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The Hierarchy of Green Information Systems Capability in Organizations to Enhance and Ensure Green Performance: An Operant Resources Perspective

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The Hierarchy of Green Information Systems Capability in Organizations to Enhance and Ensure Green Performance: An Operant Resources Perspective

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Abstract:

Green information systems (green IS) have evolved and expanded over the years, now having a broad scope in organizations. Green IS in these organizations function to help to address climate change challenges. The growing complexity of green IS in organizations needs a conceptual framework that can articulate its different impacts at various levels while taking into consideration a holistic and integrated perspective. This research focuses on how to enhance and ensure green IS-driven green performance in organizations from an operant resources hierarchy perspective. A conceptual model is proposed to examine the role of management support for green initiatives and the role of information assurance in addressing IS misuse and process automation in relationship to green IS capability and green performance. The current study tests the effects of management support as composite operant resources and information assurance as interconnected operant resources for green IS capability in enhancing and ensuring organizations' green performance using a matched dataset of 73 organizations. We illustrate the application of the proposed conceptual model in two real-world scenarios. This study contributes theoretically by illustrating the application of the operant resources hierarchy perspective in green IS research and provides practical action suggestions for organizations adopting sustainable practices to achieve Sustainable Development Goal (SDG) 13.

Keywords: Green IS, Carbon Emission, Operant Resources, Management Support, Information Assurance, SDG.

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1 Introduction

Green information systems (green IS) is the discipline, area, or focus of information systems (IS) for environmental sustainability. The scope of green IS has evolved over time to include information technology-enabled affordances and functionalities rather than being merely considered a technology or system (Melville et al., 2017). Green IS emerged to be an integral part of organizations, helping improve sustainability performance (Kranz et al., 2022; Watson et al., 2021) while contributing to achieving several Sustainable Development Goals (SDGs) established by the United Nations for a future better world (United Nations, 2015a). Among the 17 SDGs, SDG 13 aims to take urgent action to combat climate change and its impacts. It highlights the importance of reducing greenhouse gas (GHG) emissions, strengthening resilience and adaptive capacity to climate-related hazards, integrating climate change measures into policies and planning, and increasing education and awareness on climate change mitigation and adaptation (United Nations, 2015b, Goal 13). Green IS has become essential for organizations that aim to achieve SDG 13.

Green IS can help organizations and communities work towards SDG 13 by providing the information and tools they need to make sustainable decisions, reduce their environmental impact, and contribute to a more sustainable future. Green IS helps organizations meet the demands of environmental regulations and reporting requirements. The regulatory requirements are being mandated by governments, in which green IS helps ensure compliance with these regulations by providing accurate and timely data on environmental performance, emissions, and waste. Environmental responsibility is becoming increasingly important in building and maintaining a positive reputation. Organizations can enhance their reputation and improve stakeholder trust by demonstrating a commitment to sustainability and environmental responsibility through green IS. Furthermore, green IS can help organizations identify new opportunities for innovation and growth. For example, organizations can create new sources of value and competitive advantage by developing new products or services that are more sustainable or using green IS to optimize supply chains.

Overall, the scope of green IS is extended beyond technology to include performance, compliance, and reputation. Against these developments, current IS research is catching up with broadening prospectives and overarching theoretical frameworks to explain the beyond-technological integrated artifact perspectives. Considering green IS as a single artifact or implementation instance, for example, saying that a green IS standard is implemented in an organization, limits and challenges the broader evolutionary scope of green IS in organizations. In other words, green IS has been integrated at different levels in organizations for value creation through an interactive way across these levels. This integration implies that the perspective of green IS performance needs a more holistic explanation while highlighting the underlying levels and interactions. This paper proposes and validates a green IS operant resources hierarchy perspective with empirical support to extend current IS research.

Constantin and Lusch (1994) proposed the concept of operant resources as resources that produce impacts and outcomes on other resources. They considered that operant resources are typically intangible, while the opposite of operant resources, that is, operand resources, are primarily tangible and static resources such as hardware. A study by Teece (2014) categorized enterprise capabilities as ordinary and dynamic capabilities from the strategic management and competitive advantage perspectives. The relationship between these two types of capability is analogous to the operand and operant resources. However, Teece (2014) does not consider the orchestration of resources but keeps the focus on the earlier resource-based view (RBV) to explain the relationship between IT and the competitive advantage of a firm. Other researchers study IT capability and firm performance by considering the VRIN (i.e., valuable, rare, imperfectly imitable, and non-substitutable) resources (Bharadwaj, 2000).

In this study, we theorize green IS capabilities as operant resources and to gain value from green IS organizations need to deploy and integrate green IS effectively and leverage different levels of resources toward performance development. More specifically, the performance investigated is of environmental (i.e., green performance) rather than of economic value. Our study aims to answer the following research question:

> **RQ: How to enhance and ensure the green IS-driven green performance in organizations from the operant resources hierarchy perspective?**

Green performance refers to an organization's ability to operate sustainably and reduce its environmental impact and it measures how well an organization is performing in terms of sustainability and how effectively it is managing its environmental impact. Green performance can be measured in many ways, such as by reducing carbon emissions, water usage, or waste generation. Prior research suggested that environmental metrics, such as CO2 equivalent, can be used to evaluate the impact of green IS on environmental performance (Melville, 2010). In this paper, we used the reduction of carbon emissions to measure green performance.

The motivation for applying an operant resources hierarchy perspective to green IS is multifold. First, operant resources are actively managed and used to achieve organizational goals. Operant capability is a dynamic capability that involves actively managing resources to achieve organizational goals (Teece, 2014). Green IS are not just passive inputs but actively used and leveraged by organizations to achieve sustainability goals—thus, qualifying for the operant perspective. Green IS requires ongoing management and monitoring to ensure they are used effectively and contribute to sustainability goals (Melville et al., 2017). This may involve updating systems, collecting data, analyzing results, and changing operations based on the information obtained. The active management process uses green IS to monitor and measure environmental indicators and performance, such as energy and water usage, waste production, and greenhouse gas emissions (Melville, 2010). This information can be used to identify areas for improvement and set sustainability targets. Second, green IS uses knowledge and skills related to sustainability issues, environmental management, and information technology (Watson et al., 2010; Elliot, 2011). Organizations with these skills and capabilities are better equipped to leverage green IS to achieve sustainability goals through informed decisions about sustainability (Melville, 2017). For example, life-cycle analysis tools can assess the environmental impact of products and services, while carbon accounting tools can measure and report greenhouse gas emissions (Corbett, 2013). Third, green IS provides organizations with real-time data and insights into their environmental performance, allowing them to identify areas for improvement and make changes to operations as needed (Butler, 2011). Such continuous improvement can then be used to promote sustainable practices, such as recycling and energy conservation, among employees and other stakeholders. Thus, green IS can be viewed through the operant perspective because of relevant active management, knowledge and skills, support for sustainable practices, and continuous improvement. Organizations that have developed this capability are better equipped to leverage green IS to achieve their sustainability goals and drive long-term value.

Furthermore, realizing the benefits through the perspective of considering green IS as an operant resource or capability also involves articulating these different benefits in a hierarchical order, as the basis for operant perspective suggests operant resources or capabilities to be activating and orchestrating a set of operand resources or capabilities, which can then work on each other to create value — as identified and suggested in prior research. For instance, Madhavaram and Hunt (2008) proposed a three-level hierarchy: basic, composite, and interconnected operant resources. Such hierarchy has been used as a theoretical lens in the supply chain relevant research (Chandler & Vargo 2011). However, very little research has employed operant hierarchy perspectives in the IS domain. In a study on cloud computing by Kathuria et al. (2018), the authors draw on the perspective of operant resources hierarchy to examine cloud operant resource development.

In this paper, arguments and hypotheses are presented from the hierarchy of operant resources perspectives. First, by analyzing the green IS currently on the market and applied in firms, we explore the green IS capabilities closely at different organizational levels that focus on specific environmental areas, including carbon, waste recycling, energy, and compliance. Second, one common observation from the literature is the importance of top management support in achieving environmental sustainability (e.g., Huang et al., 2020; Rahim & Rahman, 2013). Therefore, the conceptual model considers the composite effects of top management support and green IS capability on environmental sustainability. We only focused on and used the top management team's management support for green initiatives instead of other organizational initiatives (e.g., DEI initiatives). Finally, we investigate the ensuring role of information assurance, considering process automation and IS misuse (Dube & Gulati, 2005) caused by green IS capability from the interconnected operant resources perspective. We examine information assurance as a mechanism to ensure green performance in organizations by addressing the potential process automation and IS misuse issues.

We collected data from multiple sources and analyzed data using econometric models to test the hypotheses empirically. Additional analysis is conducted to test the estimation robustness and to get a more nuanced understanding of the estimations. The key findings of this research are: (1) with more green IS capabilities, organizations can gain better green performance, (2) along with the green IS capability, the presence of top management support for green initiatives can enhance organizations' green performance; and (3) by addressing the process automation and IS misuse issues due to usage of green IS information assurance can ensure organizations' green performance.

In the discussions, we validated the findings by applying the conceptual model to two hypothetical companies: GreenTech and EcoBank. We aim to illustrate how the green IS for green performance approaches through the hierarchical capabilities orchestration process works in real-world scenarios. GreenTech is a hypothetical mid-sized manufacturing company with sustainable and eco-friendly production practices. It has a strong commitment to sustainability and management support and information assurance has improved its green performance. EcoBank is a hypothetical global financial institution with a solid commitment to sustainability. It could address the challenges of process automation and IS misuse through effective information assurance, demonstrating the importance of green IS capabilities and information assurance in achieving sustainability and operational efficiency. We illustrate these two scenarios in the discussion section. We also elucidate some concepts linked to these two scenarios in the other parts of the paper.

The findings of this paper derive insights to contribute to the literature on green IS and operant resource perspectives. It offers a fresh perspective on green IS research by using operant resources perspectives to understand the mechanism of green IS to improve and ensure organizations' environmental sustainability. It also complements extant research by applying the composite and interconnected operant resources theory to the IS area. By analyzing the green IS currently used by organizations, this empirical study also provides practical implications for organizations to achieve better green performance with green IS investment. In turn, reducing GHG emissions in organizations will contribute to the climate action proposed in SDG 13.

2 Literature Review and Theory Development

2.1 Information Systems Resources and Capability

There are extensive discussions around IS resources and capabilities in literature. The firm's resource-based view (RBV) is used to explain the relationship between IT and the competitive advantage of a firm as well as IT capability and performance (Bharadwaj, 2000). RBV argues that firms possess competencies, skills, and strategic assets to achieve competitive advantage and long-term performance (Wade & Hulland, 2004). Based on the RBV of the firm, researchers have proposed the integrative model of IT business value and studied factors that may affect the value of IT, such as complementary organizational resources of the firm (Melville et al., 2004). Researchers also discussed IS business value by discussing IS capabilities (Schryen, 2013). Strategy is one resource type, and the decision between shared resources and nonshared resources also affects a firm's competitive advantage (Oestreicher-Singer & Zalmanson, 2012). In the IS domain, IT capability is considered a critical resource for firms to achieve competitive advantage and improve performance, such as firm profitability and service management performance (Bhatt & Grover, 2005; Mithas et al., 2012; Ray et al., 2005).

Prior literature has investigated different types of IT/IS capabilities, such as IT infrastructure, IT business partnerships, business-IT strategic thinking, IT business process integration, IT management, external IT linkage (Chen et al., 2014), strategic IT alignment (Tallon & Pinsonneault, 2011), IT infrastructure capability, IT business spanning, IT proactive stance (Lu & Ramamurthy, 2011), IT infrastructure quality, IT business expertise (Bhatt & Grover, 2005), technical IT skills, generic technologies, IT spending, flexible IT infrastructure (Ray et al., 2005) and other factors. Studies also show the changing role of resources from operational inputs to facilitators and organizational capabilities (Olavarrieta & Ellinger, 1997). While reviewing the literature, we found a strong connection between the concept of resources and organizational capabilities (competencies). The latter is a high-level routine or collection of routines (Winter, 2003) and interconnected combinations of tangible and intangible resources (Hunt, 2000).

Green IS are not simple information technologies but IT-enabled affordances and functionality for environmental sustainability (Melville et al. 2017). Green IS enables companies to reduce environmental impacts. There are four types of green IS strategic perspectives: green IS for efficiency, green IS for innovation, green IS for transformation, and green IS for credibility (Loeser, 2017). Table 1 summarizes prior discussions from the literature on green dynamic capability (Zhang et al., 2020; Qiu et al., 2020; Amaranti et al., 2019; Dangelico et al., 2017), green innovation capability (Ardyan et al., 2017; Liao, 2017;

Xu & Zhai, 2020; Huang et al., 2020; Mellett et al., 2018), green IT capability (Rahim & Rahman, 2013; Cooper & Molla, 2017; Putri et al., 2014), and green IS capability (Howard et al., 2014).

Table 1. Relevant Themes on Green Capabilities in Prior Literature

Theme	Details	Reference
Green dynamic capability	Environmental sensing capability, resource seizing capability, resource reconfiguring capability	Zhang et al. (2020)
	Resource integration capability, resource reconfiguration capability, environmental insight capability.	Qiu et al. (2020)
	Sensing, seizing, reconfiguring; Absorptive capacity; potential: acquisition, assimilation; realized: transformation, application	Amaranti et al. (2019)
	External resource integration, internal resource integration, resource building and reconfiguration	Dangelico et al. (2017)
Green innovation capability	Green innovation capability as the driver of sustainable competitive advantages and marketing performance	Ardyan et al. (2017)
	Correlations among environmental education, environment-friendly product development, and green innovation capability in an enterprise	Liao (2017)
	Evaluation of green innovation capability of manufacturing enterprises in the innovation network	Xu & Zhai (2020)
	Impact of startups' dual learning on their green innovation capability: the effects of business executives' environmental awareness and environmental regulations	Huang et al. (2020)
	Network-facilitated green innovation capability development in micro-firms	Mellett et al. (2018)
Green IT capability	IS resources: top management, knowledge acquisition; IS capabilities: collaborative, IT business experience; green IT capability/ green IT process; management capability: The ability to deploy energy-efficient and environmentally sustainable IT process	Rahim & Rahman (2013)
	Green IT: attitude; policy & governance; practice& technology; G-readiness, green IT absorptive capacity; knowledge: acquisition and assimilation; transformation; exploitation	Cooper & Molla (2017)
	Green IT capability maturity level: initial, basic, intermediate, advanced, optimizing	Putri et al. (2014)
Green IS capabilities	Environmental data management, environmental analysis, environmental information disclosure, carbon footprint management, environmental risk management	Howard et al. (2014)

Based on the literature review, very few studies in IS research have discussed the capabilities from the hierarchy of operant resources perspective. Prior research suggests that green IS should be viewed from an integrated perspective in an organization that can be actively managed and used to achieve organizational goals. The capabilities perspectives reflect the concept that green IS are not just passive inputs but actively used and leveraged by organizations to achieve sustainability goals, thus there is a need to effectively use knowledge and skills related to sustainability issues, environmental management, and information technology (Melville, 2017). Organizations that have developed this capability are better equipped to leverage green IS to achieve their sustainability goals and drive long-term value. The concept of green IS as an operant resource and capability follows the overarching indication in prior research that green IS needs to be articulated as an operant hierarchical resource in organizations, with benefits stemming from the activating and orchestrating to create value for the organization (Madhavaram & Hunt, 2008). We follow this motivation from the prior research to suggest the hierarchy of operant resources perspective for green IS.

2.2 Hierarchy of Operant Resources

Constantin and Lusch (1994) proposed the concept of operant resources as resources that produce impacts and outcomes on other resources. Madhavaram and Hunt (2008) proposed a hierarchy of operant resources with three levels: basic operant resources, composite operant resources, and interconnected operant resources.

Basic operant resources are “the underlying, lower-level resources that form the building blocks of higher-order, operant resources.” Composite operant resources are “a combination of two or more distinct, basic resources, with low levels of interactivity that collectively enable the firm to produce efficiently and/or effectively valued market offerings." Interconnected operant resources are "a combination of two or more distinct, basic resources in which the lower order resources significantly interact, thereby reinforcing each other in enabling the firm to produce efficiently and/or effectively valued market offerings." The hierarchy proposed by Madhavaram and Hunt (2008) provides a new way to examine the orchestration of operant resources. This operant resource hierarchy has been used as an established theoretical lens in supply chain-related research (e.g., Chandler & Vargo, 2011) and other areas.

Very little research has employed this hierarchy of operant resources in the IS domain. In a study on cloud computing by Kathuria et al. (2018), the authors draw on the perspective of operant resources hierarchy to examine cloud operant resource development. Extending the prior research, we propose a three-level hierarchy of green IS capabilities in organizations for the conceptual model used in the current study.

2.3 Hierarchy of Operant Resources for Green Performance

Extant research has mainly focused on establishing the value of green IS, dealing with it as a standalone concept. The concept of complementarity with other resources and assurance of the capabilities to create value remains a sparse area of investigation. We articulate this complementarity and assurance aspect using a broad three-level process that can improve the performance effects of green IS (see Table 2).

Table 2. Three Levels of Green IS Capabilities and A Hierarchy of Operant Resources for Green Performance

Levels and Hierarchy	Level 1: Green IS Capability (Basic)	Level 2: Green IS Capability Complementarity through Management Support (Composite)	Level 3: Green IS Capability Assurance through Information Assurance (Interconnected)
Goals	Have functionality of green IS	Enhance the functionality of green IS	Ensure the functionality of green IS
Focus	The technological competence of green IS	Additional resources to increase green IS capability	Feedback to improve green IS capability
Conceptualization	Using IT/IS to improve environmental sustainability (green performance)	Support for environmental sustainability management	Independent professional assurance services that improve the quality of information from green IS
Characteristics	Can be acquired through the use of IT/IS	Green IS can create greater value with its presence	Reinforce green IS capability
Outcomes	Green performance	Enhanced green performance	Ensured green performance

In the multi-level conceptualization, the first level is the green IS capability, including green IS functionalities. General technology is primarily considered material artifacts (Orlikowski, 1992). Researchers in the IS domain distinguish IT as IT capabilities and IT assets. IT capabilities have been viewed as competencies and practices (Aral & Weill, 2007) or IT investment and management practices (Benitez-Amado & Walczuch, 2012). More specifically, for enterprise information systems, researchers considered the physical scope, such as value chain modules and enterprise support modules, as IS capabilities, whereas the functional scope, such as HR and finance, as IS resources (Ranganathan & Brown, 2006; Rush et al., 2015). Researchers also suggested Enterprise Resource Planning (ERP) functional scope as a component of ERP capabilities (Karimi et al., 2007). Green IS has a broad functional area at the three managerial decision levels, including engineering and design, procurement, manufacturing and production, sales and marketing, logistics, finance, accounting, and human resources (Sarkis et al., 2013).

The realm of green IS functionalities has extended from the common conception of "information technology tools and technologies" aspects only to include the views of the system involving the organization. For example, studies have considered information to support decision-making, direct IT assets and infrastructure, sustainable products and services, collaboration, and similar organization-wide intangible aspects (Corbett, 2018; Nishant et al., 2017). Except for the "direct IT assets and infrastructure" belonging to green IT, the other three groups are all about IT-enabled functions and capabilities for sustainability. For example, a greenhouse gas monitoring system must be embedded in a chimney or furnace at an appropriate place to monitor the emission. However, just having the monitoring device is not enough. It should be installed, connected to a computer, benchmarked, and have action taken in order to have adequate emission controls for a green impact. The latter is a decision support mechanism that acts as a monitoring tool to influence performance. Besides the decision-making support systems, collaboration systems, and sustainable products and services, some other green IS include knowledge management systems for pollution prevention and remediation and decision support systems that systemize cost-benefit analyses and improve environmental risk management (Melville, 2010). These information systems can collect and analyze energy datasets from sensors, technology-enabled data, and environmental knowledge repositories (Watson et al., 2010; Elliot, 2011). IT-based systems can manage environmental compliance and related organizational risks, support sense and decision-making, and create knowledge about environmental sustainability (Butler, 2011). Prior research notes that some of these may extend to generic and customizable organization-wide systems, with different capabilities involving data storage, validation, analytics, and reporting that help decision-making (Melville et al., 2017). This aspect of green IS is consistent with the green IS for efficiency and innovation in the aforementioned four green IS strategic perspectives.

Although the scope of green IS extends beyond tools and applications to systems approaches, a lack of integration with other existing systems may lead to challenges, illustrated in Table 2 as the second-level integration process. As explored in existing research, this integration follows a hierarchical approach, that a composite of two or more distinct operant resources can collectively increase the efficiency and effectiveness of an organization (Madhavaram & Hunt, 2008). The linkage would be the alignment and complementarity of green IS capability and other organizational factors. For example, managers' attitude toward green IS and considering future consequences can influence its implementation for environmental performance, such as pollution prevention (Gholami et al., 2013). From the operant resources perspective, complementarity occurs when operant resources produce more value in the presence of another resource (Karimi et al., 2013). Management support is considered a resource that should come along with organizations' green IS capabilities (Beitelspacher et al., 2012). Effective green IS governance and management that allocates IS decision rights to align with strategic objectives also indicates that management support can decide the outcome of using green IS (Sarkis et al., 2013). Top management support for green initiatives involves allocating complementary resources and capabilities to perform the actions. It also requires integration with other existing capabilities (i.e., green dynamic capability in Table 1).

The third aspect of the relationship between green IS and performance is the effectiveness of green IS, which measures the system's quality and can fulfill the system's functions (Hamilton & Chervany, 1981). One approach to achieving IS effectiveness is quality assurance, an "independent professional service that improves the quality of information" (Dube & Gulati, 2005). Therefore, usually, the assurance service is provided by a third party. A critical component of information assurance is integrity, meaning a system should ensure the completeness and accuracy of the information (Cherdantseva & Hilton, 2013). According to the hierarchy of operant resources perspective, the interconnected operant resources (i.e., two or more operant resources interacting and reinforcing each other) enable an organization's effectiveness and efficiency (Madhavaram & Hunt, 2008). With feedback from information assurance, green IS capability assurance can further improve green IS capability and ensure green IS functionalities, thus, it is critical for the credibility of the green IS strategic perspective (Loeser, 2017).

Based on the three levels of green IS capabilities and following the hierarchy of operant resources, we develop a hierarchy of operant resources for green performance, as shown in Table 2. First, green IS capability is a basic operant resource, which refers to using IT/IS to improve green performance. This is level one of green IS capability. Second, with green support, which means the management support for environmental sustainability management, there is complementarity with the basic green IS capability. In turn, it will enhance the green performance by enhancing the functionality of green IS. This is level two of green IS capability; thus, green support that combines support and green IS capability is a composite operant resource. Third, green information assurance refers to the independent professional assurance services that improve the quality of information from green IS, which means the assurance of green IS capability (i.e., level three of green IS capability). Green information assurance combines assurance and green IS capability. The key difference between green support and information assurance is that the latter has feedback, a significant interaction in reinforcing green IS capability, instead of the simple collective interaction. Therefore, information assurance is an interconnected operant resource that can ensure green performance.

3 Hypotheses Development

Following prior research, we define the green IS capability as the IT-enabled organizational capability to achieve environmental sustainability from the operant resources perspective. The specific environmental focus of green IS is used as a proxy for green IS capability following prior research (Rush et al., 2015) and top management support in environmental sustainability management as green support (Huang et al., 2020). Information assurance refers to the third-party assurance of environmental sustainability-related information (Dube & Gulati, 2005). Instead of financial performance, the focus is on green performance, defined as the carbon emission generated by an organization (Melville, 2010). We propose three hypotheses corresponding to the operant resource hierarchy for green performance (see Table 2). The first hypothesis suggests the direct relationship between green IS capability and green performance considering green IS capability as one basic operant resources perspective. The second hypothesis examines the impacts of green IS capability on green performance with the presence of green support from the composite operant resources perspective. The third set of two hypotheses suggests the ensuring role of information assurance on green performance by addressing the potential process automation and IS misuse issues by green IS capability.

Following the operant resources perspective, we view the use of green IS as a means by which organizations can develop environmental sustainability management capabilities that enable them to collect, manage, and analyze environmental data and information, including carbon footprint, waste recycling, energy consumption, compliance, and risk (Howard et al., 2014). First, green IS capability enables an organization to use IT to improve its environmental sensing, resource seizing, and reconfiguring abilities (Amaranti et al., 2019). It automates acquiring and assimilating environmental data and information (Cooper & Molla, 2017). For example, green IS can eliminate manual environmental data entry and validation. Cross-functional cooperation for environmental improvements becomes easier (Benitez-Amado & Walczuch, 2012). For instance, with the unified green IS platform, different units of an organization can record and submit environmental data and information quickly. Organizations can track their business workflows at a single location through such automation and coordination and understand how to standardize processes and workflows, reduce waste and consumption, and attain environmental compliance. As a result, the organization can align its processes, people, and products to improve green performance.

Second, the physical implementation scope of green IS is the level of green IS capability (Rush et al., 2015). In other words, the more environmental concentrations the deployment of green IS has, the higher the green IS capability of an organization. The environmental focus regarding carbon emission includes carbon, energy, waste, compliance, and sub-components of green IS (Molla et al., 2009). A waste recycling-focused green IS can only reduce carbon emissions through materials management. An energy consumption-focused green IS only cares about the automation control and management of PC power; a compliance-focused green IS only delivers intelligent compliance solutions; a carbon-focused green IS is only about carbon measurement.

In contrast to each type of green IS with a single environmental focus, a comprehensive green IS has higher green IS capability, and it can lead to more reduction in carbon emission due to increased capital and greater synergy (Chuang & Huang, 2018; Nevo & Wade, 2010). A comprehensive green IS can collect and consolidate all types of environmental data to provide a complete picture and allow for a holistic solution to reduce carbon emissions significantly (Giljum et al., 2011). In addition, if more comprehensive green IS are applied, an organization can consolidate the unique features of different green IS to build even more substantial green IS capability, thus reducing carbon emissions.

Third, building a higher level of green IS capabilities reflects an organization's time, investment, and commitment to spending on environmental sustainability matters (Madhavaram & Hunt, 2008). Achieving good green performance without such commitments is difficult or even impossible. Prior literature has shown a positive association between sustainability commitment and carbon emission reduction (Rush et al., 2015), suggesting organizations can improve their environmentally sustainable performance with a higher level of green IS capability. Therefore:

Hypothesis 1: There is a positive association between green IS capability and green performance.

Composite operant resources highlight the complementarity of resources, which indicates that one resource can produce more excellent value in the presence of another (Karimi et al., 2013). We focus on the composition of green IS capability and green support, which indicates the level of support from top management regarding environmental sustainability (Huang et al., 2020). Given the importance of green IS capability, we argue it is necessary for green performance. However, to achieve outstanding green performance, green IS capability is insufficient; top management support of environmental sustainability is likely to enhance the green performance of an organization.

Prior literature has shown the importance of top management support as a driver of better outcomes in product development (Wren et al., 2000), project success (Young & Jordan, 2008), customer relations (King & Burgess, 2008), and supply chain management (Zhu et al., 2008). With green support from top management, the organization can have a clear vision to plan and direct the use of green IS capability. Environmental management will not succeed if top management's green support is missing. This type of support is a critical operant resource for organizations as management operates financial and personnel resources for efficient and effective use of green IS capabilities (Thong et al., 1996). Such support also has a critical role in the promotion of new values. The more top management supports the goals of value-creation processes focused on environmental sustainability, the more successful the green performance is (Huang et al., 2020; Rahim & Rahman, 2013). Top management support for environmental sustainability indicates to what extent the top managers are committed to environmental strategy (Banerjee et al., 2003). In other words, with the green support signal shared through the organizational routine, the overall business workflow in an organization can receive that message and react accordingly.

In addition, from the organizational culture perspective, both awareness and practices of environmental sustainability are essential to motivate employees' utilization of green IS capabilities through their skills and knowledge (Beitelspacher et al., 2012), and such organizational cultures can be reinforced by top management support (Daily & Huang, 2001). Strong green support from the top management results in more communications about the importance of green IS. These communications can improve green IS deployment at the firm level and promote green IS-facilitated carbon emission reduction (Graves et al., 2019). Top management support is critical in utilizing these operant resources, such as green IS capability. The more vital the role of top management for environmental sustainability is, the more likely these resources will be utilized appropriately. To summarize, the importance of green support from top management cannot be underestimated, thus:

Hypothesis 2: The relationship between green IS capability and green performance is improved with green support.

Interconnected operant resources consist of complex combinations of a firm's operant resources, requiring some form of synergistic or interactive effects (Adams et al., 2014) or the orchestration of operant resources (Teece, 2014). We focus on the orchestration of green IS capability and information assurance, which refers to the independent assurance service provided by a third party to ensure the completeness and accuracy of environmental sustainability-related information (Dube & Gulati, 2005; Cherdantseva & Hilton, 2013). Organizations need to ensure the effectiveness of green IS to achieve environmental sustainability or improved green performance. Especially in terms of technological resources in the system-resource view, the effectiveness of green IS is indicated by the system quality and can fulfill the system's functions (Hamilton & Chervany, 1981).

One benefit of green IS is process automation. However, automated systems are not always reliable. There may be errors in the information generated through an automated green IS, such as incomplete and inaccurate information. Humans must engage in error detection and correction as a part of information assurance (McBride et al., 2014). In other words, information assurance can address the potential errors caused by process automation due to the increased green IS capability. In this process, such interaction between process automation and information assurance can reinforce green performance with feedback from information assurance.

To illustrate, GreenTech and EcoBank examples discussed later in this study demonstrated these features. GreenTech's hierarchy of operant resources in achieving improved green performance, including the implementation of green IS, support by the management team, and information assurance measures to ensure the system's integrity. Similarly, EcoBank's partnerships with third-party service providers enabled it to monitor and analyze its carbon emission data and identify discrepancies or anomalies, thereby ensuring its carbon emission data's accuracy and reliability and identifying new opportunities for carbon reduction and sustainability initiatives.

Furthermore, previous literature on sustainability reports has recognized the positive impact of implementing proper control mechanisms for monitoring and improving data measurement systems through the independent assurance of the quality of sustainability information (Briem & Wald, 2018). Researchers also revealed that third-party assurance could provide guidance and feedback on developing efficient internal systems (Park & Brorson, 2005). Similarly, information assurance can also increase the quality and effectiveness of green IS, leading to better environmental sustainability. Therefore, we hypothesize that:

Hypothesis 3a: Information assurance can ensure green performance by addressing the process automation issue caused by green IS capability.

Green IS capability may lead to some challenges related to green IS misuse. Misuse refers to the sequence of actions that any person or entity can perform to harm the system, a potential behavior or function that the system should not have, a mismatch between goals, and a sequence of actions that results in a loss (relevant to sustainability) for the organization—similar to any IS use contexts (Sindre & Opdahl, 2005). Intentions such as providing a public image through misuse to report better outcomes (Dube & Gulati, 2005; Marquis et al., 2016), misleading top management, biased ways to use and benefit from the standards (Gao et al., 2014), and naively following a standard without fully understanding its reasons or making any effort to improve or optimize the process (Ning et al., 2019) may be some of the reasons for green IS misuse. However, beyond these mal intentions, users' attempts to apply an unfamiliar standard via their IS assets may lead to misuse, as there would be a gap in expertise between the company's employees who are not sustainability-oriented and the requirement to learn new standards (Adams et al., 2016).

Information assurance can ensure green performance by increasing awareness and providing avenues for user training and learning. For instance, the American Institute of Certified Public Accountants (AICPA) suggests that independent professional service providers conduct IS assurance to improve information quality (Dube & Gulati, 2005). It underscores the importance of independent service providers as they can provide unbiased assurance. The providers of information assurance are certified experts. Information assurance creates the process and environment for the experts to interact with the non-expert users. Auditing is also part of this process, which suggests a corrective guidance and training process (Simon et al., 2011). These interactions and corrective guidance enable the non-experts to learn and use the system. For instance, the EcoBank example illustrated later in this paper showcases the idea of using third-party services to work with employees and partners to ensure its green performance by addressing the challenges of process automation and IS misuse through effective information assurance.

Green IS capability cannot improve an organization's green performance with misuse of IS. Green IS can only function more reliably to provide unbiased information, optimize usage by non-expert users, and achieve actual green performance when independent information assurance is used. Through the interactive effects of correcting the potential misuse of IS, information assurance can ensure green performance by fully leveraging the green IS capability. Thus, we hypothesize that:

Hypothesis 3b: Information assurance can ensure green performance by addressing the IS misuse issue caused by green IS capability.

4 Research Methodology

We used a matched dataset from multiple sources to empirically test the hypotheses. A cross-sectional ordinary least square (OLS) regression model is applied for the estimation.

4.1 Data

The population of organizations considered for our analyses are North American organizations that use IS for sustainability. Secondary data were collected from multiple sources, and a matched dataset was used to test the hypotheses. First, the green IS data were collected from the Computer Intelligence (CI) Technology database. This database is a source that provides insight into the installed IT of organizations. It contains company profile information and "annual spending/expenditure on information technology and telecommunications, and counts on installed technology including computer hardware, software, networks, storage and telecommunications, information technology staff/employee counts." The database covers 150,000 North American companies, 80% from the United States and 20% from Canada. We searched for the keyword GEPRG (i.e., green program), and the result showed that 1,345 organizations (local level) were using green IS in 2017. In addition, we collected enterprise-level data, such as IT employees, IT budgets on hardware, software, and service, and the number of desktop and laptop PCs, which is used to indicate the level of process automation, from this database.

Second, green support, information assurance, IS misuse, and green performance data were collected from the CDP (carbon disclosure project) database. CDP is a non-profit initiative that has conducted an annual survey on firms' carbon emission-related risks and strategies since 2003 (Matisoff et al., 2013). The survey includes four main parts: climate change-related risks and opportunities, emission calculation and verification, performance, and governance (Guenther et al., 2016). Furthermore, the amount of carbon emissions is directly requested, including the different scope and total emissions. The data was collected from the surveys conducted in 2017 (green support, information assurance, and IS misuse) and 2018 (carbon emission).

Third, Compustat is a widely used database that contains financial information about global companies. We extracted relevant financial information, such as firm size and industry of the sample firms, to control other factors that may influence green performance.

4.2 Variables

The dependent variable for the models used in the current study is green performance, which is measured by the negative value of the amount of carbon emissions (CO2 equivalent) in scopes 1 and 2. Scope 1 covers direct emissions from owned or controlled sources, while Scope 2 covers indirect emissions from the generation of purchased electricity, steam, heating, and cooling consumed by the reporting company. Other key variables are green IS capability, green support (i.e., top management support for environmental sustainability), information assurance, IS misuse (i.e., cherry-picking carbon emission standards), and process automation.

According to the CI Technology database, companies use 12 distinct and different types of systems to manage environmental sustainability (see Table 3). Some systems are comprehensive, while others only have one environmental focus (e.g., carbon, waste recycling, energy, compliance). Regarding the application, some companies use only one type, while others use multiple (up to five) systems.

Table 3. Organizational use of Different Types of Green IS as per the CI Database

	Green IS	Description	Environmental-focus
1	SAP Sustainability	The SAP Sustainability Performance Management deals with the measurement, management, and disclosure of organizational performance toward the goal of sustainable development. The first time we have a solution that allows companies to manage their entire sustainability performance holistically.	Overall
2	Enablon	A system that provides companies with an extensive, reliable, and highly popular Sustainability, EHS, and Operational Risk Management Software, cloud-based.	Overall
3	SAP Carbon Impact	A carbon measurement solution that connects with an organization's backend SAP systems provides end-to-end measurement and dashboarding capabilities of a business's carbon impact.	Carbon
4	SAP Recycling Administration	The Recycling Administration (REA) component focuses on the item-based or weight-based fee calculation for specific materials, and end-to-end transparency and implementation of the legal reporting requirements to environmental authorities.	Waste Recycling
5	ProcessMAP	A cloud-based environmental health safety (EHS) solution that also offers risk and compliance management.	Overall
6	3E Company/ Verisk 3E	Intelligent compliance solutions empower companies to reduce risk, drive continuous improvement, and create new growth opportunities.	Compliance
7	Medgate/Cority	A web-based/cloud-based software solution fully stacked with features to enhance workplace environmental, safety, and health standards. A comprehensive, modular, and enterprise-grade EHS and Quality Management software.	Overall

8	Enviance	A cloud-based environmental, health, safety, and sustainability (EHS) solution that enables businesses of all sizes to manage and track compliance requirements, employee well-being, emission inventory, and more.	Overall
9	Gensuite	Cloud-based software solutions can track their environmental impact, look after the health of their employees and manage the safety status of equipment and other important assets.	Overall
10	Verdiem	Enterprise-class PC Power Management software.	Energy
11	SiteHawk	Safety Data Sheets (SDS) and chemical data management solutions; Cloud-based Technology; cloud software and services deliver a complete approach to chemical data management, providing data, intelligence, and reporting to support safety, compliance, and risk management.	Overall
12	Verisae	Cloud-based solution that helps large retailers automate their maintenance, energy, field service, and remote monitoring programs.	Overall

We calculated the total weight of green IS based on its environmental focus (overall=1, partial=0.25) using a similar approach in prior research (Rush et al., 2015). More details about this coded variable and relevant sensitivity analysis are provided in Appendix A. This total weight is used as the proxy to measure an organization's green IS capability.

In the CDP survey, questions like "Where is the highest level of direct responsibility for climate change within your organization?" were asked to understand the top management's support for environmental sustainability. We coded the answer to this question to measure the green support variable (1=other manager/officer, 2= senior manager/officer, 3=board member or individual from the board). The CDP survey also asks to indicate the assurance status of the carbon emissions. The answer to this question was coded to measure the information assurance variable (1=third party assurance process in place, 0=No third-party assurance). Another question in the CDP survey is about the adoption of carbon emission standards by organizations. We use the answer to this question to proxy the variable of IS misuse (1=use standard to collect activity data and calculate emissions, 0=no use of such standard). The rationale is that cherry-picking carbon emission standards indicate the misuse of IS.

As mentioned earlier, we considered several control variables. IT/IS employee is measured by the number of IT or IS-related employees in an organization. The percentage of the hardware budget is calculated as the ratio of the hardware budget to the total IT budget; the percentage of the software budget is calculated as the ratio of the software budget to the entire IT budget; the percentage of the service budget is calculated as the ratio of service budget to total IT budget. Firm size is measured by an organization's total number of employees. The SIC code distinguishes the industry of a firm. The variables are listed in Table 4.

Table 4. Variables Table

Variables	Measurement	Source
	Dependent Variable	
Green Performance (GP)	The negative value of the amount of carbon emission (CO2e).	CDP, 2018
	Independent Variables	
Green IS Capability (GISC)	The capability to use IS for environmental sustainability. Coding: Environmental focus (overall=1, partial=0.25)	CI Tech, 2017
Green Support (GS)	The level of management support for environmental sustainability. Coding: 1=other manager/officer, 2= senior manager/officer, 3=board or individuals from the board	CDP, 2017
Information Assurance (IA)	The involvement of third-party assurance for carbon emissions information. Coding: 1=has third party assurance, 0=no third-party assurance	
IS Misuse (IM)	The proxy of this variable is the simple adoption of carbon emission standards. Coding: 1=use standard to collect activity data and calculate emissions, 0=no use of such standard	

Process Automation (PA)	The level of use of technology to automate manual processes. This variable is measured by the number of desktop and laptop PCs in one organization.	CI Tech, 2017
Control Variables		
IT/IS employee (ITE)	The number of IT or IS-related employees	CI Tech, 2017
% of hardware budget (Hard)	The ratio of hardware budget to total IT budget	
% of software budget (Soft)	The ratio of software budget to total IT budget	
% of service budget (Serv)	The ratio of service budget to total IT budget	
Industry (Ind)	Coded based on SIC code	Compustat, 2017
Firm size (Size)	The log of total employee	

5 Results

Table 5 presents the summary statistics and correlations of variables. The average carbon emission is about 7.7 million tons, and the average green IS capability level is 1.3. The average level of green support is 2.7, indicating a high level of green support, and the average value of information assurance is 0.7, indicating many organizations have third-party assurance for their carbon emissions information. For the control variables, the average number of IT/IS employees is 41, the average ratio of hardware budget is 3.3%, the software budget is 0.8%, and the service budget is 7.5%.

Table 5. Summary Statistics and Correlations Table

	Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11
1	GP	-7.712	16.864	1.000										
2	GISC	1.348	0.796	0.134	1.000									
3	GS	2.683	0.494	-0.137	-0.174	1.000								
4	IA	0.695	0.463	-0.135	-0.322	0.274	1.000							
5	IM	0.56	0.499	-0.414	0.177	-0.137	-0.247	1.000						
6	PA	337	1400	0.035	0.145	-0.199	-0.159	0.102	1.000					
7	ITE	41	82	0.036	0.101	-0.245	-0.211	0.169	0.408	1.000				
8	Hard	0.033	0.019	0.097	-0.033	0.007	-0.007	-0.081	-0.033	-0.176	1.000			
9	Soft	0.008	0.003	-0.067	0.080	0.015	0.209	0.054	-0.036	-0.018	0.291	1.000		
10	Serv	0.075	0.013	-0.334	-0.001	0.094	0.051	0.105	0.003	-0.085	0.417	0.446	1.000	
11	Ind	2.692	1.887	-0.122	0.081	0.182	-0.079	0.099	0.015	-0.027	-0.064	-0.247	-0.350	1.000
12	Size	4.782	1.551	-0.118	0.090	-0.225	-0.241	0.143	0.480	0.303	-0.217	0.085	0.058	0.011

Table 6 shows the first part of the main estimation results. First, column 1 of this table presents the direct relationship between the green IS capability and green performance. The result (β=4.116, $p<0.1$) indicates a significant and positive relationship between the level of green IS capability and organizations' green performance. In other words, organizations can gain better green environmental performance with a higher level of green IS capability. This result supports hypothesis H1.

Table 6. Main Estimation Results-Part 1

Variables	Green Performance (H1)	Green Performance (H2)
GreenISCapability (GISC)	**4.116* (2.228)**	3.101 (9.071)
GreenSupport (GS)		2.731 (6.873)
GISC×GS		**3.392** (1.644)**
ITEmployee	0.007 (0.012)	0.006 (0.011)

Hardware	-1.794 (1.548)	-1.862 (1.571)
Software	3.855** (1.535)	3.955** (1.540)
Server	-2.408 (2.360)	-2.593 (2.386)
Size	-0.581 (1.010)	-0.844 (1.077)
Constant	5.613 (13.047)	1.400 (20.219)
Observations	73	73
R-squared	0.336	0.342
Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; industry dummies are omitted for brevity.		

Second, model 2 in column 2 is about the impacts of green IS capability on green performance with the presence of green support. The results show that the moderating effect is significant and positive (β=3.392, p<0.05). This result is consistent with the argument in Hypotheses 2 and thus supports hypothesis H2.

Table 7. Main Estimation Results-Part 2

Variables	**Process Automation**	**Green Performance**	**Green Performance**	**IS Misuse**	**Green Performance**	**Green Performance**
		(H3a)			**(H3b)**	
GreenISCapability (GISC)	**512.303* (291.505)**			**9.192** (0.085)**		
Process Automation (PA)		0.0003 (0.001)	0.0003 (0.001)			
IS Misuse (IM)					**-14.849*** (4.212)**	**-7.843** (3.322)**
InfoAssurance (IA)			-10.166* (5.725)			-6.324 (7.662)
PA×IA			0.004 (0.003)			
IM×IA						**-9.091** (4.349)**
ITEmployee	7.222*** (1.875)	-0.177 (0.296)	-0.021 (0.016)	0.001 (0.001)	0.022 (0.037)	-0.008 (0.017)
Hardware	343.523*** (106.441)	-6.276 (14.194)	1.699 (1.714)	-0.039 (0.035)	0.166 (2.173)	0.919 (1.728)
Server	-164.631 (180.236)	6.275 (8.772)	2.843 (2.380)	0.025 (0.056)	3.155 (2.874)	3.665* (1.935)
Software	-138.721 (98.651)	-0.596 (6.138)	-3.908** (1.525)	0.053* (0.031)	-1.879 (2.477)	-3.435** (1.396)
Size	-16.586 (29.154)	-16.586 (29.154)	-0.987 (1.785)	0.002 (0.040)	1.131 (1.890)	0.524 (1.298)
Constant	-5,523.494*** (2,074.889)	124.139 (214.442)	18.949 (19.997)	0.582 (0.669)	21.103 (32.200)	16.961 (16.437)
Observations	73	73	73	67	67	67
R-squared	0.513	0.508	0.549	0.213	0.229	0.480
Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; industry dummies are omitted for brevity.						

Table 7 shows the second part of the primary estimation results. The results in the first three columns are about the testing for hypothesis H3a. The result in column 1 (β=512.303, p<0.1) indicates green IS capability's significant and positive influence on process automation. However, we did not find significant results for the relationship between process automation and green performance and the ensuring role of information assurance. In other words, the result does not support hypothesis H3a. The results in the other three columns are about the testing for H3b. We first see a significant and positive (β=9.192, p<0.05) result for the relationship between green IS capability and IS misuse. Plausibly, organizations may go for the implementation of green IS, following industry norms, without considering the expertise of the users, which results in less use of the system (Ning et al., 2023). Furthermore, the result in column 5 (β=-14.849, p<0.01) suggests that misuse of IS can harm the green performance. Then we find that the interaction of information assurance and IS misuse is significant and negative (β=-9.091, p<0.1), which is evidence of information assurance's role in reducing the adverse effects of IS misuse on green performance. In other words, information assurance can ensure the green performance of an organization by addressing the potential IS misuse problems. This result supports H3b. In addition, researchers have found that other factors, such as carbon emission goal setting and climate-related risk perception, can affect an organization's carbon emissions (Melville et al., 2017; Ning et al., 2019). We also include business strategy and risk perception as additional control variables to address the potential endogeneity issues. Table 8 shows the analysis results with these additional control variables. The results are largely consistent with the main results in Tables 6 and 7.

Table 8. Analysis Results with Additional Control Variables

Variables	Green Performance (H1)	Green Performance (H2)	Green Performance (H3a)	Green Performance (H3b)
GreenISCapability (GISC)	**4.089*** **(2.275)**	-12.052 (8.723)		
GreenSupport (GS)		-10.794 (7.880)		
GISC×GS		**3.379**** **(1.682)**		
Process Automation (PA)			0.0003 (0.001)	
IS Misuse (IM)				**-8.791**** **(4.156)**
InfoAssurance (IA)			-11.171* (6.077)	-6.721 (8.027)
PA×IA			0.004 (0.003)	
IM×IA				**-8.380*** **(4.909)**
RiskPerception	0.210 (1.142)	-0.001 (2.037)	1.104 (1.388)	-0.538 (1.519)
BusinessStrategy	-5.230 (3.380)	-1.376 (16.709)	-7.361** (3.614)	0.621 (3.053)
ITEmployee	-0.006 (0.012)	-0.004 (0.022)	-0.016 (0.018)	-0.010 (0.018)
Hardware	1.773 (1.576)	1.727 (1.186)	1.682 (1.748)	0.916 (1.764)
Software	2.348 (2.400)	2.181 (2.008)	2.791 (2.435)	3.708* (1.977)
Server	-3.883** (1.571)	-3.466*** (1.152)	-4.071** (1.570)	-3.334** (1.447)
Size	0.606 (1.037)	0.783 (1.370)	-0.980 (1.842)	0.516 (1.325)
Constant	-0.978 (15.519)	13.014 (35.209)	23.227 (22.676)	18.641 (19.061)
Observations	73	73	73	67
R-squared	0.337	0.385	0.355	0.480

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; industry dummies are omitted for brevity.

We conducted several additional analyses to test the robustness of the main estimations and to have a more nuanced understanding of the main estimations. First, one concern of using green IS implementation scope as a proxy of green IS capability is whether the organization used the IS well to achieve good environmental sustainability. To address this concern, we collected and matched the corporate score regarding climate performance from CDP to evaluate the consistency between green IS capability and actual green capability. We run a regression of green IS capability against the actual green capability. Second, a prior study (Ning et al., 2019) shows the impacts of location on the relationship between green IS and carbon disclosure performance due to regulatory differences. The sample of organizations taken for the analyses was located in different cities across two countries. Thus, we conducted a spatial analysis to examine the differences across locations.

Table 9 shows the additional analysis results. First, the actual green capability is measured by the CDP climate score of each organization. Because this climate score is ordinal and does not assume equal intervals between levels, we used ordered logit regression to estimate the relationship. The result in Column 1 of Table 9 ($\beta=0.868$, $p<0.1$) indicates the positive and significant relationship between green IS capability and actual green capabilities.

Second, for the spatial analysis, we built the spatial weight matrix (**W**) based on the longitude and latitude of each organization, followed by the spatial error model and lag model. The results of the spatial error model in column 2 and the lag model in column 3 are consistent with the main results. The lambda and rho values support the necessity of spatial analysis.

Table 9. Additional Analysis Results

	Ologit	**Spatial Analysis Error Model**	**Spatial Analysis Lag Model**
Variables	**Actual Green Capability**	**Green Performance**	**Green Performance**
GreenISCapability (GISC)	**0.868* (0.461)**	**3.861* (2.108)**	**4.197** (2.085)**
ITEmployee	0.001 (0.002)	0.004 (0.016)	0.001 (0.016)
Hardware	-0.009 (0.163)	1.851** (0.906)	1.945** (0.907)
Software	-0.122 (0.259)	2.395 (1.613)	2.495 (1.603)
Server	0.064 (0.138)	-3.356*** (0.893)	-3.681*** (0.897)
Size	0.187 (0.188)	0.024 (1.115)	-0.093 (1.127)
Observations	55	73	73
	Pseudo R-squared 0.14	Lambda 0.586 (0.221)***	Rho 0.615 (0.197)***
Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; industry dummies are omitted for brevity.			

6 Discussion

To better understand the components in the proposed hierarchy of green IS capabilities from an operant resources perspective with a future-oriented approach, we present two real-world scenarios to illustrate how to leverage green IS capabilities for better green performance in organizations (Corbett & Mellouli, 2017). We articulated these two hypothetical scenarios using publicly available sources.

The first general scenario happens in a hypothetical manufacturing company. GreenTech is a leading mid-sized manufacturing company and has established itself as a pioneer in sustainable and eco-friendly production practices. It has been in operation for over three decades. Recently, the company's management has recognized the importance of sustainability and has decided to implement green IS to improve the company's environmental performance. The implementation of these green IS is expected to lead to a significant reduction in the company's energy consumption, thereby improving its environmental performance. For example, the company uses green IS to track the environmental impact of each product component throughout its lifecycle, and it enables the company to make informed decisions and minimize its carbon footprint. The management team of GreenTech is fully committed to the company's green agenda and provides vital support to the green IS capabilities. The management team ensures that all employees are trained in using green IS and promotes a culture of sustainability throughout the organization. These training programs help employees adapt to the new system and promote communicating the benefits of the new system to employees. To support the implementation of green IS, the management team has also committed to providing the necessary resources and support. Such commitment includes allocating a budget for the implementation of green IS and assigning a dedicated team to oversee the implementation process.

GreenTech's green IS capabilities have also enabled the company to automate its production processes. The negative side of process automation is frequent system failures. In addition, the mechanical adoption of carbon emission standards also hinders the green performance enabled by green IS capabilities. To address these issues, GreenTech has implemented information assurance measures to ensure the efficient use of green IS. After the implementation of green IS, the company experiences a significant improvement in its environmental performance. The company's energy consumption is reduced, and there is a decrease in paper-based processes, reducing waste generation and carbon emissions. The company's green performance also improves due to the management team's support and the implementation of information assurance measures to address process automation and IS misuse.

GreenTech's hierarchy of green IS capabilities has shown that the company's strong commitment to sustainability, with its management support and information assurance, has improved green performance. The combination of green IS capabilities, management support, and information assurance measures has enabled GreenTech to achieve its sustainability goals while maintaining its competitive advantage in the market. This scenario illustrates the importance of green IS in improving a manufacturing company's environmental performance. The scenario also highlights the hierarchy of operant resources in achieving improved green performance, including the implementation of green IS, support by the management team, and information assurance measures to ensure the system's integrity.

The second scenario focusing on the role of information assurance for green performance is in the context of a bank. EcoBank is a hypothetical global financial institution with a solid commitment to sustainability. The bank is dedicated to reducing its carbon footprint and contributing to a sustainable future. The bank has established a comprehensive Environmental, Social, and Governance (ESG) program, including various initiatives to reduce carbon emissions, promote sustainable practices, and ensure responsible investment. The bank has also implemented various green initiatives to reduce its environmental footprint, including energy-efficient buildings, renewable energy sources, and sustainable procurement practices. In addition, the bank has invested heavily in information technology (IT) and information systems (IS) to improve its operational efficiency and customer service. These initiatives have helped the bank reduce carbon emissions and improve operational efficiency and cost savings.

EcoBank has recognized the potential of green IS to support its sustainability goals. By using green IS, the bank has implemented several measures to improve its green performance, including tracking its energy use and carbon emissions, setting targets for reduction, and engaging employees in sustainability initiatives. The bank has found that its green IS capabilities have been a critical driver of its green performance, enabling it to reduce costs, improve efficiency, and enhance its reputation as a sustainable institution. However, to truly become a leader in sustainable banking, EcoBank realizes that it needs to go beyond just implementing green technologies. The bank must also ensure that the information it uses to measure its carbon footprint is accurate, reliable, and transparent. In other words, the bank must ensure the quality of carbon emission data. The bank has implemented more sophisticated green IS and encountered process automation and IS misuse challenges.

Process automation has enabled EcoBank to streamline operations, reduce costs, and improve efficiency. However, it has also introduced new risks like errors and fraud. Another challenge in ensuring the integrity of its carbon emission data is the potential for IS misuse, such as manipulating data to achieve desired results. To address these challenges, EcoBank has established partnerships with third-party service providers to ensure the accuracy and completeness of its carbon emission data. These partnerships enable the bank to monitor and analyze its carbon emission data and identify discrepancies or anomalies. The information assurance process has helped EcoBank ensure its carbon emission data's accuracy and reliability and identify new opportunities for carbon reduction and sustainability initiatives. For example, the bank identified areas of high carbon intensity in its supply chain and worked with suppliers to implement more sustainable practices. The bank has ensured its green performance by addressing the challenges of process automation and IS misuse through effective information assurance. This scenario demonstrates the importance of green IS capabilities and information assurance in achieving sustainability and operational efficiency. The bank's efforts have not only helped it reduce its carbon footprint but also contributed to the broader goal of achieving a more sustainable future for all.

Organizations use green IS technologies or systems to achieve better environmental sustainability and green performance (Melville, 2010). Studies relevant to strategy and green outcomes of specific green IS from operant resources perspectives are limited. The current study highlights the operant nature of green IS capability to address the research gap by anchoring it to the operant resources perspective. We propose the three levels of green IS capability, and we study the hierarchy of operant resources for green performance in the order of basic, composite, and interconnected operant resources. Accordingly, we develop three hypotheses to explain how green IS influences the green performance of organizations. Matched data from multiple sources are used to test these hypotheses, and we found support for our hypotheses from the analysis results. We first found a significant positive relationship between green IS capability and performance. This finding implies that organizations can gain better environmental sustainability performance with higher green IS capability. We also found the positive moderating effects of green support on the relationship between green IS capability and green performance, indicating that green support can enhance green performance enabled by green IS capability. Finally, we found that green IS capability can cause process automation and IS misuse, but only IS misuse significantly and negatively impacts green performance. Information assurance can reduce such adverse impacts, which implies the ensuring role of information assurance on green performance.

We contribute to theory in several ways by extending current research. First, prior literature on IT for sustainability primarily focused on the antecedents and consequences of green IS. By examining the framework from green IS capability to green performance, we contribute to the knowledge of how green IS capability influences green performance. Second, researchers have applied various theories or frameworks, such as the belief–action–outcome (BAO) framework and RBV theory in green IS research (Anthony Jr., 2019). Still, few researchers have applied the operant resources perspective in IS research (Kathuria et al., 2018). Drawing on the hierarchy of operant resources, we proposed the three levels of green IS capability, which can be generalized in future green IS research. The hierarchy view of green IS capability provides a novel and emerging approach for researchers to understand digital strategies, thus adding to the growing literature in this arena. Third, we extensively discussed resources and capabilities to explore the operant nature of green IS capabilities – consistent with the emerging research in green IS area, yet, providing a novel perspective to extend the body of knowledge (Santos et al., 2019). Therefore, the current study contributes to the growing literature on IT-enabled capabilities, especially in the environmental sustainability area.

The findings also have important practical implications. First, it demonstrates the positive impacts of green IS capability on green performance. This finding can facilitate the use of green IS in businesses. It is recommended that organizations implement comprehensive green IS with more functionalities to achieve better environmental sustainability. Second, the findings suggest the complementarity of green IS capability and green support from the composite operant resources perspective. Practically, the management team should present more support to the environmental sustainability practices to leverage green IS further for enhanced green performance. Third, from the interconnected operant resources perspective, we show the significance of information assurance on green performance when addressing the potential IS misuse caused by green IS capability. While aiming to use green IS to improve green performance, organizations should employ third-party information assurance services to assure information quality and objectivity, and to ensure organizations' green performance. Furthermore, the two real-world scenarios provide more details about opportunities to leverage green IS capability for better green performance by organizations.

This study has some limitations that could be addressed in future research. First, we only used single-year data of the green IS capability to test the hypotheses, which limits our findings' generalizability. The same limitation also goes with the relatively small sample size. We tried to utilize several additional analyses to evaluate the reliability and validity of the results. Nevertheless, future research should use multiple years of panel data and a large sample size to improve the robustness of the results. Second, the variables in the current study are coded based on secondary data. Even though such a measurement scheme provides adequate insights into the interactions of these variables, future research could include survey data that measures the intensity of green IS capability, green support, and information assurance which may provide additional insights. Although sensitivity analysis supports the current coding schema of green

IS capability. The relatively simple coding process of this variable is a limitation. Finally, although we considered additional control variables in additional analysis, it is plausible that other variables intervene or mediate in the research model examined, which presents an opportunity for future inquiry.

7 Conclusion

Our objective was to answer the research question of enhancing and ensuring the green IS-enabled green performance in organizations from the operant resources hierarchy perspective. We developed a conceptual model with three hypotheses to answer this research question. We then tested these hypotheses using a matched dataset. We found that first, more green IS capabilities can lead to better green performance; second, along with the green IS capability, the presence of top management green support can enhance the green performance of the organization; and third, green IS capability can cause process automation and IS misuse, while process automation does not affect the green performance, IS misuse can negatively affect green performance, but information assurance can ensure the green performance by reducing the negative effect of IS misuse. These findings fulfilled the research objectives. In addition, in the two real-world scenarios that illustrate the application of our proposed conceptual model, we present more details on how organizations in different industries can achieve, enhance, and ensure their green performance from green IS capabilities.

With the growing climate change challenges, efforts to promote environmental sustainability profoundly impact our society. Information technologies can potentially address environmental sustainability issues for climate action proposed in SDG 13. Business organizations use green IS to manage their environmental-related activities to achieve environmental objectives. Drawing on the operant resources perspective, we highlight the role of green IS capabilities as operant resources in improving environmental performance. By applying the operant resources perspective to the green IS area, it is possible to address several research questions that will further our understanding. For example, the critical component of the operant resources perspective is dynamic interactions. Thus, at the individual level, it is worth examining how individuals' behaviors and decision-making processes regarding environmental sustainability interact with the design and implementation of green IS to avoid issues such as IS misuse. The mirror question could be how green IS can be designed to encourage pro-environmental behaviors and promote sustainable practices among individuals. Furthermore, another core element of the operant resources perspective is the hierarchy of operant resources. Besides the management support for green initiatives and information assurance discussed in this study, future studies may explore the key organizational factors that influence the successful implementation of green IS from the composite and interconnected operant resources perspectives.

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Appendix A: Measurement of Green IS Capability and Sensitivity Analysis

According to the CI Technology database, companies use 12 distinct and different types of systems to manage environmental sustainability (see Table 3). Some systems are comprehensive, while others only have one environmental focus (e.g., carbon, waste recycling, energy, compliance). Regarding the application, some companies use only one type, while others use multiple (up to five) systems. Adopting more comprehensive/full-focus systems that cover these four environmental areas indicates more ability to use IS for environmental sustainability.

A study on enterprise IS capability and GHG pollution emissions reductions defines using a full suite ERP installed or 2+ value chain modules of an ERP as a greater functional scope while using 0-1 value chain modules and 1 or more enterprise support (ES) modules as a lesser functional scope. They used the ratio of ES modules that span multiple sites to multiple sites to measure the ES physical scope proportion (Rush et al., 2015).

Our paper does not have multiple sites but four environmental focusing areas. We assume the full-focus systems only cover these four areas, and the proportion of each focus is the ratio ¼=0.25. Another assumption here is that all four areas play the same role equally. Using this method, we calculate the total weight of green IS based on its environmental focus (overall=1, partial=0.25). Three researchers were involved in this coding process. First, they discussed and agreed on this method and then one researcher did the first round of coding, which was reviewed by another researcher. With updates and changes, all three researchers met again and reviewed the coding together.

We understand this is a relatively straightforward coding schema, considering this method's strong and strict assumptions. A comprehensive system may cover more than the four environmental areas used in this coding approach. Also, a carbon-focus system may not play the same role as a waste recycling-focus system regarding carbon emissions reduction. Therefore, we conducted two sensitivity analyses to evaluate the effects of our current coding method.

First, we conduct a sensitivity analysis by changing the weight of the partial-focus system from 0.1 to 0.95 in increments of 0.1. It then calculates the difference in mean between the original weighted value and each changed value. Based on the sensitivity analysis results, the range of values for the coded variable does not significantly impact the overall distribution of the variable. This indicates that the coded variable is not particularly sensitive in this context.

Second, we conduct the sensitivity analysis using a Monte Carlo simulation. This involves generating a large number of random samples from the dataset, each time adding a small amount of noise to the coded variable to simulate different possible values. The mean and standard deviation of the resulting sample statistics can then be calculated to assess the sensitivity of the analysis to small changes in the coded variable. We perform a Monte Carlo simulation with 10,000 iterations, where for each iteration, we add a random value drawn from a normal distribution with a mean of 0 and a standard deviation of 0.05 to the coded variable. We then count the number of functions for each sample and calculate the mean and standard deviation of the resulting distribution. For our dataset, we obtain a mean of 1.35 and a standard deviation of 0.84 for the number of functions. Running the Monte Carlo simulation, we obtain a mean of 1.35 and a standard deviation of 0.60, indicating that the analysis is relatively insensitive to small changes in the coded variable. This suggests that the analysis results are robust and not heavily influenced by the specific coding scheme used for the variable.

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