. This capability helps

moderate the relationship by guaranteeing that leadership brought ideas translate into real technological enhancements. According to Qiu et al., (2020), R & D capabilities play a crucial role to sustain the competitive advantage of organizations in delivering green technologies for markets. In addition, those leaders foster innovation, which means that they allow their subordinates to try out new things and take risks, which is a must for R&D teams in green innovation. Research has established that firms with robust R&D proficiency are well placed for spearheading leadership vision for green innovation since R&D endowment undergird green technology.

H5. Organizational Green Strategic Capability mediates the relationship between Green Transformational Leadership and Green Technological Innovation.
H6. Organizational Green Management mediates the relationship between Green Transformational Leadership and Green Technological Innovation.
H7. R&D Green Innovation Capability mediates the relationship between Green Transformational Leadership and Green Technological Innovation.



Research Model

Methodology
Sample and Procedure
To have the desired sample size of manufacturing firms for this study, we contacted 720 manufacturing firms dealing in Omani manufacturing sector asking them for their participation. The five-firm sample was obtained from the Oman's Ministry of Commerce and Industry enrolled firms. All the firms were first contacted through an e-mail invitation, followed by two reminder e-mails and the survey had a total of 400 usable responses, which yielded a response rate of approximately 55.6%. In as much as the study relied on a sample of voluntary responding firms, whenever one of the targeted firms agreed to take part in the study, one of the researcher paid them a visit and met the managerial representatives including but not limited to the COO, the HRM and the Production Manager. All these representatives filled a survey questionnaire in the respective establishments and returned the forms the same day. It reduced chances of delays in receiving responses while at the same time guaranteeing genuine feedback.
The data were collected through self-administered structured questionnaires that includes scales borrowed from prior studies. All the items used were Likert scale type and this has a 5- point scale of 1 signifying strongly disagree while 5 is a signifying strongly agree. The items of the survey instrument were pilot tested to 30 respondents to ensure the validity of the items used. After the pilot some changes were made in an attempt to make the questionnaire much clearer to the respondents.

Non-response Bias Test

Our research tested the risk of non-response bias through Levene's Test that compared early and late survey respondents on key topic areas. Our study findings show matching responses between early and late respondents which demonstrates no bias impact.

Table 1: Non-response Bias Test

Construct	Levene's Test	Sig.
Green Transformational Leadership	0.487	0.535
Organizational Green Strategic Capability	0.356	0.591
Organizational Green Management	0.414	0.562
R&D Green Innovation Capability	0.372	0.614
Green Technological Innovation	0.442	0.521

The table 1 shows statistical evidence that early and late respondents share similar response patterns. The data remains dependable for future use in research because both early and late participants react the same way.

Table 2: Demographics

Demographics	**Category**	**Number**	**Percentage**
Gender	Male	371	93.2
	Female	27	6.8
Age	25-30 years	90	22.5
	31-40 years	151	37.8
	41-50 years	109	27.3
	51+ years	50	12.5
Educational Qualification	Bachelor's	261	65.25
	Master's	131	32.75
	PhD	8	2
Job Position	COO	79	19.75
	HR Manager	120	30
	Production Manager	199	49.75
Years of Experience	1-5 years	90	22.5
	6-10 years	151	37.8
	11-15 years	98	24.5
	16+ years	61	15.2

The study participants were males which were 371 of them (93.2%) while the females were 27 of them (6.8%) the result depicted the fact of the current manufacturing organization which is a male dominated sector. By age, the largest number of respondents are those within 31-40 years =37.8%, respondents within 41-50 years = 27.3 %, those within 25-30 years= 22.5% while those within 51+ =12.5%. Educational level confirms that 261 employees (65.25%) have a bachelor's degree, 131 employees (32.75%) have a Master degree while only 8 (2%) employees have a PhD mapping to an adequately qualified workforce mostly with under and postgraduate education. The target job positions include Production Managers 199 (49.75 %), HR managers 120 (30 %), and COOs 79 (19.75 %), which shows the engagement of the strategic and operational employees in this study. About the work experience, a considerable number of respondents have 6-10 years of experience 37.8%, 1-5 years 22.5%, 11-15 24.5% and 16 and more years, 15.2%: it means that we deal with managers and senior professionals. Despite their diverse origin, this sample ensures that the study obtains a broad view of the manufacturing sector.

Results

The level of reliability and validity of the study constructs is presented in the following table3. Cronbach's alpha coefficients for all the constructs are above the desired level of 0.70, which means reliability. More particularly, the alpha has been calculated as 0.886 for Green Transformational Leadership, Green Technological Innovation has been assessed as 0.787, Organizational Green Management Capability has been evaluated as 0.798, Organizational Green Strategic Capability has Green Innovation, measuring 0.873. The rho_a and rho_c values range of all the constructs is above 0.70, thereby affirming the reliability of the measures. Hypothesis testing yielded Rho_c values of between 0.844 to 0.912 indicating strong reliability in the measurement model. The convergent validity is acceptable for all constructs with the average variance extracted (AVE) at 0.536, 0.644, 0.659, 0.722 and 0.538 respectively exceeding the

acceptable value of 0.50. OGSC yields the highest AVE of 0.722, providing a good explanation of variance by the items used to measure this construct. These results therefore go further to show that the constructs in the study are reliable and valid hence establishing the reliability of the measure model for the structural measurement tests.

Table 3 Reliability Analysis

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
GTFL	0.886	0.914	0.912	0.636
GTI	0.787	0.933	0.844	0.536
OGMC	0.798	0.852	0.870	0.634
OGSC	0.872	0.890	0.912	0.722
R&DGIC	0.873	0.914	0.871	0.549

To test the discriminant validity of the constructs, the Heterotrait-Monotrait Ratio (HTMT) analysis was done. Discriminant validity speaks to the extent to which the various constructs in the model are either on different theoretical dimensions or from different theoretical perspectives. The results of these tests show that all HTMT values are less than 0.85 or 0.90 thereby ascertaining discriminant validity of the model. In particular, the differentiation of Green Transformational Leadership (GTFL) and Green Technological Innovation (GTI) is supported when HTMT value is less than 0.8 with the value of 0.755in this study. Similarly, GTFL shows acceptable HTMT values with Organizational Green Management Capability (OGMC: 0.617).

Among these factors, the percentage of importance index is maximum in the Organizational Green Strategic Capability (OGSC: 0.784), followed by the Research and development Green Innovation Capability (R&DGIC: 0.729), the Green performance index (0.617). The internal construct validity is also supported by GTI having different degree of association with OGMC with correlation ranging from significant 0.817, OGSC with correlation of 0.735, and R&DGIC with correlation of 0.759. Also, there is a good internal and external HTMT with OGSC = 0.630 and with R & D G I C = 0.832 as restrict by the criterion of reasonable values. The discriminant validity is also tested by calculating the HTMT value between OGSC and R&DGIC which is 0.767. Since these results established that the constructs are distinct across both theoretical and operational understandings, they support the validity of the measurement model. As a result of discriminant validity achievement, the further analysis of the relationships between variables is possible.

Table 4 HTMT Analysis

	GTFL	GTI	OGMC	OGSC	R&DGIC
GTFL	1.000				
GTI	0.755	1.000			
OGMC	0.617	0.817	1.000		
OGSC	0.784	0.735	0.630	1.000	
R&DGIC	0.729	0.759	0.832	0.767	1.000

Direct Effects

In fact, the findings of the analysis of the structural model focusing on GTL and its relation with the mediating factor and its impact on GTI present strong links to one another. GTL shows a positive impact on Organizational Green Strategic Capability (OGSC) with path coefficient of 0.871 thus highlighting TL as an important determinant of organisational commitment towards sustainability strategy. Likewise, GTL has a significant and positive impact on R&D Green Innovation Capability (R&DGIC) with a coefficient value of 0.751 mean to underline the importance of leadership to drive innovations research and development for green technology. Furthermore, GTL is directly related to Organizational Green Management (OGMC) equalling 0.578 indicating the significance of the involvement of green aspects in regular operations. The mediating constructs also have an impact on GTI with moderate effect sizes. As for the work hypothesis H2, OGMC has a positive influence on GTI (coefficient = 0.358) speaking to how green management practices help improve the organization's biological capacity to develop and implement innovations in the support of Environmentally Friendly Technologies (ETs).

Similarly, the fairly high positive parameter, 0.339 is noted between OGSC and GTI, emphasizing the notion of strategic positioning as a key to fostering green technological progress. Moreover, R&DGIC has a positive effect on GTI with coefficient of 0.315 providing evidence of the fact that investments in R&D programs concerning\sustainability have a moderate, positive impact on the technological innovation outcomes. Taken together, these results highlight the importance of GTL in enabling organizational enablers for green technological advancement.

Table 5 Direct Effects

Direct Effects	Path coefficients
GTFL -> OGMC	0.578
GTFL -> OGSC	0.871
GTFL -> R&DGIC	0.751
OGMC -> GTI	0.358
OGSC -> GTI	0.339
R&DGIC -> GTI	0.315

Indirect Effects

In table 6 indirect effects, one gets to understand the moderating roles played by Organizational Green Strategic Capability (OGSC), R&D Green Innovation Capability (R&DGIC), and Organizational Green Management (OGMC) between Green Transformational Leadership (GTL) and Green Technological Innovation (GTI). These values show the essence and intensity of the indirect relationships between GTL and GTI. Out of all the mediating effects, GTL has the highest indirect effect with OGSC, with a coefficient of 0.296, which supports the idea of aligning organizational strategy with green objectives as the most important mechanism for enhancing green technological innovation. Thus, initiatives of leaders should be aimed at the integration of sustainability into the strategic approach since it is the major means of implementing the corresponding objectives with reference to the promotion of environmental innovations. Furthermore, the mediating role of R&D innovation capabilities is also effectively supported through an estimate of 0.237 for the indirect effect of GTL on GTI. In light of this outcome, it is important to understand how transformational leaders fosterR&D efforts that advance environmental sustainability so as to improve the organisation's technological impact. Finally, GTL impacts GTI through OGMC with a borrowed indirect influence coefficient of 0.207 as indicated in the impact of sustainable operational practices within the model. Even though this pathway is slightly lesser impactful compared to the OGSC and R&DGIC models, this pathway proves that proper green management practices remain an essential vehicle for leadership in green innovation. These results together paint a picture of how GTL affects green technological innovation comprehensively, by using premeditated capability, R&D innovation, and management measures as important mediators.

Table 6 Indirect Effects

Indirect effects	Standardized Indirect Effect
GTFL -> R&DGIC -> GTI	0.237
GTFL -> OGSC -> GTI	0.296
GTFL -> OGMC -> GTI	0.207

Discussion

Consequently, the GTI model demonstrates that Green Transformational Leadership crucially influences key organisational capabilities required for GTI through the development of a green culture amongst employees. Thus, the findings isolated positive relationships between GTL and the explanatory variables, including OGSC, R&DGIC, and OGMC as mediators of GTI. Out of these mediators, OGSC stands out to be the strongest suggesting that organizational processes need to be synergised with the sustainable goals for promoting green innovation. Also, the study finds that R&DGIC becomes central in directing leadership's effort into environment-friendly technological activities, and OGMC adds to the conversation by integrating green aspects in operations. These research findings show that sustainability- oriented innovation can be achieved through a range of transformational leadership processes. Summing up, it is possible to state that the aspects of green innovation performance can be improved by utilizing the transformational leadership in the field of strategic management, innovative research in the manufacturing sector, and implementing green management practices to gain and sustain competitive advantages and support the improvement on environmental sustainability.

Theoretical Implication

The implications of the current study present the following theoretical contributions for expanding the current literature

on GTL, sustainability, and innovation. First, the significant and positive correlation between GTL and Organizational Green Strategic Capability (OGSC) provides the theoretical validation of the contention that transformational leadership enhances green organizational goals alignment. This brings out how through GTL values of sustainability can be mainstreamed into the strategic management of organizations, which is in concordance with theoretical frameworks pointing towards the centrality of leadership in arising establishment of organizational strategy. Likewise, the substantial indirect relationship between OGSC and GTI enriches sustainability literature by affirming how strategic capability is an essential mediator through which leadership can be operationalized and made impactful in the innovative process more generally and for manufacturing particularly.

Second, the mediated relationships reveal the significance of R&D Green Innovation Capability (R&DGIC) stressing that GTL has a significant positive impact on the development of eco-innovation through research and development activities. This provides a rich elaboration of theories of innovation by connecting leadership behaviours to the generation of environmentally sustainable technology thus underlining dynamic capability theory on the centrality of innovation capabilities for sustaining competitive advantage in volatile contexts. Moreover, the link between GTL and Organizational Green Management (OGMC) supports the hypothesis that green operant transformational leadership determines green operational practices, thus enriching the green management literature and indicating the leadership pathways for implementing sustainability into actionable routines.

The Resource-Based View (RBV) is further supported by these relationships as the emergence of intangible organizational capabilities namely, OGSC, R&DGIC, and OGMC as valuable organisational resources that can help the organisation improve its sustainable innovative capability. Thus, integrating leadership and RBV theories the study shows how these capabilities moderate the GTL-GTI relationship and provides a methodological framework that links leadership behaviors to strategic, operational and innovation- oriented resources. They not only expand on current general theoretical assumptions but also bring into focus the multi- fold value of GTL within sustainability-oriented innovation.

Practical Implications

The study provides useful practical insights on the practical connections between sustainability performance and Green Technological Innovation (GTI) into the organization for organizations particularly in the manufacturing industry. Thus, the outcomes emphasize the need to promote Green Transformational Leadership (GTL) as a key enabler of change for sustainability and innovation. The leadership of each organization should enforce its human resource management policies to encourage development of transformational leadership indicators, including: a vision for change, generating commitment towards a green change, and creative solutions and innovation. In so doing, organisations can facilitate leaders in managing change for the uptake as well as implementation of sustainability technologies.

Second, the highly significant relationship between Organizational Green Strategic Capability (OGSC) and GTI provides a strong support for organizations to consider including sustainability into their strategic management frameworks. The senior management should therefore ensure that the long term business strategies are synchronized with the environmental goals by providing strategic and overall sustainability solutions, resources, and cooperation from various department. The integration plan is to build sustainability into strategic planning to guarantee that leadership initiatives produce tangible innovation results.

Third, the results highlight the mediating role of R&D Green Innovation Capability; thus, organisations should improve the R&D environment focused on developing green technologies. This can be done through providing funding for the EC-INNOV projects, introducing colleagues of the R & D departments with the other departments of the company, and using bonuses and other types of rewards for stimulating the use of sustainable innovations. In addition, the cross-functional and the external teaming with universities, research institutions, and green technology vendors can boost innovation.

Moreover, the positive influence of Organizational Green Management (OGMC) claim that organizations should work on sustainable operational practices, including minimizing waste, utilizing the resources and implementing green supply chain management. Other supporting initiatives include orientation of employees and managers to green practices in workplace and incorporation of sustainability KPIs into evaluation frameworks. Through these practices, it becomes possible both to achieve compliance with environmental requirements and to increase organizational productivity and competitiveness in conditions of a shift towards sustainable development. In a nutshell, it is evident from this study that leadership, strategy, R & D, and operation practices should be congruent in order to support long-term innovation.

Limitations and Future Recommendations

This study offers useful information to understand the moderating role of Green Transformational Leadership (GTL) on Green Technological Innovation (GTI) in Oman's manufacturing organizations; nonetheless, some shortcomings should be considered and future research implications are discussed below. First, the data collection targeted manufacturing sector in Oman, therefore, the findings may not be easily extendable to other sectors or another Oman region. Future research could extend to other industries, for example, service industries or the energy industries, and it may also compare countries, thus increasing generalizability. Moreover, cross-sectional study design used in the present study with 400 participants provides only a single point estimate of cross-sectional temporal relationships between GTL and GTI. Future research could use longitudinal designs in order to capture developmental trajectories of these relations. It also means that the data collected is subject to common method variance which can also be minimized in future work by use of multi-source data collection methods, for example, using a mixture of self-completed questionnaires and performance appraisals. Moreover, apart from OGSC, R&DGIC, and OGMC as the mediators, other factors such as the organization culture, obligatory/recalled regulation pressure, and market demand could also influence the outcome, and to identify these additional factors could give a more complete picture. Lastly, the study is him by adding by the culture and economy of Oman; there is potential for future studies to replicate this study in distinct cultures and institutions to determine how culture and institutions affect these relations. Overcoming such limitations would advance this theoretical and practical knowledge of GTL and its ability to consistently and systemically prompt sustainable innovation in industries and regions.

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