

# **Green construction supply chain management: integrating governmental intervention and public–private partnerships through ecological modernisation**

## **Abstract**

There has been global recognition of the urgent need to tackle adverse environmental impacts of the construction industry. Construction companies are called upon to switch to ecological modernisation by scaling up the implementation of environmental management practices while maintaining a level of economic development. Under ecological modernisation theory, green supply chain management has emerged as an environmental technological innovation, helping organisations to switch to ecological modernisation. Past research revealed a need to identify mechanisms aimed at resolving conflicts among construction supply chain actors, speeding collaboration among them, and managing the transition to green supply chain management. This research aims to examine whether governmental intervention can act as an effective mechanism with which to foster public–private partnerships among construction companies, thereby promoting ecological modernisation through the adoption of green supply chain management. Data were collected from survey responses from 229 Chinese construction companies and analysed using partial least squares structural equation modelling. The results show that coordination between governmental support and public–private partnerships is necessary to aid construction companies in implementing green supply chain innovation and complying with environmental regulations and, thus, achieving multiple performance benefits, including environmental and short-term economic performance improvements. However, it is unlikely that green supply chain management alone could drive the long-term goal of ecological modernisation theory unless more proactive actions are taken by all stakeholders. This study demonstrates how ecological modernisation theory can be applied to advance green supply chain management studies. Enforcing and incentivising aspects of governmental intervention, i.e. environmental regulations and governmental support, have been proven to be effective in developing a regulatory framework for, and partnerships among, stakeholders. This results in the sharing of resources, knowledge and practices to contemplate a new paradigm of supply chain integration and coordination for the construction sector and promote active adaptation to green supply chain management.

**Keywords:** green supply chain management, construction, government intervention, public–private partnerships, ecological modernisation

## 1. Introduction

The combined building and construction sectors are responsible for 39% of global carbon emissions (WorldGBC 2019). In recent years there has been growing global recognition of the urgent need to tackle carbon emission levels within the construction industry (Badi and Murtagh 2019). The European Union has introduced directives on waste reduction; the UK Government’s strategy is to achieve a 50% carbon reduction from the built environment by 2025 in comparison to the 1990 baseline; the Chinese Government aimed to increase the proportion of newly-constructed green buildings in urban areas to 50% by 2020 (WorldGBC 2018). These targets impose considerable pressures upon the construction industry **to integrate environmental concerns into their operations and business strategies (Balasubramanian and Shukla 2017)**. However, industries in the construction sector need to maintain a level of economic development; additionally, there is a paucity of sustainable knowledge, potentially further impeding the implementation of environmental management practices (Hwang and Tan 2012).

Ecological modernisation theory (EMT) has been offered as a possible solution with which to tackle the conflict between economic development and environmental protection (Murphy and Gouldson 2000). EMT proposes the achievement of continued industrial development without environmental degradation through continuous scientific and technological innovation (Alkhuzaim et al. 2020). EMT argues that governmental policies related to the environment, and certain forms of governmental intervention, promote the development and adoption of scientific and technological innovation, consequently driving the process of industrial innovation with enhanced competitiveness (Lazzarotti et al. 2019). Under EMT, green supply chain management (GSCM) has emerged as an environmentally technological innovation, helping organisations to move beyond control technologies, nowadays considered as clean technologies (Genovese et al. 2017). GSCM focuses on improving environmental performance while maintaining economic profitability and gaining competitiveness in the global market (Liu et al. 2018).

**EMT has been applied in building conceptual models, developing analytical models, and conducting empirical data analysis so as to advance GSCM studies and enhance development of the circular economy (Sehnem et al. 2021). A recent literature review conducted by Liu et al. (2018) revealed that GSCM studies using EMT were limited, and**

they proposed extending EMT to additional GSCM studies to investigate how the two dimensions of EMT, i.e. governmental intervention and technological innovation, influence GSCM research. A survey of empirical research between 2001 and 2019 indicated that research gaps exist in relation to GSCM in the construction sector, with only 1.39% of the GSCM research being conducted in the construction industry (Bhatia and Gangwani 2020). Bhatia and Gangwani (2020) argued that it is important to broaden the ambit of GSCM and identify how GSCM practices differ across industries. The construction industry is characterised by its project-based nature, with a large number of actors involved (potentially thousands), short-term, ad hoc projects that lack continuity, and a relatively unstable supply chain (Ofori 2000). The unique nature of the construction supply chain means that traditional GSCM activities may not be applicable, or could become less effective (Badi and Murtagh 2019). Past research revealed a need to identify mechanisms aimed at resolving conflicts among supply chain actors and accelerating collaboration and integration among those actors (Mojumder and Singh 2021), as well as managing the transition to GSCM (Badi and Murtagh 2019). Public–private partnerships (PPPs) in the construction industry (Zhang et al. 2020) have been identified as a mechanism with which to close the gap of infrastructural investment, enable collaborations among multiple parties, and promote economic growth and wider political reform (Cheng et al. 2016). Research also indicated that the ecological switchover in construction companies was driven by governmental regulations and enabled by governments’ incentives and support (Mojumder and Singh 2021). However, it remains unclear as to whether such drivers and enablers may foster collaborations or partnerships among construction supply chain actors by resolving conflicts between them.

To supplement the existing research and address these gaps, this research aims to examine whether governmental intervention can foster public–private partnerships among construction companies, thereby promoting ecological modernisation through the adoption of GSCM. Four research objectives will be achieved in this study: 1) to investigate the influence of governmental intervention on GSCM implementation in the construction industry; 2) to investigate the impact of governmental intervention on promoting PPPs; 3) to examine the influence of PPPs on GSCM implementation; and 4) to examine the impact of GSCM on economic and environmental performance in a construction supply chain.

Drawing on EMT, this paper addressed the four research objectives through an empirical study of 229 Chinese construction companies. The surveyed companies were at different stages of implementing various aspects of GSCM innovation, with some having fully integrated it into

their operational process, and some in the process of implementing it or considering the adoption altogether. **This study investigated the relationships between governmental intervention, PPPs, and GSCM implementation by means of Partial Least Squares Structural Equation Modelling (PLS-SEM). Examining the mediating effects of governmental support (GS) and PPPs on GSCM implementation can provide further insights into better management of GSCM complexities in the construction supply chain.**

Relevant literature is reviewed in Section 2. EMT is introduced to develop the theoretical framework in Section 3, followed by the development of hypotheses in Section 4. In Section 5, statistical analysis is undertaken to discuss the relationships between constructs. A discussion of the findings is presented in Section 6, with conclusions and future work presented in Section 7.

## 2. Literature review

### 2.1 Green supply chain management in construction

GSCM is defined as an evolution of supply chain management that incorporates environmental thinking into all phases of the supply chain (De Carvalho et al. 2020; Govindan et al. 2014), including product design, procurement, manufacturing, delivery of the final product to consumers, and end-of-life management of the product (Srivastava 2007). GSCM primarily aims to minimise the detrimental environmental consequences of operational activities and processes, including atmospheric emissions, excessive resource consumption, waste generation, and improper product disposal (Laari et al. 2016). The five major elements of GSCM practices embedded in the supply chain phases were defined as: eco-design, green purchasing, management of the internal environment, customer cooperation for environmental concerns, and investment recovery. Table 1 summarises the key activities that have been explored under each GSCM practice.

**Table 1 Five elements of green supply chain management practices (Zhu et al. 2007)**

<b>Eco-design</b>	<b>Green purchasing</b>	<b>Internal environmental management</b>	<b>Customer cooperation for environmental concerns</b>	<b>Investment recovery</b>
Eco-design of products (Zheng et al. 2019)	Selection, monitoring, control, and collaboration with suppliers (Youn et al. 2012)	Top management commitment (Gavronski et al. 2011)	Cooperation with customers for product recycling	Reduction, recycling and reuse (3Rs) of materials (Liu et al. 2018)
Eco-production process (Aoe 2007)	Environmental auditing (Youn et al. 2012)	ISO14000 certification (Liu et al. 2018)	Cooperation with customers for green marketing	Remanufacturing (Pazoki and Samarghandi 2020)

Eco-packaging (Zeng et al. 2020)	Eco-labelling (Taufique et al. 2019)	Cleaner production (Liu et al. 2018)	Cooperation with customers for green logistics (Zhu et al. 2017)	Reverse logistics (Zhu et al. 2008)
Fulfilling stakeholder demand (Choi and Hwang 2015)		Environmental management system (Laari et al. 2016)	Cooperation with customers to improve environmental performance (Geng et al. 2017)	Product take-back regulations (Pazoki and Samarghandi 2020)
		Knowledge exchange (Gavronski et al. 2011)		Sale of excess materials (Bing et al. 2015)

GSCM has been used as a holistic innovation (Balasubramanian and Shukla 2017) to incorporate environmental concerns into the supply chain (Malviya and Kant 2015) and help firms to improve their sustainability (De Carvalho et al. 2020). Compared with GSCM research in other industrial sectors, research into GSCM in construction management has lagged, showing that this is an underresearched area (Badi and Murtagh 2019; Bhatia and Gangwani 2021). The construction supply chain is highly complex, diverse, and disjointed; the number of organisations involved in a large construction project can reach hundreds or thousands (Akintoye et al. 2000). The project-based nature of construction means that relationships between stakeholders are often one-off and short-term, leading to low trust and potential adversarial attitudes among stakeholders (Ofori 2000). A construction supply chain encompasses material developers, architects/consultants, contractors, and suppliers. Developers initiate a construction project as a conceptual design and hire architects and other consultants to prepare drawings and project specifications. Contractors are appointed in order to execute the project, covering a wide range of activities including the extraction of materials, the manufacturing of parts, engineering, the assembly of elements, and final construction on site. Contractors are responsible for the employment of subcontractors and the procurement of materials from suppliers.

Adverse environmental impacts of construction projects occur across a project lifecycle and are generated by three main causes: construction waste, energy consumption, and operational inefficiency (Wibowo et al. 2018). The resultant serious impacts on the environment, such as the excessive use of resources, the depletion of land, excessive energy consumption, air pollution, and hazardous waste, have necessitated a rapid shift to green construction (Shi et al. 2013). Greater awareness of green construction promotes the development and implementation of the circular economy in the construction industry (Hossain et al. 2020). The key steps towards a successful circular economy rely on a systematic approach to integrating building design, the supply chain of construction materials (Akinade and Oyedele 2019), and the

recovery of construction materials for reuse (Pan et al. 2015). The application of GSCM was proposed as a systematic approach to integrating supply chain players and their activities in a transparent manner to achieve the overall aim of a circular economy, but with a stronger emphasis on environmental performance (Liu et al. 2018), while the traditional circular economy model has a relatively greater emphasis on economic performance. Such integration would involve collaboration and communication between supply chain players across the entire lifetime of a building (from design to end of life) (Leising et al. 2018).

One stream of literature addressed GSCM as a holistic innovation in the construction sector (Neppach et al. 2017; Mojumder and Singh 2021), while another discussed specific practices of GSCM, such as green purchasing (Ofori 2000), the management of materials (Chen et al. 2015), or waste management (Chileshe et al. 2014). However, due to the complexity of the construction supply chain, only 1.39% of research has addressed applying GSCM in the construction industry (Bhatia and Gangwani 2021), and there is a lack of research investigating special tools and techniques with which to facilitate lifecycle analysis of construction projects and collaboration between supply chain players (Kucukvar et al. 2016).

The complexity of construction was discussed in many papers, with reference to the variety of supply chain actors in the construction supply chain (Arroyo et al. 2016; Neppach et al. 2017). The literature revealed that the lack of uptake of GSCM across the construction supply chain was mainly due to the lack of interorganisational collaboration among supply chain actors (Balasubramanian and Shukla 2017). However, the roles, engagement and partnerships of stakeholders in environmental commitment were inadequately addressed, leaving a research gap when it comes to establishing a more collaborative paradigm in the construction supply chain so as to drive environmentalism (Udawatta et al. 2015). Furthermore, the above inadequacy raised the need for an effective mechanism with which to resolve conflicts among supply chain actors or foster collaboration or partnerships among them (Badi and Murtagh 2019). To address these research gaps, this research explores how governmental intervention and partnerships stimulate buy-in from a specific subdomain among construction supply chain actors, namely contractors and suppliers of building materials, to engage in environmental commitment and implement GSCM as an innovative approach.

## ***2.2 Governmental intervention***

Governments are regarded as key players in promoting environmental protection, seeking to create a sustainable society whilst safeguarding economic development (Wu et al. 2020; Bao and Lu 2020; Goodstein and Polasky 2017). Governments can influence companies' carbon

emission levels by enacting environmental regulations and applying economic incentives (Mahmoudi and Rasti-Barzoki 2018). However, requiring companies to comply with environmental regulations can create complexity in operational processes, imposing high costs and stifling innovation and competitiveness (Jänicke 2008). Enforcement of ERs alone is unlikely to deliver the expected outcomes (Wu et al. 2020). Centralised enforcement of ERs relies on local governments to strengthen environmental supervision, supply public goods and infrastructure (Cai and Ye 2020), rectify deficiencies in law enforcement, and coordinate public participation (Wu et al. 2020).

Centralised command-and-control ERs may enhance regulatory enforcement at some level, but such approaches have their inherent limitations in realising long-term environmental and economic gains (Tang et al. 2010). It has been argued that appropriate models of environmental interventions are required from governments to provide clarity surrounding top-level environmental objectives and innovation-friendly instruments (Jänicke 2008). Such instruments refer to market-based GS, i.e. creating a market for environment-friendly innovation through providing economic incentives, supporting individual organisations in integrating eco-innovation into strategic environmental management, and helping organisations to develop technical competence and increase productivity (Zhu et al. 2012). What is more, these instruments are expected to internalise social costs, commercialise ecological innovations, connect green and social innovations to potential markets, and provide investors with an appropriate economic return on investment (Lüdeke-Freund 2020). Commercialising innovations often requires the development of new market segments and new business models; thus, there is a need for a more decentralised and more consensual approach, ensuring that economic and market dynamics interact with an effective environmental governance system (Tang et al. 2010; Wu et al. 2020). In this research, two forms of governmental intervention were considered, namely an enforcement measure of ERs and an incentivising measure of GS (Zhang and Yousaf 2020). The research examined whether balanced governmental intervention, i.e. ERs coupled with GS, leads to the wider adoption of GSCM innovation.

### ***2.3 Public–private partnerships***

A partnership represents a long-term relationship between supply chain partners, and functions like a network, in which resources, knowledge, skills, risks, and decision making are shared (Glasbergen 2011). Partnerships have been used as a measure with which to resolve conflicts, eliminate adversarial relationships, and increase efficiency in construction projects (Naoum 2003). Past research showed that the use of partnerships led to an improvement in

innovation and learning in complex construction projects (Chan et al. 2010). Compared with hierarchical governance, partnerships were more effective in producing flexible, responsive, creative and innovative solutions to social problems such as environmental protection (McQuaid 2010), generating and disseminating knowledge, building capacity, and encouraging public participation (Pattberg et al. 2012).

Public–private partnerships (PPPs) have become common pre-tender requirements for government-funded construction projects around the world (Robert et al. 2014). A PPP is a contractual agreement between a public agency (national, state or local) and a private sector entity. Under the agreement, skills, knowledge and assets of the partners are shared in delivering a service or facility for public use (Akintoye et al. 2015). In this research, we focus on the discussion of PPPs as a special type of partnership. Depending on the varying levels of involvement and responsibilities of public and private sectors, the forms of PPP are classified as: creating wider markets, private finance initiatives, joint ventures, partnership companies, partnership investments, and franchises (Tang et al. 2010).

PPPs are proposed as a potential vehicle for achieving key elements in sustainable development (Lenferink et al. 2013), i.e. economic, environmental and social objectives, wherein participants are involved in joint decision making and network governance (Regeczi 2005). Regarding environmental protection, PPPs are promoted to empower the private sector to take ownership of, and play a leading role in, implementing green initiatives and achieving environmental growth through sustainable development (Liu et al. 2012). It is believed that private partners could be incentivised to take project lifecycle costs into account and go beyond the design stage to build in environmentally friendly features that may be more costly initially but could deliver long-term cost-effectiveness (Grimsey and Lewis 2004). Based on these findings, there is a recognised need to incorporate PPPs into infrastructural projects (Hueskes et al. 2017), and to provide services to complex sectors such as construction (Regeczi 2005) in order to drive sustainable development.

#### ***2.4 Environmental and economic performance***

Organisational environmental performance refers to the measurable results of environmental policy and green practices related to an organisation's compliance with the applicable environmental laws and regulations and its impacts on the environment (Hussain and Malik 2020). The key indicators of environmental performance are defined as: reduction of carbon emissions, reduction of solid waste, reduction of effluent waste, reduction of energy

consumption, reduced consumption of hazardous or dangerous materials, reduced use of input, and reduced frequency of environmental accidents (Jabbour et al. 2015; Jadhav et al. 2019).

Commercial organisations are, by their nature, profit-driven. Even though they are compelled to reduce their impact on the environment, they inevitably seek trade-offs by balancing their economic performance and environmental performance (Ding et al. 2016). Organisational economic performance refers to profit, turnover, market share, and financial returns on assets (Geng et al. 2017). It is claimed that the cost-saving nature of environmental performance produces short-term economic performance gains (Green et al. 2012). Organisations need to reengineer business processes to implement GSCM, which may improve operational efficiency and save costs (Chiu and Hsieh 2016). Green innovations, through either product design or process management, have been proven to benefit organisations in saving costs, enhancing efficiency in environmental management, and improving organisations' green image (Chen 2008).

Improved environmental performance may lead to an enhanced corporate green image and, thus, help firms to achieve a new market share, increase sales volumes, and improve profits over the medium or long term (De Giovanni and Esposito Vinzi 2012). Past studies adopted different measures to improve economic performance (Laari et al. 2016; Jiang et al. 2020), including reduced cost of waste management, growth in sales, growth in profit, growth in return on investment, growth in return on assets, and growth in market share.

Although economic performance can be measured through different variables at an organisational level, two types of economic performance were monitored in this paper, namely short-term economic performance and medium- and long-term economic performance. Short-term economic performance refers to economic efficiency in the context of a reduced environmental impact in terms of waste generation, carbon emissions, use of materials, and energy consumption (Murphy and Gouldson 2000). Medium- and long-term benefits are associated with industrial modernisation, improved corporate reputation (Tang et al. 2012), and enhanced competitiveness in the market (Jänicke 2008), measured as increased organisational productivity, increased capacity, increased competitiveness, and increased market share.

### **3. Ecological modernisation theory**

**EMT promotes a harmonious balance between economic and environmental performance by increasing resource efficiency, improving sustainability, and reconstructing the capitalist political economy in a modern way (Joo et al. 2018). Firstly, the modernisation aspect of EMT calls for the use of innovation and modern technology**

**for ecological reform (Sehnm et al. 2021). Secondly, EMT stresses the need for political reforms that lead to the development of more supportive policies and participatory processes which proactively prevent environmental problems (Kassolis 2007).**

Eco-innovations and diffusion require governmental intervention that addresses environmental, knowledge and network externalities, as well as financial investment in new technologies (Vollebergh and Van Der Werf 2020). EMT was adopted as a theoretical framework to understand the impacts which democracy, political globalisation, and urbanisation have on air pollution (Wang et al. 2018). In the construction sector, due to knowledge gaps regarding sustainable construction practices, EMT was applied in order to understand the complexities surrounding contractors' adaptation to environmentally sustainable construction practices (Mensah et al. 2020); empirical results also showed that governmental support and incentives were positively correlated with GSCM implementation and that the successful implementation of innovative GSCM led to achieving the goals of both industrial development and environmental protection (Mojumder and Singh 2021). These results supported EMT. **In the present research, EMT was adopted as a theoretical framework to design the research model and investigate the relationships among constructs at two levels:**

- 1) At the macro-level, EMT was used as a framework of reference, redirecting environmental policymaking, under which governments make commitments to protecting the environment and increasing innovation capacity.
- 2) At the micro-level, EMT was applied in focusing on organisational-level reform, with emphasis placed on the need to recognise technological advancements and innovative mechanisms, simultaneously improving the environmental and economic performance of organisations.

At the macro-level, EMT envisages that synergy between environmental protection and economic development can be created through appropriate governmental intervention (Joo et al. 2018) proceeding based on open, democratic decision making with the participation and involvement of multiple stakeholders (public, private and non-governmental). **The first research objective** was addressed to investigate whether governments can act as an effective mechanism with which to motivate supply chain actors to implement GSCM as an environmental innovation. **The second research objective** was also addressed at this level to examine whether governmental intervention, in the form of ERs and GS, can resolve conflicts among actors, fostering PPPs in the construction supply chain in order to achieve environmental goals (Figure 1).

At the micro-level, EMT provides insights into the adoption of GSCM as an innovative mechanism for institutions to mitigate environmental problems while retaining economic performance. GSCM is consistent with the concept of environmental innovation under EMT, as institutions restructure production (or construction) and consumption towards ecological goals. EMT emphasises developing and diffusing eco-innovation across organisations, enabling them to improve their efficiency of resource usage, develop technical competence in clean technologies, improve productivity, move into new environmentally friendly products/services, enhance competitiveness, drive the performance of green innovation, and gain an additional market share (Huang and Li 2018). At the micro-level, **the third research objective** was addressed by investigating whether PPPs encourage supply chain stakeholders to adopt GSCM; meanwhile, **the fourth research objective** examined whether GSCM innovation helps construction supply chain actors to mitigate environmental problems while making economic gains (Figure 1).

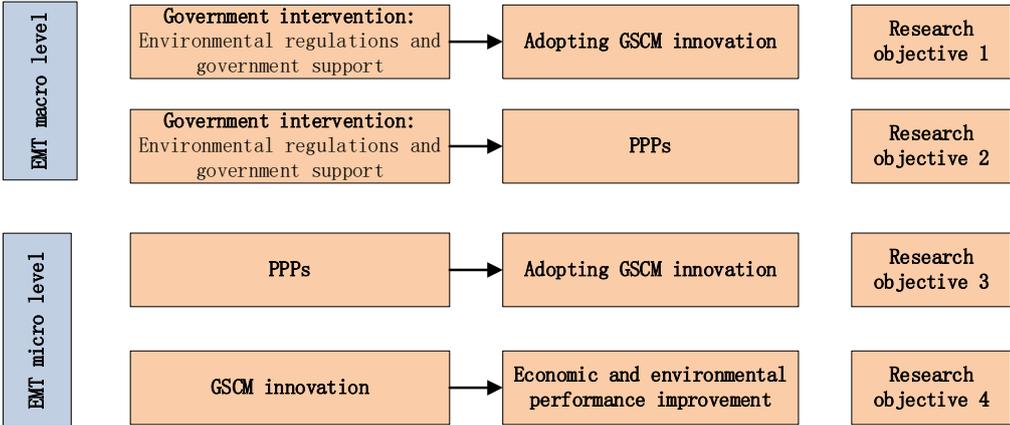


Figure 1. Theoretical framework based on ecological modernisation theory

4. Development of hypotheses

By implementing GSCM as an environmental innovation, supply chain partners could achieve better environmental and economic performance (Liu et al. 2018). Mojumder and Singh (2021) argued that speeding the collaboration and partnerships among supply chain actors would facilitate the transition to GSCM adoption. The same study found that governmental regulations were one of the highest-rated drivers affecting construction companies’ shift to GSCM practices, and that governmental incentives and support had enabler power. However, the study did not explore the relationship between governmental intervention and collaboration, or the relationship between collaboration and GSCM implementation. The present research explores whether governmental intervention could

be an effective mechanism in establishing partnerships in the construction supply chain to drive GSCM implementation.

Under the guidance of the theoretical framework presented in Figure 1, a research model was configured in Figure 2(a), linking the enforcement measure of ERs with GSCM, under the mediating effects of the incentive measures of GS and PPPs. The causal relationships between GSCM and environmental and economic performance were examined. The possible mediating effects of GS and PPPs are separated from the research model in Figure 2(a) and presented in Figures 2(b), 2(c) and 2(d). Model 2(b) argues that GS mediates the relationship between ERs and PPPs. Model 2(c) contends that GS mediates the relationship between ERs and GSCM, while Model 2(d) posits that GS and PPPs sequentially mediate the relationship between ERs and GSCM. A series of hypotheses were proposed to test which model in Figure 2 best signifies the relationships between the constructs.

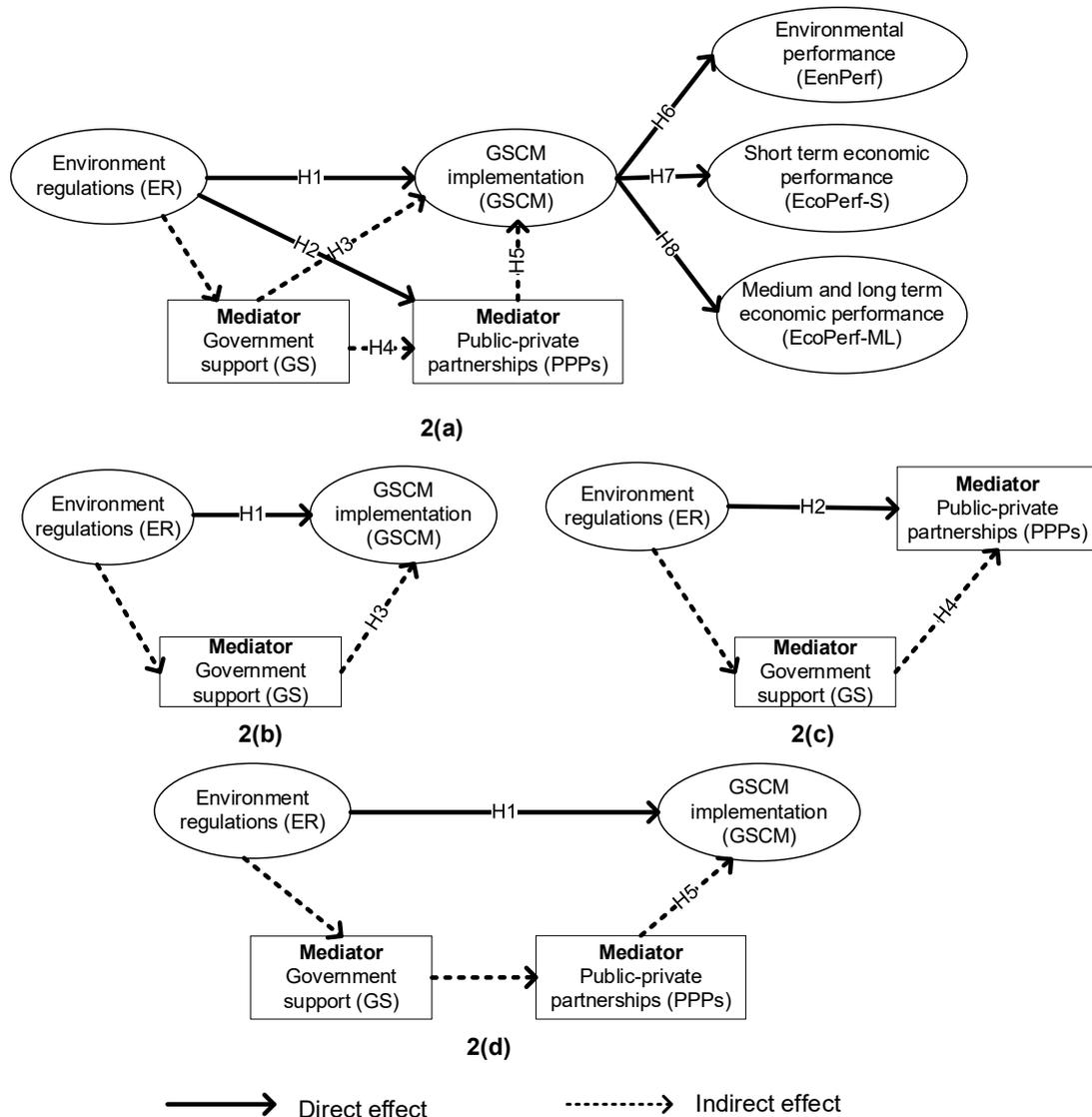


Figure 2. The proposed model

#### ***4.1 Environmental regulations and green supply chain management***

The scarcity of resources, degradation of the living environment, and increased pressures from the public to protect one's environment and its resources have prompted governments to introduce ERs as a form of governmental intervention. These regulations aim to impose pressures and constraints on businesses and industries to regulate their practices (Bai and Imura 2000). ERs were defined as coercive pressures driving the implementation of GSCM in order to improve environmental performance (Zhu et al. 2013). Enterprises need guidance and regulation from national governments to push and assist their transformation to green operations and production (He et al. 2018). In the construction sector, building energy standards were introduced with the intention to regulate construction industry actions, certify green buildings, and promote top technologies for sustainable construction (Liu et al. 2012).

ERs are effective in promoting technological innovation and inducing organisational efficiency, thus creating win-win situations between organisational competitiveness and ERs (López-Gamero et al. 2010). ERs were found to be positively associated with corporate environmental responsibility (Li et al. 2017). When faced with more stringent ERs, firms became increasingly concerned about environmental problems and engaged more actively with their environmental responsibilities.

In countries where ERs are dominated by command-and-control regulations, e.g. in China, command-and-control regulations proved to have a positive impact on organisational environmental management (Zhao et al. 2015). In the construction and building sector, command-and-control ERs proved to have significant effects on the development of eco-innovation (Testa et al. 2011; Balasubramanian and Shukla 2017), with arguments that eco-innovation promoted the efficient utilisation of clean energy and resources (Yang and Wang 2013).

Therefore, the first hypothesis is proposed:

**H1: Environmental regulations (ER) are positively related to green supply chain management (GSCM) implementation.**

#### ***4.2 Environmental regulations and public-private partnerships***

A command-level ER itself is not sufficient in driving organisations to adopt green practices (Liu et al. 2019). To be compliant with ERs and achieve carbon emission reduction targets, supply chain players started to develop collaborative partnerships across all stages of supply

chain processes, including planning, forecasting, procurement, production, and replenishment (Ramanathan and Muyltermans 2010). However, there might be a distinct disconnect between knowledge, capital and projects among supply chain players and they may have different levels of resources available to fulfil the responsibilities of reducing carbon emissions (Hasan and Zhang 2016). Collaboration and cooperation between partners are required in order to share knowledge and secure progress during innovative processes (Nissen et al. 2014), e.g. the adoption of GSCM in the context of this research. PPPs are a more advanced form of collaboration and cooperation, within which experiences of successful green projects and knowledge of environmental measures are shared and facilitated by an authority, e.g. the government, which plays a strong coordinating role (Van den Hurk and Hueskes 2017). Collaboration and integration, as well as environmental policies and regulations, drive GSCM implementation in the construction industry (Mojumder and Singh 2021). Supply chain stakeholders need to act collaboratively to lead, support and train construction firms to improve their sustainability. Environmental regulations play an important role in promoting such collaboration and enforcing the adoption of GSCM. These arguments lead to the second hypothesis:

**H2: Environmental regulations (ER) are positively associated with public–private partnerships (PPPs).**

#### ***4.3 The mediation effect of governmental support***

A mediation effect indicates that a mediator is necessary for an exogenous variable to produce a result in an endogenous variable. Propelled by governmental policies, environmental issues may be addressed by technological innovation, yet the impact of command-and-control ERs on green growth performance may have a negative influence (Guo et al. 2017), or possibly have no significant influence on proactive environmental management (López-Gamero et al. 2010). Wang et al. (2021) found that ERs, as a form of governmental intervention, inhibit the efficiency of environmental measures at the early stage of economic development, but promote the efficiency of environmental protection when economic development reaches a certain stage. These findings are attributed to the fact that the effectiveness of regional governmental intervention largely depends on the local government's emphasis on economic development or environmental protection (Fredriksson and Millimet 2002). Command-and-control ERs and unbalanced governmental investment in technological advancement were found to inhibit both economic growth and carbon emission reduction in China (Liu et al. 2019). There were arguments that multifaceted support, including governments, industrial enterprises, civil

societies, and the general public, should be in place to support regulatory enforcement (Tang et al. 2010).

On the other hand, GS was believed to be more effective in driving environmental protection behaviour (Fischer and Fox 2012). To improve the effectiveness of regulatory enforcement, environment-conscious governments developed policies and strategies with which to build a better environment that would encourage the adoption of green innovations. They enacted market-based regulations to require organisations to comply with regulations and to promote proactive environmental management (López-Gamero et al. 2010). Furthermore, they implemented a wide spectrum of initiatives that address environmental issues, ranging from product-based initiatives, such as stipulating energy requirement criteria for procurement, to process-based initiatives, such as using local suppliers and offering service contracts to green contractors (Preuss 2009). In addition to regulatory pressure, governments facilitate the diffusion of innovation (Chou et al. 2012) and offer incentives in the form of subsidies or tax reductions to organisations that adopt green technologies and practices (Hsu et al. 2013).

The aforementioned arguments imply that GS may be necessary in order to achieve the effectiveness of enforcing ERs and GSCM implementation. Financial support, an effective regulatory framework, and an attractive market are all necessary for supply chain partners to adopt GSCM practices. These arguments lead to the third hypothesis:

**H3: Governmental support (GS) positively mediates the relationship between environmental regulations (ERs) and green supply chain management (GSCM).**

PPPs work as a form of privatisation and an abdication of governmental responsibility, and have been proposed as a tool with which to allow public and private players to deliver better outcomes by combining their complementary skills. However, complex projects, such as green construction, usually involve multiple players and run over a number of years; without effective GS or guarantees (with regard to risk or the minimum level of revenue), players would be discouraged from engaging in extensive and effective collaboration (Liu et al. 2009). To alleviate the level of obstruction imposed by such obstacles, the critical role of governments in PPPs has been widely discussed by researchers (Kwak et al. 2009):

- 1) Governments can create a favourable environment to attract private investors, fostering PPPs between the private and public sectors (Ye and Tiong 2000). This may involve governmental efforts in creating stable legal, economic and financial conditions, improving infrastructure (such as transport infrastructure or sanitation, recycling and recreation facilities), or guaranteeing a minimum revenue.

- 2) Governments need to establish a well-structured regulatory framework that secures proper risk allocation among PPP partners, increasing the benefits for all parties by ensuring that projects operate efficiently (Zouggari 2003).
- 3) Governments can provide financial and non-financial incentives to enhance the attractiveness of a PPP project. Financial incentives are offered in the form of subsidies, direct grants, tax incentives, loan guarantees, and discounted development application fees (Diyana and Abidin 2013), while non-financial incentives include expedited permitting, regulatory relief, business-planning assistance, and guarantee programmes (Choi 2010).
- 4) Successful PPP implementation requires its participants to possess diverse skills and expertise in various operational activities. Governments may act as a coordinating and supportive authority in reconciling conflicts between partners in PPP projects; they may set up a mechanism, such as a forum or database, that enables PPP partners to share experiences, expertise and skills acquired from different PPP implementations (Abdel Aziz 2007).

The aforementioned literature indicates that GS is necessary in incentivising, regulating, promoting and coordinating PPPs among the players in the construction industry. The literature has recognised the need for governing PPPs, inspecting the quality of infrastructure/service delivery, and introducing contractual mechanisms for cost and time control (Regeczi 2005). Thus, the following hypothesis is argued:

**H4: Governmental support (GS) positively mediates the relationship between environmental regulations (ER) and public–private partnerships (PPPs).**

#### *4.4 Serial mediation of governmental support and PPPs between environmental regulations and green supply chain management*

The literature suggests that governments play important roles in improving the financial viability of a PPP project, as well as in fostering PPPs among organisations (Cimato and Mullan 2010), forcing and incentivising them to comply with environmental standards and regulations (Mojumder and Singh 2021). On the one hand, PPPs offer ways for governments to simultaneously manage rising costs and reduce governmental budgets (Blanken and Dewulf 2010; Bosakova et al. 2019), while, concurrently, PPPs prove to be effective in mediating between governmental levels, fostering networking amid public and private actors, sharing resources, and eventually facilitating the implementation of green practices across levels of

government and across societal domains (Bauer and Steurer 2014). PPPs essentially represent collaborative arrangements, advancing the development of green policies and green infrastructure and acting as an effective platform for environmental knowledge and practice diffusion (Lee 2014).

The aforementioned findings suggest that GS and PPPs may play mediating roles in a serial causal order between ERs and GSCM; in other words, ERs impact the provision of GS, in turn affecting the development of PPPs among organisations. Both GS and PPPs affect the implementation of GSCM. Therefore:

**H5: Governmental support (GS) and public–private partnerships (PPPs) serially mediate the relationship between environmental regulations (ERs) and green supply chain management (GSCM).**

#### *4.5 Green supply chain management and environmental performance*

Past empirical studies (Murphy and Gouldson 2000; Zhu et al. 2007) suggested that ERs can establish the imperative for adopting green practices to improve environmental performance. ERs and governmental subsidies have positively impacted efficiency improvement and carbon emission reductions, but ERs themselves often fail to incentivise organisations to incorporate environmental issues as a strategic concern so as to promote radical innovations. Ultimately, organisations' limits make it impossible to continually realise medium- or long-term economic and environmental improvements.

GSCM promotes efficiency and synergy among supply chain players, focusing on improving environmental performance while associating economic performance with green practices (Liu et al. 2018). The five GSCM practices prove to be effective in improving economic and environmental performance (Geng et al. 2017), but environmental practices at supply chain levels usually result in greater environmental performance and less significant economic performance (Liu et al. 2018). Many studies in the first decade of the 21<sup>st</sup> century investigated the five GSCM practices and their connection with improved environmental, economic and operational performance (Yang et al. 2013; Zhu et al. 2013; Perotti et al. 2012).

GSCM practices, such as internal environmental practices, have proved to significantly, and positively, impact environmental performance (Ahmed and Najmi 2018). A recent study conducted by Seman et al. (2019) found that green innovation had a significant positive effect on environmental performance. Green innovation improved organisational resilience and adaptability, enabling organisations to make continuous cost-saving improvements and comply

with ERs. GSCM encompasses green innovation along with all of the supply chain processes and activities, including green products and process innovation. Therefore, the following hypothesis is proposed:

**H6: Green supply chain management (GSCM) implementation is positively associated with environmental performance (EnvPerf).**

#### *4.6 Green supply chain management and economic performance*

Short-term economic benefits are achieved when the implementation of GSCM makes construction supply chain activities and processes more resource-efficient, leading to reduced costs and, thus, contributing to economic gains. Cost advantages derived from reduced costs in waste generation and disposal, carbon emission tax, and resource consumption (Galdeano-Gómez et al. 2008; López-Gamero et al. 2010) provide evidence that higher cost savings are gained from the implementation of enhanced green innovation. Therefore, the seventh hypothesis is proposed:

**H7: Green supply chain management (GSCM) implementation is positively associated with short-term economic performance (EcoPerf-S).**

Despite the short-term economic benefits attained from reduced costs in waste management and resource use, it is important to examine how GSCM can lead to medium- and long-term economic benefits which are associated with industrial modernisation, improved corporate reputation, and competitiveness in the market.

Implementing GSCM involves adopting green innovations in procurement, product/process design, production, and transportation, all of which allow organisations to develop differentiation advantages (Molina-Azorín et al. 2009), develop new market opportunities, and gain competitive advantages (López-Gamero et al. 2010). Previous studies showed that implementing green innovation enabled organisations to become pioneers that enjoyed higher profits with an improved corporate green image, product differentiation advantages (Chen et al. 2006), and higher customer satisfaction (Tang et al. 2012). As pioneers of delivering new green products, organisations must provide customers with unique, distinctive products, creating the perception of value for money and increasing their competitive advantages. A powerful corporate image will lead to a strong reputation among customers, further enhancing organisations' competitiveness in the market and, in turn, helping them to increase their market share and profits, all whilst having a positive impact on the organisations' medium- and long-

term economic performance (López-Gamero et al. 2010). Therefore, the eighth hypothesis is proposed:

**H8: Green supply chain management (GSCM) implementation is positively associated with medium- and long-term economic performance (EcoPerf-ML).**

## **5. Research methods**

### ***5.1 Instrument development***

A pretested questionnaire was used to collect data from the Chinese construction sector from May to October 2019. The questionnaire was tested and revised through a pilot study with six mid-level managers in the construction sector in Shandong Province, China; they were asked to review the survey instrument in terms of its structure, readability, ambiguity and completeness. Based on suggestions from the respondents, modifications were made to the questionnaire by removing repeated items and further clarifying questions. The constructs used in the model were operationalised as reflective constructs. The underlying measurement items of each construct are summarised in Appendix 1.

#### ***5.1.1 Measuring importance of environmental regulations***

A three-item scale was developed in order to measure the importance of ERs for the participating organisations' implementation of GSCM (see Appendix 1). The items were derived from a review of relevant literature (Zhu et al. 2008; Zhu et al. 2013) and of ERs, carbon emission targets, and resource conservation policies at both national and regional levels. The respondents were asked to evaluate the importance of ERs through the use of a five-point Likert scale (1=unimportant, 2=slightly important, 3=moderately important, 4=important, and 5=very important).

#### ***5.1.2 Measuring level of governmental support***

A four-item scale was derived from Holt et al. (2001), Brandao and Saraiva (2008), Lee et al. (2008) and Hwang and Tan (2012) to evaluate the forms of GS received by the participants. GS encompasses: 1) government creating a regulatory framework for risk allocation; 2) government acting as a coordinating authority; 3) government providing financial and non-financial incentives; and 4) government creating a favourable environment. The respondents were asked to specify their level of agreement with the aforementioned statements on GS by means of a five-point Likert scale (1=strongly disagree, 2=disagree, 3=neutral, 4=agree, and 5=strongly agree).

### **5.1.3 Measuring forms of PPPs**

A three-item scale was developed on the basis of existing literature, including Regeczi (2005), Blanken et al. (2010), Bauer and Steurer (2014), Bosakova et al. (2019) and Schneider et al. (2019). PPPs can exist in various forms, including:

- i. Government providing training and education on green innovations (Bauer and Steurer 2014).
- ii. Programmes partially funded by government that encourage collaboration between industries and research institutions to advance state-of-the-art low-carbon technologies and green practices, such as knowledge transfer partnerships (Carrillo et al. 2006).
- iii. Partnerships coordinated by government or research organisations whereby early adopters of GSCM (Zhu et al. 2012), which can be industries, cities or districts, share industry best practices and advanced knowledge to accelerate urban efficiency initiatives.

The respondents were asked to specify their level of agreement with the aforementioned statements on PPPs via a five-point Likert scale (1=strongly disagree, 2=disagree, 3=neutral, 4=agree, and 5=strongly agree).

### **5.1.4 Measuring extent of GSCM implementation**

Referring to the GSCM practices summarised in Table 1, we identified six GSCM practices for the construction industry and used them to develop the construct measurements in Appendix 1 (Wibowo et al. 2018; Balasubramanian and Shukla 2017), consisting of: 1) eco-design; 2) cleaner production; 3) green purchasing; 4) reducing, reusing, recycling and recovering materials; 5) cooperation with contractors and subcontractors towards environmental objectives; and 6) green transportation.

The respondents were also requested to evaluate the perceived extent of GSCM implementation through the use of a five-point Likert-type scale (1=no consideration of implementation, 2=planning to consider implementation, 3=considering implementation, 4=being implemented, and 5=successful implementation).

### **5.1.5 Measuring environmental performance and economic performance**

As discussed in Section 2.4, performance was classified into environmental performance (EnvPerf), short-term economic performance (EcoPerf-S), and medium- and long-term economic performance (EcoPerf-ML). A three-item scale was used to measure short-term economic performance, focusing on cost savings from reduced waste, reduced waste disposal,

energy consumption reduction, reduced material costs, and the subsequent economic efficiency (Laari et al. 2016; Jiang et al. 2020). Medium- and long-term economic performance is gained from an improved corporate green image, process reengineering, improved productivity and capacity, and market share increment (Fraj et al. 2013); as such, a list of seven items was adopted in order to measure this construct (López-Gamero et al. 2010; Tang et al. 2012; Molina-Azorín et al. 2009). Environmental performance (EnvPerf) focuses on reduced carbon emissions, reduced waste production, reduced energy use, and reduced consumption of hazardous materials (Jabbour et al. 2015; Jadhav et al. 2019). Four items were developed in order to measure this construct.

The respondents were asked to evaluate the significance level of performance improvement caused by GSCM implementation, again using a five-point Likert-type scale (1=insignificant, 2=minor, 3=moderate, 4=major, and 5=significant).

## ***5.2 Data collection***

The data were collected using convenience sampling. From May to October 2019, a total of 408 surveys were distributed to Chinese contractors and suppliers of building materials through subsidies of the Municipal Housing and Urban-Rural Development Bureaus (MH-URDB) in Shandong Province. The contractors are based in various cities around China but undertake construction projects across the country and overseas; therefore, their motivations for implementing GSCM could be influenced by the ERs and GS issued through the municipal governments in which construction projects take place. As suppliers of materials have manufacturing plants in Shandong Province, their activities in relation to implementing GSCM are largely influenced by local ERs or standards in Shandong, despite distributing their products across China. The equipment or materials used in the construction projects are sourced from local, national or international suppliers.

**The survey was conducted at three major conferences organised by MH-URDB subsidies, which were held in May, June and July 2019. The participants at each conference were different and encouraged to complete the survey in hard copy form before returning it at the end of the conference; however, some participants took the questionnaire with them and returned it several months after the conference. Structured questionnaires, along with a cover letter, were distributed to the conference participants, and explained the aim and methodologies in relation to the research. A total of 103 complete and valid responses were received at the end of the conferences, i.e. during the**

first wave from May to July 2019, while another 126 valid responses were received during the second wave (from August to October 2019). It is worth noting that responses received during the second wave were not classified by which conference the respondents attended; therefore, the responses received from August to October 2019 may be from participants at any of the three conferences. This approach is suitable for research in the uniquely Chinese social and cultural context, wherein business activities are largely influenced by personal relationships and networks (Baruch and Holtom 2008). Personal relationships and support from the MH-URDB significantly improved the response rate. In total, 229 completed questionnaires were received, and the characteristics of the survey participants are presented in Table 2.

The sample size must be large enough to achieve reliability of the parameter estimates, a model fit, and statistical power (Peng and Lai 2012). Setting the statistical power at 0.95, the effect size at 0.15, and the significance level at 0.05, the minimum sample size a priori was calculated to be 178 by means of the software G\*Power (Faul et al. 2009). Indeed, this shows that our sample size of 229 is adequate to produce reliable parameter estimates and fit models at a statistical power of 0.95.

*Table 2. Profile of survey respondents*

	<b>Responses</b>	<b>Percentage</b>
<b>Ownership</b>		
Foreign or joint venture	145	63%
Private sector	40	17%
State-owned	44	20%
<b>Industrial sector</b>		
Contractors	116	51%
Suppliers of building materials	113	49%
<b>Firm size</b>		
Small (<250)	36	16%
Medium (250–2000)	147	64%
Large (>2000)	46	20%
<b>Total</b>	229	

### **5.3 Non-response bias**

The analysis of variance technique was used to test the non-response bias from the data collection (Armstrong and Overton 1977; Chen and Paulraj 2004). The 126 late respondents (i.e. respondents who returned their responses from August to October 2019) were more likely to be non-respondents; thus, a comparison between the 103 early respondents (i.e. respondents who returned their responses from May to July 2019) and the 126 late respondents was

conducted (Gunasekaran et al. 2017). The non-response bias was determined by comparing the respondents to the non-respondents based on their demographic characteristics (i.e. ownership, industrial sector, and firm size) by means of chi-square analysis. The results of the chi-square analysis are presented in Table 3, showing that there are no significant differences between the two groups in terms of demographic characteristics at the 5% level of significance, leading to the conclusion that the respondents did not differ from the non-respondents. Therefore, it is reasonable to combine the samples collected during the two periods for data analysis.

**Table 3. Chi-square test results for non-response bias test**

<b>Demographic Characteristics</b>	$\chi^2$	<b>P-value</b>
Ownership	0.266	0.875
Industrial sector	0.410	0.519
Firm size	0.423	0.810

**5.4 ANOVA of responses**

We compared the responses received from organisations with different demographic characteristics, i.e. ownership, industrial sector, and firm size. Descriptive statistics of the constructs of ER, GS, PPPs, GSCM, EcoPerf-S, EcoPerf-ML and EnvPerf, as well as the measurement items under them, are presented in Table 4. In order to evaluate whether any significant differences exist in the ERs, GS, PPPs and GSCM experienced by the organisations, and whether there is any significant difference in the performance achieved by those organisations, we performed a one-way ANOVA. The ANOVA results across different ownerships, industrial sectors, and firm sizes, and their significance values (p-values), are presented in Table 4.

The ANOVA results show that no significant difference (at the 5% significance level) exists in any of the constructs across different organisations. The means that the constructs of ER, GS, PPP and GSCM are above 4.30 (regardless of the ownership, industrial sector, or firm size). The results indicate that ERs seemed to exert strong pressure upon the surveyed organisations, and governments seemed to be very supportive of them, which led to a high level of partnership between the public and private sectors and, ultimately, a high level of GSCM implementation. However, the GSCM implementation did not seem to cause much economic or environmental performance improvement. The means of EcoPerf-S vary with ownership, industrial sector, and

firm size, ranging from 2.93 to 3.27, which shows that the surveyed organisations acknowledged moderate improvement in short-term economic performance (2=minor, 3=moderate, 4=major). The means of EcoPerf-ML and EnvPerf are between 3.0 and 4.0, indicating that moderate improvement was made in these performances.

*Table 4 Comparison of responses by firm size, ownership and industry sector*

Constructs and Items	Ownership	Mean	Std. Deviation	ANOVA (p-value)	Industrial Sector	Mean	Std. Deviation	ANOVA (p-value)	Firm Size	Mean	Std. Deviation	ANOVA (p-value)
<b>ER</b>	<b>Foreign or JV</b>	<b>4.38</b>	<b>0.480</b>	<b>0.933</b>	<b>Contractors</b>	<b>4.34</b>	<b>0.496</b>	<b>0.260</b>	<b>Small</b>	<b>4.31</b>	<b>0.508</b>	<b>0.401</b>
	<b>Private</b>	<b>4.36</b>	<b>0.564</b>		<b>Building materials</b>	<b>4.41</b>	<b>0.502</b>		<b>Medium</b>	<b>4.41</b>	<b>0.489</b>	
	<b>State-owned</b>	<b>4.39</b>	<b>0.496</b>		<b>Large</b>	<b>4.32</b>	<b>0.528</b>					
ER1	Foreign or JV	4.37	0.615	0.670	Contractors	4.31	0.590	0.046*	Small	4.29	0.622	0.135
	Private	4.42	0.723		Building materials	4.48	0.647		Medium	4.46	0.597	
	State-owned	4.46	0.569		Large	4.29	0.708					
ER2	Foreign or JV	4.42	0.695	0.862	Contractors	4.34	0.763	0.190	Small	4.31	0.718	0.685
	Private	4.36	0.645		Building materials	4.46	0.620		Medium	4.43	0.687	
	State-owned	4.42	0.731		Large	4.40	0.701					
ER3	Foreign or JV	4.36	0.752	0.526	Contractors	4.38	0.680	0.200	Small	4.34	0.765	0.950
	Private	4.24	0.802		Building materials	4.25	0.849		Medium	4.31	0.748	
	State-owned	4.25	0.808		Large	4.29	0.891					
<b>GS</b>	<b>Foreign or JV</b>	<b>4.44</b>	<b>0.455</b>	<b>0.988</b>	<b>Contractors</b>	<b>4.40</b>	<b>0.490</b>	<b>0.307</b>	<b>Small</b>	<b>4.37</b>	<b>0.498</b>	<b>0.221</b>
	<b>Private</b>	<b>4.43</b>	<b>0.513</b>		<b>Building materials</b>	<b>4.46</b>	<b>0.460</b>		<b>Medium</b>	<b>4.47</b>	<b>0.461</b>	
	<b>State-owned</b>	<b>4.42</b>	<b>0.495</b>		<b>Large</b>	<b>4.34</b>	<b>0.497</b>					
GS1	Foreign or JV	4.51	0.641	0.967	Contractors	4.44	0.631	0.188	Small	4.31	0.718	0.143
	Private	4.49	0.589		Building materials	4.55	0.618		Medium	4.53	0.608	
	State-owned	4.49	0.630		Large	4.57	0.590					
GS2	Foreign or JV	4.24	0.695	0.488	Contractors	4.24	0.682	0.472	Small	4.29	0.667	0.160
	Private	4.38	0.650		Building materials	4.31	0.681		Medium	4.32	0.667	
	State-owned	4.28	0.675		Large	4.28	0.681		Large	4.10	0.726	
GS3	Foreign or JV	4.53	0.589	0.647	Contractors	4.46	0.647	0.482	Small	4.46	0.611	0.653
	Private	4.44	0.693		Building materials	4.52	0.593		Medium	4.52	0.609	
	State-owned	4.46	0.629		Large	4.49	0.619		Large	4.43	0.668	
GS4	Foreign or JV	4.50	0.616	0.767	Contractors	4.46	0.587	0.678	Small	4.43	0.655	0.136
	Private	4.42	0.583		Building materials	4.50	0.607		Medium	4.53	0.563	
	State-owned	4.49	0.571		Large	4.48	0.597		Large	4.33	0.650	
<b>PPPs</b>	<b>Foreign or JV</b>	<b>4.44</b>	<b>0.465</b>	<b>0.280</b>	<b>Contractors</b>	<b>4.41</b>	<b>0.491</b>	<b>0.587</b>	<b>Small</b>	<b>4.37</b>	<b>0.519</b>	<b>0.159</b>
	<b>Private</b>	<b>4.34</b>	<b>0.561</b>		<b>Building materials</b>	<b>4.45</b>	<b>0.466</b>		<b>Medium</b>	<b>4.47</b>	<b>0.455</b>	
	<b>State-owned</b>	<b>4.48</b>	<b>0.427</b>		<b>Large</b>	<b>4.33</b>	<b>0.509</b>					
PPPs1	Foreign or JV	4.55	0.613	0.597	Contractors	4.48	0.603	0.315	Small	4.51	0.658	0.948
	Private	4.44	0.624		Building materials	4.56	0.604		Medium	4.53	0.597	
	State-owned	4.53	0.570		Large	4.50	0.595		Large	4.50	0.595	
PPPs2	Foreign or JV	4.33	0.702	0.405	Contractors	4.34	0.738	0.836	Small	4.31	0.718	0.100
	Private	4.22	0.876			4.32	0.744		Medium	4.39	0.729	

	State-owned	4.42	0.706		Building materials				Large	4.12	0.772	
PPPs3	Foreign or JV	4.42	0.660	0.371	Contractors	4.40	0.626	0.710	Small	4.23	0.646	0.073
	Private	4.31	0.668		Building materials	4.43	0.656		Medium	4.48	0.609	
	State-owned	4.49	0.571		Building materials				Large	4.33	0.721	
<b>GSCM</b>	<b>Foreign or JV</b>	<b>4.36</b>	<b>0.427</b>	<b>0.650</b>	<b>Contractors</b>	<b>4.36</b>	<b>0.461</b>	<b>0.472</b>	<b>Small</b>	<b>4.40</b>	<b>0.435</b>	<b>0.783</b>
	<b>Private</b>	<b>4.40</b>	<b>0.509</b>		<b>Building materials</b>	<b>4.41</b>	<b>0.434</b>		<b>Medium</b>	<b>4.40</b>	<b>0.452</b>	
	<b>State-owned</b>	<b>4.43</b>	<b>0.441</b>		<b>Building materials</b>				<b>Large</b>	<b>4.34</b>	<b>0.444</b>	
GSCM1	Foreign or JV	4.31	0.675	0.494	Contractors	4.31	0.665	0.656	Small	4.37	0.547	0.129
	Private	4.44	0.659		Building materials	4.36	0.705		Medium	4.38	0.680	
	State-owned	4.30	0.731		Building materials				Large	4.14	0.783	
GSCM2	Foreign or JV	4.40	0.693	0.836	Contractors	4.39	0.681	0.455	Small	4.40	0.651	0.974
	Private	4.47	0.661		Building materials	4.45	0.645		Medium	4.43	0.667	
	State-owned	4.44	0.598		Building materials				Large	4.43	0.668	
GSCM3	Foreign or JV	4.31	0.663	0.174	Contractors	4.37	0.678	0.913	Small	4.40	0.695	0.962
	Private	4.53	0.661		Building materials	4.38	0.674		Medium	4.38	0.659	
	State-owned	4.39	0.701		Building materials				Large	4.36	0.727	
GSCM4	Foreign or JV	4.48	0.653	0.457	Contractors	4.46	0.676	0.781	Small	4.46	0.701	0.843
	Private	4.38	0.806		Building materials	4.49	0.660		Medium	4.49	0.661	
	State-owned	4.54	0.569		Building materials				Large	4.43	0.668	
GSCM5	Foreign or JV	4.32	0.700	0.003**	Contractors	4.25	0.685	0.313	Small	4.26	0.741	0.901
	Private	4.00	0.826		Building materials	4.35	0.761		Medium	4.32	0.758	
	State-owned	4.49	0.630		Building materials				Large	4.29	0.596	
GSCM6	Foreign or JV	4.34	0.657	0.291	Contractors	4.38	0.637	0.770	Small	4.49	0.562	0.627
	Private	4.51	0.661		Building materials	4.40	0.666		Medium	4.37	0.668	
	State-owned	4.42	0.625		Building materials				Large	4.40	0.665	
<b>EcoPerf-S</b>	<b>Foreign or JV</b>	<b>3.06</b>	<b>0.998</b>	<b>0.994</b>	<b>Contractors</b>	<b>3.11</b>	<b>1.004</b>	<b>0.519</b>	<b>Small</b>	<b>3.21</b>	<b>0.963</b>	<b>0.474</b>
	<b>Private</b>	<b>3.08</b>	<b>1.021</b>		<b>Building materials</b>	<b>3.02</b>	<b>0.999</b>		<b>Medium</b>	<b>3.07</b>	<b>0.983</b>	
	<b>State-owned</b>	<b>3.05</b>	<b>1.005</b>		<b>Building materials</b>				<b>Large</b>	<b>2.93</b>	<b>1.095</b>	
EcoPerf-S1	Foreign or JV	3.48	1.140	0.313	Contractors	3.53	1.106	0.994	Small	3.63	1.060	0.821
	Private	3.42	1.158		Building materials	3.53	1.119		Medium	3.50	1.116	
	State-owned	3.72	0.996		Building materials				Large	3.55	1.152	
EcoPerf-S2	Foreign or JV	2.81	1.314	0.609	Contractors	2.82	1.267	0.515	Small	3.09	1.292	0.148
	Private	2.82	1.319		Building materials	2.71	1.351		Medium	2.76	1.290	
	State-owned	2.61	1.306		Building materials				Large	2.50	1.366	
EcoPerf-S3	Foreign or JV	2.87	1.184	0.753	Contractors	2.93	1.197	0.388	Small	2.94	1.187	0.542
	Private	2.93	1.304		Building materials	2.79	1.260		Medium	2.88	1.218	
	State-owned	2.75	1.286		Building materials				Large	2.67	1.319	
<b>EcoPerf-ML</b>	<b>Foreign or JV</b>	<b>3.31</b>	<b>0.948</b>	<b>0.947</b>	<b>Contractors</b>	<b>3.42</b>	<b>0.916</b>	<b>0.055</b>	<b>Small</b>	<b>3.59</b>	<b>0.869</b>	<b>0.137</b>

	<b>Private</b>	<b>3.26</b>	<b>0.910</b>		<b>Building materials</b>	<b>3.18</b>	<b>0.971</b>		<b>Medium</b>	<b>3.24</b>	<b>0.939</b>	
	<b>State-owned</b>	<b>3.28</b>	<b>1.004</b>						<b>Large</b>	<b>3.24</b>	<b>1.035</b>	
EcoPerf-ML1	Foreign or JV	3.20	1.215	0.779	Contractors	3.29	1.160	0.142	Small	3.71	1.073	0.010*
	Private	3.20	1.057		Building materials	3.06	1.185		Medium	3.05	1.159	
	State-owned	3.07	1.193		Large	3.14	1.221					
EcoPerf-ML2	Foreign or JV	3.67	1.162	0.775	Contractors	3.82	1.092	0.076	Small	3.86	1.115	0.598
	Private	3.62	1.134		Building materials	3.56	1.125		Medium	3.64	1.100	
	State-owned	3.77	1.000		Large	3.69	1.179					
EcoPerf-ML3	Foreign or JV	3.56	1.029	0.364	Contractors	3.62	1.039	0.040	Small	3.89	1.051	0.036
	Private	3.36	1.048		Building materials	3.34	1.021		Medium	3.39	1.004	
	State-owned	3.37	1.046		Large	3.40	1.083					
EcoPerf-ML4	Foreign or JV	3.39	1.084	0.206	Contractors	3.45	1.045	0.017*	Small	3.60	1.090	0.153
	Private	3.11	1.071		Building materials	3.11	1.117		Medium	3.22	1.067	
	State-owned	3.14	1.125		Large	3.19	1.174					
EcoPerf-ML5	Foreign or JV	3.30	1.115	0.956	Contractors	3.36	1.098	0.310	Small	3.54	1.039	0.326
	Private	3.24	1.190		Building materials	3.21	1.190		Medium	3.24	1.151	
	State-owned	3.26	1.203		Large	3.19	1.215					
EcoPerf-ML6	Foreign or JV	3.09	1.116	0.460	Contractors	3.31	1.165	0.094	Small	3.43	1.065	0.377
	Private	3.31	1.125		Building materials	3.06	1.142		Medium	3.13	1.175	
	State-owned	3.26	1.275		Large	3.17	1.167					
EcoPerf-ML7	Foreign or JV	3.13	1.136	0.370	Contractors	3.34	1.112	0.090	Small	3.29	1.100	0.909
	Private	3.20	1.079		Building materials	3.09	1.118		Medium	3.20	1.104	
	State-owned	3.39	1.114		Large	3.19	1.215					
<i>EnvPerf</i>	<b>Foreign or JV</b>	<b>3.28</b>	<b>1.139</b>	<b>0.493</b>	Contractors	<b>3.50</b>	<b>0.967</b>	<b>0.540</b>	<b>Small</b>	<b>3.69</b>	<b>0.927</b>	<b>0.279</b>
	<b>Private</b>	<b>3.31</b>	<b>1.083</b>		Building materials	<b>3.42</b>	<b>0.956</b>		<b>Medium</b>	<b>3.43</b>	<b>0.968</b>	
	<b>State-owned</b>	<b>3.58</b>	<b>1.068</b>		<b>Large</b>	<b>3.37</b>	<b>0.949</b>					
EnvPerf1	Foreign or JV	3.28	1.139	0.222	Contractors	3.39	1.151	0.693	Small	3.51	1.095	0.501
	Private	3.31	1.083		Building materials	3.33	1.083		Medium	3.36	1.125	
	State-owned	3.58	1.068		Large	3.21	1.094					
EnvPerf2	Foreign or JV	3.29	1.077	0.337	Contractors	3.41	1.059	0.760	Small	3.66	1.056	0.238
	Private	3.53	1.120		Building materials	3.36	1.103		Medium	3.36	1.076	
	State-owned	3.47	1.054		Large	3.26	1.106					
EnvPerf3	Foreign or JV	3.30	1.064	0.330	Contractors	3.43	1.061	0.661	Small	3.57	1.065	0.531
	Private	3.49	1.079		Building materials	3.36	1.080		Medium	3.38	1.066	
	State-owned	3.53	1.071		Large	3.31	1.093					
EnvPerf4	Foreign or JV	3.59	1.108	0.926	Contractors	3.68	1.101	0.408	Small	3.91	1.011	0.216
	Private	3.67	1.066		Building materials	3.55	1.125		Medium	3.55	1.144	
	State-owned	3.61	1.176		Large	3.57	1.063					

\*\*\* p<0.001, \*\* p<0.01, \*p<0.05

### ***5.5 Statistical analysis and findings***

PLS\_SEM was used to analyse the empirical data and test the hypothesised relationships, as shown in Figure 2. The data consist primarily of perceptual measures, and the hypotheses represent a series of relationships that include exogenous and endogenous variables. There are a number of reasons as to why PLS\_SEM is chosen (Kaufmann and Gaeckler 2015):

- 1) Exploratory research and focusing on prediction: as opposed to covariance-based (CB) SEM, PLS\_SEM tends to focus primarily on the predictive power of a hypothesised model (Davcik 2014), and is a preferred method for exploratory research.
- 2) Non-normal data and small sample size: PLS\_SEM is able to achieve high levels of statistical power with small sample sizes, and its nonparametric nature enables it to handle data that fail to meet a parametric assumption, such as multivariate normality distribution (Hair et al. 2014).
- 3) Formative construct: PLS\_SEM can handle formative constructs without leading to unidentified models; the reason is that the algorithms performed in a PLS analysis are a series of ordinary least squares recursive models (Peng and Lai 2012), and identification is not a problem for recursive models.

For the aforementioned reasons, the application of PLS\_SEM in the area of GSCM has experienced increasing popularity in recent years. Vanalle et al. (2017) explored the relationships between GSCM pressures, practices, and environmental and economic performance via PLS\_SEM based on 41 samples. With a sample size of 123, Seman et al. (2019) performed PLS-SEM to test GSCM practices, green innovation, and the consequent environmental performance. Ahmed and Najmi (2018) collected data from 174 manufacturing firms and used PLS-SEM to test the influence of leadership and institutional pressures upon firms' adoption of GSCM and the resultant environmental and economic performance.

In this study, the proposed relationships between constructs were guided by distinct theories, namely the relationships between ERs, GS, PPPs, GSCM, and performance improvement. However, these relationships were not examined or tested in the literature, and therefore the present research is exploratory. The normality distribution of data considered in this research was not confirmed either. As such, PLS\_SEM was chosen as a suitable technique for data analysis (Dubey et al. 2018). Anderson and Gerbing (1988) recommended that a two-step approach be used to test hypotheses: 1) testing the measurement model to examine the validity and reliability of the scales used in analysis, and 2) testing and analysing the structural relationships between constructs.

## ***5.6 Control variables***

Although there was no significant difference in the average responses attributable to the ownership, industrial sector, and firm size, the following items were modelled as control variables in the structural model in order to check whether they influence structural relationships and path coefficients between the constructs: i) ownership, ii) industrial sector, and iii) firm size. Each control variable was modelled as several dummy variables. For example, ownership was modelled as two dummy variables, with the first dummy variable being set equal to 1 for a Foreign or Joint Venture and 0 otherwise (Foreign or JV); meanwhile, the second dummy variable was set equal to 1 for a State-Owned Organisation and 0 otherwise (State-Owned), with the category of Private (Private) being treated as the base group. Similarly, the industrial sector variable was modelled as one dummy variable, i.e. BuildingM (BuildingM=1 refers to Building Materials), and the category of Contractors (Contractors) was used as the base group; meanwhile, the firm size variable was modelled as two dummy variables, namely Large and Medium, with the category of Small being the base group. The ownership variable accounts for the business strategy, the relationship with government, compliance with ERs, etc., while the industrial sector variable accounts for the nature of the business and differences in business processes; the firm size variable was included so as to account for available resources and differences in the organisational structure. These control variables were entered into the construct of GSCM in the model, since the ownership, industrial sector, and firm size may account for variations between firms in relation to the extent to which they implement GSCM practices.

## ***5.7 Measurement model reliability and validity***

To ascertain whether the measures satisfied all requirements of reliability and validity (Chen and Paulraj 2004), the following tests were used: 1) scale composite reliability (SCR) to check the internal consistency; 2) factor loadings to evaluate the inter-item reliability (Hair et al. 2016); 3) the average variance extracted (AVE) to assess the convergent validity; and 4) the heterotrait-monotrait ratio of the correlations (HTMT) between the constructs to evaluate the discriminant validity (Kline 2005). The results of these tests are presented in Appendix 1, showing that the SCRs are above 0.7 and that the AVE for each construct is above 0.5. The HTMT ratios between paired constructs are below 0.90, as shown in Appendix 2. All measures indicate adequate reliability and validity (Fornell and Larcker 1981; Peng and Lai 2012).

**Common method bias:** In PLS-SEM, common method bias can be assessed using the VIF values. According to Kock (2015), if all VIFs resulting from a full collinearity test are equal to

or below 3.3, a model can be considered free of common method bias. The highest VIF values of GS and PPPs are 1.718 and 1.862 (see Appendix 3); therefore, common method bias is unlikely to affect the results.

### ***5.8 Structural model assessment***

Having confirmed the construct measures as being reliable and valid, an assessment of the validity of the structural model was performed by examining its collinearity and explanatory and predictive power.

**Collinearity:** Collinearity was examined between ER, GS, PPP and GSCM, as they serve as predictors. The VIF values of these variables range from 1.000 to 1.862, well below the threshold of 10, which provides confidence that the results of the structural model are not negatively affected by collinearity.

**Explanatory and predictive power:** The coefficient of determination of  $R^2$  was examined to determine the explanatory power of the proposed model in Figure 2(a). The values of  $R^2$  achieved for the endogenous variables of GS, PPP, GSCM, EcoPerf-S, EcoPerf-ML and EnvPerf are presented in Table 5. The values of GS, PPP and GSCM are above the suggested threshold of 0.10 (Falk and Miller 1992). Chin (1998) described results above the thresholds of 0.67, 0.33 and 0.19 as being “substantial”, “moderate” and “weak”, respectively. Therefore, the  $R^2$  shown in Table 5 would be considered to be of moderate strength in explaining the variables of GSCM and PPP, with relatively weak GS prediction. Considering the multitude of potential antecedents of GS, the  $R^2$  of this construct was considered to be acceptable. GSCM recorded the highest  $R^2$  value of 0.479, indicating that ER, GS and PPP accounted for 47.9% of the total variance in GSCM. Similarly, 22.3% of the total variance in GS can be assessed by ER, and 45.0% of the total variance in PPP is accounted for by ER and GS. The  $R^2$  values of EcoPerf-S, EcoPerf-ML and EnvPerf are lower than the threshold of 0.10, indicating the extremely weak explanatory power of GSCM for these endogenous variables.  $R^2$  is a measure of explanatory power, which can be low if other relevant predictors are not included in order to explain the outcome variables. In our structural model, only GSCM was included so as to explain the three types of performance, i.e. EcoPerf-S, EcoPerf-ML and EnvPerf. The low  $R^2$  means that the variance in economic and environmental performance could be attributed to the absence of other important predictors such as demand, market size, supply, leadership, business strategy, organisational culture, employee engagement, etc.

Blindfolding analysis was performed to assess the model’s predictive relevance (with an omission distance of 7). Cross-validated redundancy values of  $Q^2$  were obtained for all of the

endogenous constructs (see Table 5), with all values being above 0, thereby indicating acceptable predictive relevance at the construct level (Peng and Lai 2012).

*Table 5. The explanatory and predictive power of the model*

	$R^2$	$Q^2$
GSCM	0.479	0.183
GS	0.223	0.116
PPPs	0.450	0.184
EcoPerf-S	0.016	0.006
EcoPerf-ML	0.009	0.002
EnvPerf	0.020	0.012

### 5.9 Testing of the hypotheses

Path analysis was chosen for examining the causal relationships between the endogenous and exogenous variables. Even though GSCM accounts for very low variance in the three types of performance (EcoPerf-S, EcoPerf-ML and EnvPerf), we are interested in the causal relationships between GSCM and each of these, i.e. if an increase (reduction) in the level of GSCM implementation leads to an increase (reduction) in economic and environmental performance. This is consistent with prior works on GSCM practices and the resultant performance (Zhu et al. 2013).

In the structural model, the direct and indirect effects which the exogenous variables had on the endogenous variables were calculated, illustrating the nature of the relationships between them. The path coefficient beta ( $\beta$ ) is a measure that evaluates the magnitude of change in each endogenous variable caused by the exogenous variable. In this study, SmartPLS was used to calculate the path coefficients, test the hypotheses, and assess the significance of the path coefficients (Anderson and Gerbing 1988). Bootstrapping with 5,000 samples was performed to determine the structural equation model and the significance level of the parameter estimates (Hair et al. 2016). The results of the hypothesis testing, i.e. the beta ( $\beta$ ) values of the paths, the control variables, and their corresponding p-values, are summarised in Table 6.

*Table 6. Path coefficients and significance of control variables*

Hypotheses	Relationships	Beta	P-values	Results	Mediation
1	ER->GSCM	0.357	0.000***	Supported	
2	ER->PPPs	0.299	0.000***	Supported	
3	ER->GS->GSCM	0.116	0.001***	Supported	Partial
4	ER->GS->PPPs	0.230	0.000***	Supported	Partial
5	ER->GS->PPPs->GSCM	0.056	0.004***	Supported	Partial
6	GSCM->EnvPerf	0.147	0.032*	Supported	
7	GSCM->EcoPerf-S	0.139	0.042*	Supported	
8	GSCM->EcoPerf-ML	0.098	0.380	Unsupported	
Control variables	Relationships	Beta	P-values	Results	
Medium	Medium->GSCM	-0.099	0.212	Insignificant	
Large	Large->GSCM	-0.044	0.534	Insignificant	
Foreign or JV	Foreign or JV->GSCM	-0.081	0.218	Insignificant	
State-owned	State-owned->GSCM	-0.006	0.949	Insignificant	
BuildingM	BuildingM->GSCM	0.001	0.956	Insignificant	

\*\*\* p<0.001, \*\* p<0.01, \*p<0.05

H1 and H2 (0.357 and 0.299 respectively) posit that there is a positive relationship between ERs and GSCM as well as a positive relationship between ERs and PPPs; the results in Table 3 fully support these hypotheses, showing that ERs compel construction companies to implement GSCM and develop PPPs. The above results support previous findings (Zhu et al. 2007; Zhu et al. 2008; Wong 2010; Hwang and Tan 2012).

Following the recommendations of Preacher and Hayes (2004), this paper tested the indirect effects of the mediators in performing bootstrapping (see Table 5). The path coefficients of H3 and H4 (0.116 and 0.230 respectively) indicate that GS has a partial mediation effect on the relationship between ERs and GSCM, as well as on the relationship between ERs and PPPs. These results show that construction companies make an effort to implement GSCM in order to comply with ER enforcement. However, construction companies can improve the extent of GSCM implementation only when they receive GS. These findings in relation to H1 and H3 addressed the first research objective, demonstrating that the two forms of governmental intervention have joint positive impacts on GSCM implementation. With respect to H2 and H4, the results concerning the impacts of ERs and GS on PPPs reveal that ERs themselves are effective in driving partnership development among construction supply chain players, while GS can assist ERs in driving such partnerships. The second research objective was achieved using the findings in relation to H2 and H4, which show that the two forms of governmental intervention have positive and significant impacts on PPPs development among construction partners. GS, in the form of financial and non-financial support, further motivates organisations to implement GSCM and form PPPs.

H5 posits that GS and PPPs sequentially mediate the relationship between ERs and GSCM (H5, ER->GS->PPPs->GSCM). The sequential mediation is supported by the results of the indirect effect. The findings suggest that the effectiveness of enforcing ERs upon GSCM implementation is partially realised through the sequential mediated effects of GS and PPPs; in other words, ERs promote GS, in turn fostering PPPs and, thus, leading to GSM implementation. These findings addressed the third research objective. When compared to the direct effects of ERs on GSCM (0.357), the mediated indirect effects are relatively weak (0.116 and 0.056) (see Table 5).

H6–8 speculate regarding the positive relationship between GSCM and economic and environmental performance. The results indicate that GSCM ameliorated environmental performance (EnvPerf), which reduced the costs associated with waste processing and energy consumption, leading to improvement in short-term economic performance (EcoPerf-S). The empirical results addressed the fourth research objective and suggested that economic

performance is not achieved in the medium and long term, specifically in terms of productivity, capacity, product differentiation, customer satisfaction, corporate green image, market share, and revenue.

Lastly, none of the control variables, i.e. ownership, industrial sector, or firm size, have a significant impact on GSCM implementation. This means that the inclusion of these control variables does not change the estimates of the exogenous variables of ER, GS and PPPs, or their relationships with the endogenous variable of GSCM. We could remove them from the model for subsequent analysis.

## **6. Discussion of findings**

The review of EMT highlighted that governmental intervention, such as command-and-control ERs and market-based GS, could be powerful in driving eco-innovation, simultaneously reducing environmental impacts and enhancing economic competitiveness. In this research, through empirical studies in the construction sector, governments' ability to stimulate the implementation of GSCM was examined. More specifically, this paper assessed whether the two forms of governmental intervention, i.e. ERs and GS, jointly promote PPPs among partners in the construction supply chain, therefore upscaling the implementation of GSCM and improving economic and environmental performance.

Concerning the influence of ERs on GSCM, the results show that they were effective in exerting direct pressures upon contractors and suppliers of materials, forcing them to comply with ERs and laws (Li et al. 2017). The results are consistent with findings reported in the literature, specifically that ERs incentivise investment in technological and product innovation (Testa et al. 2011), as well as improving internal environmental management, such as sourcing clean materials, using clean technologies, implementing the 3Rs for waste management, and employing green transportation (Zhu et al. 2013). The partial mediation effect of GS in driving GSCM and promoting PPPs supports the argument that GS is required to enable an ecological switchover to environmental innovation (Mojumder and Singh 2021), and that GS may be necessary for driving up PPP uptake in a country (Verhoest et al. 2015). The serial influences of GS and PPPs on the relationship between ERs and GSCM are complementary to existing research. Nevertheless, forcing construction stakeholders to comply with ERs may conflict with their interests in economic growth. The effectiveness of regulatory enforcement also depends on stakeholders' capacities and capabilities in making, and adapting to, the required changes. The integration of ERs and GS proves to be an effective mechanism in fostering PPPs among contractors and suppliers, which in turn have joint effects on implementing GSCM innovation.

The empirical results show that GSCM implementation enabled construction stakeholders to reduce waste generation and energy use; as such, they could make savings in waste management and achieve short-term economic benefits. These findings are similar to what Zhu et al. (2007) and Zhu et al. (2012) found in empirical studies with manufacturers in China. However, they examined the influence of specific GSCM practices on environmental and economic performance, such as international environmental management, eco-design, green purchasing, customer cooperation, etc. The present study, on the other hand, examined GSCM as an integrated environmental innovation, encompassing both internal and external environmental management. It is interesting to observe how government- and PPPs-incentivised GSCM innovation varied in its impact on short-term economic gains, as well as on medium- and long-term economic benefits. GSCM practices, such as eco-design and sourcing clean materials, require an initial capital investment, yet they can lead to reduced material and energy consumption, therefore reducing the cost associated with waste management in the short term. However, the long-term benefits can only be realised when the direct cost savings and indirect revenue gains exceed the significant start-up investment (Zhu et al. 2013). Past research showed that technological innovation and environmental management improved organisational competitiveness in China. Competitiveness was built up through product differentiation, production cost reduction, improving the corporate image, and compliance with cost reduction (Lopez-Gamero et al. 2010; Zhao et al. 2015). Construction stakeholders have not been able to make use of the advantages of product differentiation or increment in productivity, thus imposing limitations upon construction stakeholders' ability to realise economic benefits in increasing their market share and profits.

### ***6.1 Theoretical contributions***

This study employs EMT in designing the research framework. EMT theoretical perspectives help to explain the impact of governments, project prospects, and operations, as well as PPPs, on the adoption of GSCM innovation. The results support using EMT at a macro- and micro-level to study the relationship among GS, PPPs and the adoption of GSCM innovation. This study enriches the literature on EMT application in GSCM studies. EMT provides an opportunity to advance the circular economy, and the two strategic elements of EMT, i.e. environmental innovation and governmental policies, enable manufacturers to switch to ecological modernisation while reconciling economic growth and resolving environmental conflicts (Sehnm et al. 2021). Moreover, EMT posits that organisations perceive the adoption of environmental innovation as an opportunity to fulfil their social responsibilities (Pekovic et

al. 2016), which provides some guidance as to how EMT can be integrated into social theories, such as social capital, social systems and social exchange theories, to address the social aspects within the sustainability agenda. Addressing social sustainability has become increasingly important for GSCM studies (Genovese et al. 2017).

The current study further elaborates on the arguments put forth by Zhu et al. (2008) and Zhu et al. (2013) that ERs force organisations to implement GSCM. Organisations often make environment-related decisions while under pressure from ERs, markets or competitors; the parameters impacting the effectiveness of these pressures, such as GS and PPPs, have rarely been investigated. From a research perspective, understanding the roles of government and partnerships in terms of GSCM adoption creates new research avenues through which to develop theories on GSCM and, more broadly, on green practices. Building upon the arguments of Zhu et al. (2008), Bauer and Steurer (2014) and Regeczi (2005), the empirical findings in this paper highlight GS and PPPs as being important in partially mediating the impact of ERs on the implementation of GSCM in the construction supply chain. Based on recent debates surrounding the valuable contributions made by PPPs to complex projects, there is a clear opportunity for stakeholders in construction supply chains, particularly in developing partnerships with multiple levels of government, thus engaging in decision making, the sharing of resources, as well as disseminating knowledge and building capacity; the conditions required to form such partnerships include economic viability, sufficient technical competence, and transparent communications. This underscores the strategic importance for organisations to cooperate with multiple stakeholders, including government, research institutions, industrial partners, and customers, in conducting environmental activities.

Based on a systematic literature review concerning GSCM in the construction sector, Badi and Murtagh (2019) identified a need to develop mechanisms with which to strengthen the relationships among supply chain actors and manage the transition to green supply chain processes and activities. The current research responded to this need by examining the roles of ERs, GS and PPPs in establishing such mechanisms. The enforcement measure of ERs has been proven to be effective in directly driving PPPs and GSCM implementation, with GS being necessary in order to support construction companies with GSCM implementation. Furthermore, GS is necessary in order to build the regulatory framework and create a favourable environment for private enterprises, as well as to coordinate activities among them, to develop PPPs. GS and PPPs are necessary in enabling ecological switchover in construction companies.

This study also makes an important contribution to advancing knowledge in overcoming barriers to, and maximising the effectiveness of drivers and enablers for, GSCM implementation. Barriers to GSCM implementation were identified as a lack of knowledge and

training on green practices and the absence of shared goals and collaboration among stakeholders; meanwhile, drivers were identified as governmental regulations and demand from environmental groups, and enablers were identified as incentives and support from government (Mojumder and Singh 2021). The current study provides empirical evidence for the necessary and important roles played by government in driving and enabling GSCM implementation, and demonstrates how governmental intervention could act as an effective mechanism with which to overcome barriers and foster collaboration and integration among construction stakeholders.

The research findings regarding the mediating effects of GS and PPPs have significant implications for several bodies of literature. This evidence is revealed for the first time in research on GSCM, PPPs, and green construction, but echoes previous studies highlighting the importance of engaging stakeholders, such as contractors, suppliers and the public, in working collectively to address environmental issues (Gunningham 2009). Without a well-coordinated and consistent approach from governments, it is difficult to optimise the engagement and collaboration of stakeholders. Furthermore, without promising project prospects and a competent project team, PPPs will not be successful. In these regards, the present study contributes to the literature by arguing that successful implementation of GSCM is the net outcome of the opposing pressures from ERs and the stimulating measures from GS.

The research findings add a new dimension to the existing literature on GSCM, which often focuses on the direct relationships between research constructs (Zhu et al. 2007; Zhu et al. 2012; Balasubramanian and Shukla 2017; Zhang and Yousaf 2020). The study of the mediators of GS and PPPs contributes valuable insights into the critical success factors for PPPs and the mechanisms that influence the implementation of green practices in the construction sector.

## ***6.2 Managerial implications***

The knowledge derived from this study helps practitioners to recognise the role of governments in fostering and improving collaborative relationships between partners in a construction supply chain. Governments play an important role in encouraging and motivating construction stakeholders to participate in green supply chain initiatives, which is in line with the findings in other industrial sectors (Lee 2008). PPPs, as one form of collaborative relationship, provide a platform through which to diffuse knowledge, technologies and skills and, therefore, scale up the learning and adoption of GSCM innovation in the construction supply chain (Chan et al. 2010).

PPPs cannot be successful without GS. Governments establish a suitable regulatory framework by enacting ERs, and GS creates a favourable environment in order to attract the

private sector, coordinating collaboration and partnerships between the private and public sectors, making an investment in green infrastructure, and providing technical assistance and training at all levels. GS drives the initial start-up and effectiveness of PPPs, under which diverse private, public (including governmental) and non-governmental stakeholders work together towards environmental protection (Gunningham 2009). The results of this study serve as evidence that forming partnerships provides substantial support and benefits in adopting GSCM innovation. This conclusion is consistent with findings from Cheah and Liu (2006), Gao et al. (2017) and Bauer and Steurer (2014). The joint impacts of ERs and GS prove to be effective in formulating a regulatory framework through participatory, interactive and coordinated processes, capable of developing partnerships among stakeholders and sharing resources, knowledge and practices. This results in a new paradigm of supply chain integration and coordination for the construction sector and the promotion of active adaptation to GSCM.

International environmental regulations and carbon emission criteria represent continuing challenges for organisations competing in the international market. To advance their policies in relation to ecological improvement, governments can support organisations in learning from early adopters of GSCM by fostering partnerships and providing technical assistance and training (Regeczi 2005). Besides, governments should recognise the environmental achievements of pioneering organisations in the construction sector by providing subsidies in order to intensify their proactive adoption of GSCM and promote the dissemination of good practices (Zhu et al. 2012).

In the surveyed Chinese construction sector, given that regulated companies are still in the early stages of adopting green practices and their focus remains on the short-term economic benefits, the goals of ecological modernisation are likely to be realised in the short term. Medium- and long-term economic gains may be achieved when GSCM innovation leads to higher eco-efficiency (Iasevoli and Massi 2012), improved resource efficiency (Zhang et al. 2012), increased capacity, and improved business competitiveness (Zhu et al. 2012).

The complexity of construction supply chains, coupled with the differing experiences of stakeholders in implementing GSCM practices, means that standalone GSCM innovation is not able to improve organisational competitiveness through productivity, capacity, differentiated products, customer satisfaction or a corporate green image. Improving the productivity and capacity on a construction site requires rethinking the design and engineering processes, rewiring the contractual framework, improving onsite execution, infusing technologies and new materials, and reskilling the workforce. These activities require significant investment, regular training and monitoring, as well as careful planning and coordination. Green buildings can be delivered as a product which is differentiated from conventional buildings, but scaling up the

use of green buildings can only be realised by unlocking the potential of green buildings in developing sustainable cities. The green construction industry delivers macroeconomic benefits and societal priorities such as mitigating climate change, resource conservation, and quality of life. The corporate green image and customer satisfaction can only be achieved when economic and societal benefits from green buildings are fully understood. There is a lack of hard evidence showing whether an investment in green buildings generates a positive return of long-term economic and societal benefits (Ramboll 2019); as such, it is pivotal that government and industrial leaders take rapid action on regulations, policies and targets to conduct evidence-based studies and motivate residents and businesses to move towards green building construction and occupation (WorldGBC 2013).

## **7. Conclusions, limitations, and future research**

**Drawing on EMT, this research examines the effects of ERs, GS and PPPs on GSCM implementation in the construction supply chain, and the influence of GSCM on economic and environmental performance. To sum up, ERs successfully enforce GSCM implementation and PPPs, but GS is necessary in order to build a regulatory framework, and to create a favourable environment for construction companies to develop PPPs and implement GSCM. GS and PPPs proved to be necessary in enabling an ecological switchover to GSCM and, thus, achieving multiple performance benefits (including environmental and short-term economic performance improvements). However, it is unlikely that GSCM alone could drive the long-term goal of EMT, unless all parties, including government, construction industry leaders, and customers, work together to scale up green building construction and occupation.**

The research findings strengthen and refine empirical work on the application of EMT in GSCM studies; what is more, the findings provide supporting evidence for the integration of governmental intervention and PPPs to drive GSCM implementation in a complex construction supply chain. This research makes both theoretical and practical contributions. The application of EMT in GSCM studies is demonstrated through the empirical work in the construction supply chain, while related governmental regulations and support were also explored, thus contributing to the existing literature on popular theories in GSCM studies. The body of knowledge on GSCM in the construction sector can be reinforced as a result of the additional empirical evidence showing the positive influence of governmental intervention, which, along with PPPs, proves to be an effective mechanism in developing collaboration in construction supply chains. On the practical side, the insights obtained from this study can support decision makers (such

as governments and environmental regulation bodies) and practitioners in taking the necessary actions to minimise the environmental impacts of the construction industry. The main takeaway would be that government can integrate ecological regulations and support and can formulate an effective regulatory framework through a participatory, interactive and coordinated process. Such a mechanism has been proven to be able to foster PPPs among stakeholders, enable resource sharing and knowledge transfer, contemplate a new paradigm of supply chain integration and coordination for the construction sector, and promote active adaptation to GSCM. The GSCM discussed in this research will need to be evaluated and assessed by construction supply chain stakeholders in order to best suit individual ambitions and their clients' needs.

Notwithstanding the substantial insights provided by this research for academics and practitioners, the study has several limitations **which present opportunities for future research**. Firstly, this study focuses on testing the hypotheses in the Chinese construction industry through empirical analysis; the study only included a limited sample of companies, and so it may not be truly representative of the Chinese construction industry as a whole. **A larger and more representative sample of the industry is needed so as to enhance the robustness of the results of this study. Multiple case studies should be conducted with contractors and suppliers, adding depth to enhance the empirical findings and arrive at a clearer and more comprehensive picture of environmentally sustainable practices in the construction supply chain.**

Secondly, **only the mediation effects of GS and a specific form of partnership, namely PPPs, were examined**. To improve the explanatory power of the structural model, the impacts of additional constructs and other types of partnerships or alliances can be explored.

Thirdly, the explanatory power of environmental and economic performance is extremely weak, since only GSCM implementation was included as the predictor. Future work will need to consider other possible predictors such as demand, market size, supplies, leadership, business strategy, organisational culture, employees' engagement, etc.

Fourthly, the research examined the impact of only one type of institutional pressure, namely coercive pressure represented by ERs. Further examination of normative pressures and mimetic pressures, such as market pressures and competitive benchmarking, is needed in order to better understand the relationships between institutional pressures and GSCM adoption in the construction supply chain.

### Appendix 1: Measurement model (factor loadings, SCR, AVE)

Factors	Items	Factor Loadings	SCR	AVE
<b>Environmental regulations (ER)</b> (Zhu et al. 2008; Zhu et al. 2013)	National environmental regulations (ER1)	0.720	0.772	0.531
	Regional environmental regulations (ER2)	0.760		
	Regional resource and conservation regulations (ER3)	0.707		
<b>Governmental support</b> (Brandao and Saraiva 2008; Lee et al. 2008; Hwang and Tan 2012)	Well-structured regulatory framework for risk allocation (GS1)	0.775	0.839	0.568
	Government fostering collaborations with other organisations (including both private and public sectors) (GS2)	0.706		
	Government incentive (financial and non-financial) for green practices (GS3)	0.762		
	Favourable and attractive environment (GS4)	0.776		
<b>Public-private partnerships (PPPs)</b> (Regeczi 2005; Blanken et al. 2010; Bauer and Steuer 2014; Bosakova et al. 2019)	Knowledge transfer partnerships (PPPs1)	0.648	0.770	0.532
	Training and education on green innovation from the government-funded scheme (PPPs2)	0.784		
	Good practice or new skill sharing (PPPs3)	0.750		
<b>Green supply chain management (GSCM)</b> (Balasubramanian and Shukla 2017; Zhu et al. 2012)	Eco-design for building materials, or eco-building design (GSCM1)	0.701	0.822	0.502
	Clean technologies in production/construction (GSCM2)	0.643		
	Sourcing environmentally friendly materials (GSCM3)	0.701		
	Reducing, reusing, recycling and recovering materials, disposing of waste in a safe way (GSCM4)	0.673		
	Cooperation with contractors and subcontractors towards environmental objectives (GSCM5)	0.705		
	Green transportation (GSCM6)	0.629		
<b>Short-term economic performance (EcoPerf-S)</b> (Zhu et al. 2012)	Decreasing waste-processing cost (EcoPerf-S1)	0.888	0.816	0.634
	Decreasing the cost of energy consumption (EcoPerf-S2)	0.735		
	Reducing waste material and material cost (EcoPerf-S3)	0.842		
<b>Medium- and long-term economic performance (EcoPerf-ML)</b> (López-Gamero et al. 2010; Tang et al. 2012; Molina-Azorín et al. 2009)	Increasing productivity (EcoPerf-ML1)	0.811	0.880	0.586
	Increasing capacity (EcoPerf-ML2)	0.674		
	Improving corporate green image (EcoPerf-ML3)	0.666		

	Bringing differentiation advantages of products/green buildings (EcoPerf-ML4)	0.877		
	Improving customer satisfaction (EcoPerf-ML5)	0.925		
	Increasing market share (EcoPerf-ML6)	0.864		
	Increasing profits (EcoPerf-ML7)	0.812		
<b>Environmental performance</b> (EnvPerf) (Jabbour et al. 2015; Jadhav et al. 2019)	Reducing solid or liquid (or both) waste production (EnvPerf1)	0.865	0.904	0.735
	Reducing carbon emissions (EnvPerf2)	0.877		
	Decreasing consumption of hazardous materials (EnvPerf3)	0.927		
	Decreasing energy consumption (EnvPerf4)	0.844		

## Appendix 2: Discriminant validity (HTMT)

	EcoPerf-ML	EcoPerf-S	EnvPerf	ER	GSCM	GS
EcoPerf-S	0.771					
EnvPerf	0.634	0.637				
EnvReg	0.122	0.084	0.160			
GSCM	0.093	0.126	0.139	0.588		
GS	0.026	0.000	0.016	0.471	0.547	
PPPs	0.155	0.150	0.134	0.524	0.563	0.618

## Appendix 3: Inner VIF values

	EcoPerf-S	EcoPerf-ML	EnvPerf	GSCM	GS	PPPs
ER				1.455	1.000	1.286
GSCM	1.000	1.000	1.000			
GS				1.718		1.286
PPPs				1.862		

## Appendix 4: A list of initialisms

EMT: Ecological Modernisation Theory

ER: Environmental Regulation

GS: Governmental Support

GSCM: Green Supply Chain Management

PPPs: Public–Private Partnership

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