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## Article

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# A model for green supply chain management in the South African manufacturing sector

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## ABSTRACT

Green supply chain management is growing as a key component of sustainability. Its implementation improves the firms' supply chain competitiveness and performance. The literature on green supply chain management in various organisations has increased over the years. However, contextual literature on green supply chain management, green capabilities and supply chain performance is still limited within the manufacturing sector in developing countries such as South Africa. The study examined the relationships between green supply chain management practices, green capabilities, and supply chain performance in the South African manufacturing sector. The study employed a quantitative method on a sample consisting of 402 supply chain professionals drawn from the manufacturing sector across the four provinces of the country (i.e. Gauteng, Free State, Limpopo, and Mpumalanga). Data were collected over six months in the second half of 2022. Hypotheses were tested using structural equation modelling based on the SMART partial least squares technique. Eco-design, green distribution, and green training impacted positively on green capabilities, the latter of which, in turn, is linked to improved agility, reliability, and reduced supply chain costs. However, green manufacturing, legislation and regulations, reverse logistics, and product returns negatively impacted green capabilities. Green capability significantly mediated the relationships between green training and distribution and eco-design, and supply chain performance. To the management and leadership in the manufacturing sector, the study suggests that the implementation of green supply chain management activities is vital in influencing green capabilities. This study contributes to green supply chain management and capabilities literature as it is one of the few studies exploring green supply chain management practices, green capabilities, and performance in the context of the South African manufacturing sector. It encourages managers to develop and implement policies to improve environmental management practices in manufacturing supply chains.

## ARTICLE HISTORY

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Green supply chain management; green capabilities; supply chain performance; supply chain agility; supply chain costs; supply chain reliability



## SUBJECTS

Production, Operations & Information Management; Management Education

## Introduction

The South African manufacturing sector is plagued with sustainability-related problems, despite its evident desire to transition to green manufacturing. The low pace of implementing sustainable measures has resulted in inefficiency and ineffectiveness at various levels, as well as slowed down the competitiveness of the manufacturing sector (Maama et al., 2021). To enhance the competitiveness of this sector, manufacturers need to develop operational efficiency throughout their supply chain networks by improving their competencies and embracing practices that promote sustainability for a sustainable competitive advantage (Fatoki, 2019).

Despite the ratification of the Paris Agreement in 2015 by the world economies to reduce their carbon emissions, as well as the efforts of the South African Government to reinforce the implementation of the accord in its various economic sectors, the issue of environmental sustainability remains the 'grand'

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challenge for South African manufacturing sector (Fatoki, 2019). Alone, the manufacturing sector contributed almost 20 per cent to the total emissions in South Africa between 1999 and 2020, making it one of the most important polluters in the country (Kan et al., 2020). If the sector continues to act under the business-as-usual scenario, its gas emissions will increase global temperatures to between 3 and 4 degrees Celsius (Fatoki, 2019; Kan et al., 2020). This indicates the urgent need to implement mitigative measures that promote cleaner production through GSCM practices. This challenge affects not only all sectors of the South African economy, the manufacturing sector in particular, but also the well-being of the population (Fatoki, 2019; Maama et al., 2021). Consequently, sustainable development is essential to curb the effect of global warming through the manufacturing sector.

South African manufacturing firms must integrate green practices in their supply chains to improve their performance as well as the level of competitiveness of their products in both the local and global markets. South African manufacturing firms have the challenge of streamlining their production activities, which focus on implementing sustainable supply chain practices (Garbie, 2017). An understanding of these challenges can help firms to improve their global competitiveness. From a competitiveness viewpoint, the South African manufacturing sector is faced with immense and increasing pressure to improve its productivity to survive within the global market (Bag et al., 2022). Improving productivity will require the manufacturing sector to enhance its processes and reduce its production costs while maintaining the quality of its products (Gaglio et al., 2022). Measuring competitiveness depends mainly on the firms' capacity and ability to innovate and upgrade their existing production processes, which highlights the importance of GSCM and SCGC (Nyam et al., 2022). Innovation through green practices can drive performance in terms of productivity, effectiveness and efficiency, and profitability (Gaglio et al., 2022; Nyam et al., 2022). To this end, the South African manufacturing sector has to embrace the shift towards sustainable supply chain practices. These practices can help reduce the impact of manufacturing operations on the environment and improve processes and competitiveness.

It has been suggested that to overcome its sustainability and competitiveness problems, the South African manufacturing sector faces the task of adopting the use of GSCM practices such as green procurement (GP), eco-design (ED), and green manufacturing (GM), among others in the quest to enhance both production and environmental efficiency and effectiveness (Bag et al., 2022). It has been recommended that manufacturing firms in South Africa should become environmentally sentient by embracing and implementing GSCM practices (Rukuni et al., 2022). The adoption of such initiatives is likely to boost the competitiveness of the sector, empowering it to compete with other manufacturing firms in the world (Shetty & Bhat, 2022).

The current study examines the relationship between GSCM practices, green capabilities (GCs) and supply chain performance (SCP) in the South African manufacturing sector. Specifically, the study was directed to addressing the three objectives below

1. To examine the impact of GSCM practices on GCs.
2. To determine the impact of GCs on SCP.
3. To establish the mediating influence of GCs on the relationship between GSCM and SCP.

In the past years, there has been a growing interest in research and the strategic significance of implementing GSCM in manufacturing firms around South Africa. Various studies have investigated the effect of GSCM practices on SCP in South African organisations (Bag et al., 2022; Niehaus et al., 2018; Rukuni et al., 2022). Most of these studies focussed on the impacts of GSCM on either an individual dimension or all three dimensions of corporate performance, which include environmental performance, economic/financial performance, and social performance, without considering combining these performance dimensions in a single study. Unlike such attempts, the present study integrates these performance dimensions to capture the impact of GSCM within the manufacturing sector holistically. Furthermore, there appears to be a paucity of studies that have considered all GSCM practices and their impact on the GCs and SCP in the South African manufacturing sector, as the study attempts to do. Additionally, although it is well established in research that the concepts of GSCM practices lead to higher GCs and superior SCP (Bag et al., 2022; Niehaus et al., 2018; Rukuni et al., 2022; Shetty & Bhat, 2022), there is still a dearth in literature in South Africa concerning the

adoption and the implementation of GSCM to achieve sustainable development. Moreover, the area of GSCM is still at an emergent stage in most developing nations, such as South Africa and the rest of Africa (Epoh & Mafini, 2018). This low-level implementation of GSCM requires more research to enable SCM professionals to develop strategies suitable for their organisations. Within South Africa, various studies (Bag et al., 2020; 2022; Epoh & Mafini, 2018) on GSCM have been conducted using different topics. However, limited evidence exists of research on GSCM, GCs and SCP in the South African manufacturing sector. The study, therefore, will contribute to the existing body of literature by addressing these gaps.

## **Literature review**

### ***Green supply chain management***

The practices of GSCM have become the backbone for many organisations as competition increases in the marketplace and consumers are becoming more and more environmentally conscious (Liu et al., 2020). GSCM is fundamentally growing as a key component of sustainability within the SCM in that its adoption and implementation improve the competitiveness of the supply chain (Aityassine et al., 2021). GSCM is an important piece of the puzzle concerning sustainability and decreasing the carbon footprint. GSCM is a process of integrating environmental thinking into the supply chain to achieve a sustainable competitive advantage (Liu et al., 2020). It is the process of managing the environmental impact of the supply chain (Aityassine et al., 2021). A more sustainable supply chain is a less wasteful supply chain, and reducing waste can lower costs while improving the industry's reputation (Sahoo & Vijayvargy, 2021). This is one of many reasons green supply chain management is important. Greening a supply chain will make it more resource efficient. After all, one of the key objectives of GSCM is to reduce waste and optimise processes (Sahoo & Vijayvargy, 2021).

### ***Green supply chain management practices***

Green supply chain management practices are activities performed by firms in their supply chains to minimise their impact on the environment (Habib et al., 2021). Given the fact that sustainability is multidimensional in its scope, firms should select practices that are deemed necessary for them to improve the performance of their supply chains (Khan et al., 2022). The study focussed on eight GSCM practices, namely: green purchasing (GP); eco-design (ED); green manufacturing (GM); green distribution (GD); reverse logistics (RL); product returns (PR), regulations, and legislation (LR); and green training (GT). Green practices are important for manufacturing organisations to achieve their strategic goals and maintain the sustainability required for their operations (Habib et al., 2021).

### ***Eco-design***

Eco-design is perceived as the design of new products in such a way as to reduce their impact on the environment throughout their entire life cycle, from the procurement of raw materials to their disposal (Fang & Zhang, 2018). ED is a very important stage of manufacturing as it improves efficiency and facilitates the recycling of materials (Liu et al., 2020). The design phase can potentially reduce waste and improve manufacturing costs (Epoh & Mafini, 2018). Liu et al. (2020) further report that 80 per cent of environmental burdens and costs are fixed during the design process. Moreover, the scope of ED includes environmental risk management, product safety, pollution prevention, ecology, material conservation, accident prevention and waste management (Fang & Zhang, 2018).

### ***Green distribution***

Green distribution is a process of 'integrating environmental concerns into packaging, transportation and logistics activities' (Ricardianto et al., 2022). GD includes all activities that promote the reduction of environmental damages and waste during shipping (Yildiz Çankaya & Sezen, 2019). It emphasises the

consumption of fuel by vehicles transporting products, the frequency of transportation activities, the distance to consumers and the packaging characteristics that affect GD performance.

### **Green manufacturing**

Green manufacturing (GM) is a set of activities designed to improve the efficiency of the supply chain and reduce waste during the process of converting raw materials into finished products (Yildiz Çankaya & Sezen, 2019). The process aims to produce environmentally friendly products to satisfy the needs of consumers, meet environmental requirements and increase profitability and sustainability. GM incorporates various strategies, drivers and techniques that make the manufacturing processes more efficient and generate products that are safe for consumption and recyclable (Seth et al., 2018)

### **Green purchasing**

Green purchasing (GP) integrates environmental thinking into the procurement of materials (Yildiz Çankaya & Sezen, 2019). It influences the supply chain upstream as the buying organisation communicates to its suppliers the specifications that the ordered products must meet (Fang & Zhang, 2018). This entails that the supplier's selection plays a critical role in helping to achieve organisational goals. The buying organisation and its suppliers must strive to preserve their common interests, minimise the impact of their business activities on the environment and improve SCP.

### **Green training**

Green training (GT) is a process of on-the-job training and continued education intended to achieve corporate environmental management targets and purposes (Umar et al., 2022). It enables personnel and top management to think green in exercising their functions to improve the performance of their organisations (Nureen et al., 2023). GT provides firms with means to help achieve innovative development and improve their competitive position. In addition, GT also provides a firm with the ability to incorporate green capabilities into its internal processes contributing to building essential elements in the models of competitiveness (Umar et al., 2022).

### **Legislation and regulations**

Legislation and regulations refer to laws, policies and rules that are usually promulgated by governments and other regulatory bodies to promote the preservation of the environment (Epoh & Mafini, 2018). Firms are highly likely to adopt and implement green practices because of the role LR plays in fostering the implementation of sustainable practices (El Baz et al., 2022). LR provides a roadmap for firms to adapt their strategies and business activities to effectively create harmony in implementing sustainable practices and mitigate discrepancies (Davis-Sramek et al., 2019). This entails that firms should pursue the quest towards sustainability, share common values and norms and over time, the implementation of green practices can become similar.

### **Product returns**

Product returns (PR) is the set of processes used for tracking returnable packaging or for returned products for some specific reason at some point within the supply chain (Li & Liu, 2021). If PR is well managed, it can help cut costs and increase profit margins (Fernando et al., 2023). Moreover, it can result in higher financial returns, improved customer satisfaction and increased public perception by handling product returns efficiently and incorporating customer feedback (Srhir et al., 2023).

### **Reverse logistics**

Reverse logistics is a process of retrieving used products from the point of consumption to the point of origin for possible reusing, recycling, and remanufacturing (Khan et al., 2023). RL includes collection,

inspection, selection, cleaning, sorting, recycling, recovery, redistribution, and disposal of products (Ye & Lau, 2022). This process in itself helps to achieve ecological balance in supply chains. RL provides numerous sustainable benefits through the return to resell, refurbish, recondition, remanufacture, cannibalise parts, or recycle products to minimise landfill waste (Wijewickrama et al., 2021).

### ***Supply chain green capabilities***

In this study, SCGCs and GCs are used interchangeably. GC refers to organisational capacity that leverages current resources and expertise to grow its skill to adapt to dynamic market challenges (Khan et al., 2023). It is the ability of an organisation to integrate and organise its internal and external resources (Siems et al., 2021). GCs include the technologies, assets, knowledge and skills that organisations can utilise to manage the different environmental requirements of stakeholders (Shaharudin et al., 2019). A firm's GCs are drawn from their inimitable skills, expertise and resources in response to environmental challenges in the ever-dynamic marketplace (Khan et al., 2023). These capabilities may include green supplier development (GSD), green marketing, green manufacturing and packaging and environmental participation (Khan et al., 2023). GSD refers to the ability of the focal firm to identify and collaborate effectively with suppliers for greater green results (Shaharudin et al., 2019). Green marketing is the ability of the focal firm to effectively market its green products and green programmes to its customers and relevant stakeholders (Yousaf, 2021). Green manufacturing and packaging denote the capability of firms to modify their manufacturing and packaging processes and outputs to reflect green concerns (Nkrumah et al., 2021). Finally, environmental participation considers the ability of the focal firm to bring together its internal stakeholders (employees, departments and management) to work together towards green initiatives (Yousaf, 2021). GCs are important in organisations because they minimise resource use, environmental damage, and human threats; the main goal is to reduce environmental degradation while focusing on profit maximisation (Nkrumah et al., 2021). Furthermore, GCs can enable firms to adjust and adapt to the ever-changing market environment, making them enablers of market dominance through the continued implementation of strategies based on environmental changes (Gupta et al., 2020).

### ***Supply chain performance***

Measuring the performance of an organisation is very important to determine the direction the firm is taking. This process allows management to develop a strategic emphasis on their operations and their implementation (Asamoah et al., 2021). SCP is an orderly, planned process that enables an organisation to measure the effectiveness and efficiency of supply chain operations (Xie et al., 2020). This study used three constructs to measure the level of performance of the supply chains in the South African manufacturing sector, namely supply chain agility (SCA), supply chain reliability (SCREL), and supply chain costs (SCC).

### ***Research framework and hypotheses development***

Figure 1 outlines the research framework that guides the current study. The model postulates that implementing GSCM in the manufacturing sector positively influences GCs, which, in turn, significantly impacts the SCP of manufacturing firms through SCA, SCREL, and SCCs.

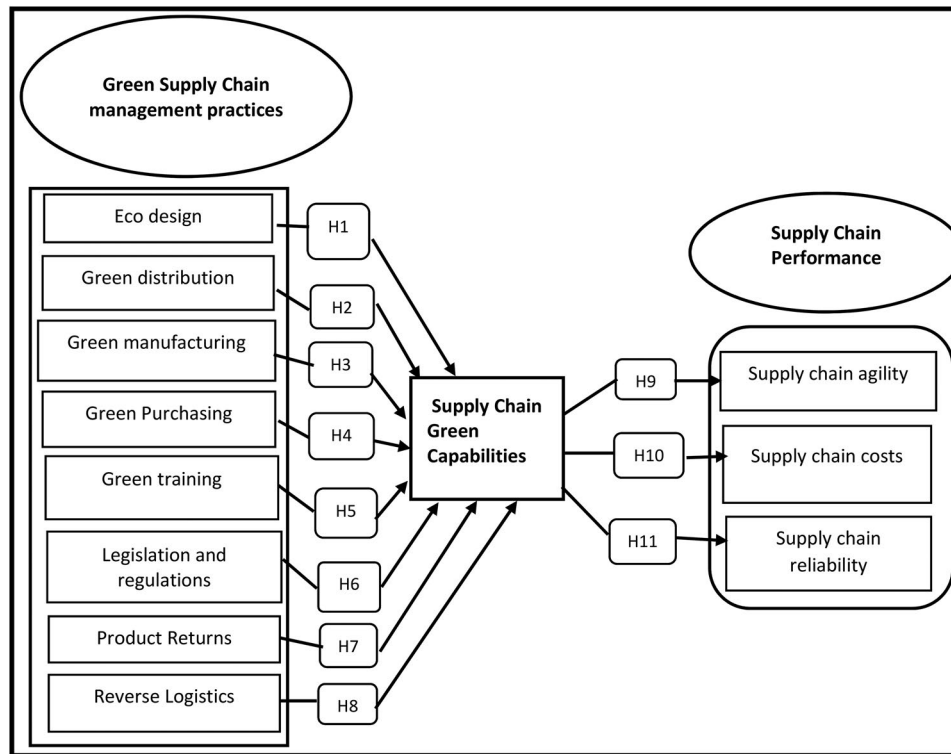
### ***Hypotheses development***

The arguments below illustrate the justification of the hypotheses developed.

### ***Green supply chain management and supply chain green capabilities***

The practices of GSCM and GCs are both vital for the success of the supply chain as they allow organisations to achieve flexibility and improved performance (Isnaini et al., 2020). Other authors postulate that





**Figure 1.** Research framework.  
Source: Authors' compilation.

the implementation of sustainable practices is dictated by the size of an organisation (Huang et al., 2017). It is indicated that large organisations are likely to adopt green practices because they possess resources and capabilities that small organisations do not have (Isnaini et al., 2020). This suggests that GCs play a mediating role in the adoption and implementation of environmental sustainability. Moreover, a mere reaction to environmental pressures may not lead to better GCs (Yu et al., 2019). Combining sustainable supply chain practices (SSCPs) such as GSCM practices with GCs makes organisations more flexible to changes in a dynamic environment while providing at the same time a competitive advantage (Isnaini et al., 2020). Furthermore, GCs can positively affect the ability of a firm to commit to green practices (Siems et al., 2021). Introducing green practices into a supply chain allows the change of existing technologies, processes, or routine activities (Yu et al., 2019). Given this background, the following hypotheses were formulated:

H1: Eco-design exerts a positive influence on supply chain green capabilities in the South African manufacturing sector.

H2: Green distribution exerts a positive influence on supply chain green capabilities in the South African manufacturing sector.

H3: Green manufacturing exerts a positive influence on supply chain green capabilities in the South African manufacturing sector.

H4: Green purchasing exerts a positive influence on supply chain green capabilities in the South African manufacturing sector.

H5: Green training exerts a positive influence on supply chain green capabilities in the South African manufacturing sector.

H6: Legislation and regulations exert a positive influence on supply chain green capabilities in the South African manufacturing sector.

H7: Product Returns exert a positive influence on supply chain green capabilities in the South African manufacturing sector.



H8: Reverse logistics exerts a positive influence on supply chain green capabilities in the South African manufacturing sector.

### ***Green capabilities and supply chain performance***

There is evidence of a positive relationship between GCs and organisational performance, which is linked to SCP in several previous studies (Isnaini et al., 2020; Lambourdiere & Corbin, 2020; Yu et al., 2019). On the other hand, the role of GCs in increasing the performance of an organisation is still questionable as there are still unidentified drawbacks and a lack of grounded evidence to support the idea (Kareem & Kummitha, 2020). Correspondingly, some studies (Manzoor et al., 2022; Teece, 2018) argue that GCs need to be strong to influence organisational performance, thereby improving the SCP. This suggests that possessing GCs is not enough to achieve enhanced SCP. GCs allow firms to sense uncertainties and seize opportunities in their supply chains, thus improving the performance of the supply chains (Manzoor et al., 2022). Based on the research studies above, the present study argues that GCs may enable the success of a supply chain in terms of SCA, SCC, and SCREL. Thus, the study hypothesises that:

H9: Supply chain green capabilities exert a positive influence on supply chain agility in the South African manufacturing sector.

H10: Supply chain green capabilities exert a positive influence on supply chain costs in the South African manufacturing sector.

H11: Supply chain green capabilities exert a positive influence on supply chain reliability in the South African manufacturing sector.

## **Materials and methods**

### ***Research approach and design***

A quantitative approach was used to collect and analyse data. The rationale behind this choice was that the investigation was predictive and causal as it tried to explain the relationships among research constructs. To maximise the response rate, a combination of correlational and survey research designs using a questionnaire for data collection was employed in the empirical part of the study.

### ***Research sample and sampling method***

The questionnaire was administered to a subset of the population of interest, which is supply chain, operations, and quality management professionals of the South African manufacturing sector in Gauteng, Free State, Mpumalanga, and Limpopo provinces. A sample size of  $n=402$  was deemed adequate, based on the recommendations from (Hodge, 2020) that sample sizes of between 150 and 500 cases are adequate for multivariate studies, and prevent limiting the statistical significance of the results as would be the case if small size is used. To ensure that supply chain professionals from various provinces were represented in the final sample, non-probability purposive sampling was used to select respondents.

In purposive sampling, the researcher uses some criteria to select respondents who possess information relevant to the study (Blumberg et al., 2014). The purposive technique lies within the non-probability sampling approach because the respondents do not have an equal chance of being selected for the actual sample (Antonius, 2017). In the current study, the sampled elements were intentionally selected based on their possession of some characteristics relevant to the research objectives. The prerequisites consisted of knowledge of SCM and involvement in supply chain activities.

### ***Measurement items***

Existing scales were used to develop the measurement items. Items measuring GSCM practices were adapted from (Jasmi, 2019), while those for GCs were adapted from (Yildiz Çankaya & Sezen, 2019).

The SCP scale was adapted from (Peng et al., 2020). All measurement scales were validated in previous studies, having scored Cronbach alpha values above 0.7. Each item in the measurement scale was designed for response using a five-point Likert scale in which 1 corresponds to 'strongly disagree' and 5 to 'strongly agree'. A self-administered online survey questionnaire was used in the data collection process. Data were collected between April and September 2022. The extended period of six months was attributed to the number of questionnaires distributed. The online survey was developed using Google Forms and distributed to targeted respondents through their emails. A submit button permitted the completed questionnaires to be routed back to the primary researcher's online repository.

### ***Statistical analysis***

Data were analysed using descriptive and inferential statistics. The SMART partial least square (PLS version 3.0) was employed as a tool to achieve the complete analysis of data.

### ***Ethical considerations***

The study was conducted after permission to collect data had been obtained from relevant authorities in manufacturing firms in South Africa. Respondents were made aware that their participation in the study was voluntary and that they were free to withdraw from the study at any time without reprisals. Respondents remained anonymous, and their confidentiality was maintained by ensuring that their identities were not mentioned anywhere in the study. Respondents were not given any monetary incentives for participating in the study.

## **Results**

### ***Respondents' characteristics***

Of the 500 questionnaires that were sent, 402 were successfully completed and deemed valid for analysis, thus resulting in an overall response rate of 80.40%. Several studies (Bauer et al., 2021; Cortina, 2020; Hodge, 2020) recommend 60% as the minimum acceptable criterion for survey response rate. Much of the sample was constituted of black Africans (59%,  $n=237$ ). Regarding gender, 77.1% ( $n=310$ ) and 30% ( $n=22.9$ ) were male and female, respectively. The majority age group was 36-40 years, representing 30% ( $n=119$ ). Regarding the level of education, the majority of the respondents held diplomas (39.3%,  $n=158$ ). In terms of work experience, respondents with 6 to 10 years of work experience made up the majority of the total respondents (36.3%,  $n=146$ ). Companies with 51-100 employees were mostly represented, with 24.6% ( $n=99$ ). The province with the largest proportion of respondents compared to the other three provinces was Gauteng, with 71% ( $n=285$ ). Concerning the industry classification, the Metals, fabricated metal products, machinery and equipment industry was mostly represented by more than half of the total respondents 63.4% ( $n=255$ ). Lastly, most of the respondents were working in the logistics and supply chain department (42.5%,  $n=171$ ).

### ***Measurement properties of the constructs***

#### ***Analysis of reliability and validity***

The measurement properties of the constructs were tested using reliability and item-to-total correlation analysis. All of the average variance extracted (AVE) estimates of constructs were greater than the cut-off point (0.5) (Forbes et al., 2021). These tests, thus, exhibit convergence validity. The squared correlation coefficients between two latent constructs to their AVE estimates were also compared (Price et al., 2015). According to this test, discriminant validity exists if the items share more common variance with their respective construct than any variance the construct shares with other constructs. Thus, the squared correlation coefficient between each pair of constructs should be less than the AVE estimates for each individual construct. Comparing the correlation coefficients given in Table 2 with the AVE estimates

reported in Table 1, all of the squared correlations were smaller than the AVE for each construct. Therefore, these results jointly provided evidence of discriminant validity among the constructs.

Item-to-total correlation analysis results provided in Table 1 suggest a reasonable fit of the latent factors to the data collected. Cronbach's alpha values for all factors were greater than 0.80, which ensured the internal consistency and validity of the constructs as they were well above the suggested value of 0.70 (Price et al., 2015). The item factor loadings were all acceptable, meaning all were much greater than 0.5. Alternatively, composite reliability (CR) scores were computed to assess construct reliability. A CR greater than 0.80 would imply that the variance captured by the factor is significantly more than the

**Table 1.** Constructs and measurement items.

Construct	Item code	Mean	SD	Item-to-item correlation	Cronbach's alpha	CR	AVE	$\sqrt{AVE}$
Green Purchasing	GP2	3.764	0.604	0,850	0.818	0.843	0.574	0.758
	GP3			0,645				
	GP4			0,764				
	GP5			0,784				
Eco-design	ED1	4.002	0.442	0,868	0.907	0.917	0.728	0.853
	ED2			0,870				
	ED3			0,871				
	ED4			0,859				
	ED5			0,796				
Green Manufacturing	GM1	4.009	0.406	0,787	0.834	0,849	0.602	0.776
	GM2			0,829				
	GM3			0,691				
	GM4			0,845				
	GM5			0,714				
Green Distribution	GD2	3.869	0.529	0,749	0,867	0.902	0.647	0.804
	GD3			0,765				
	GD4			0,803				
	GD5			0,850				
	GD6			0,849				
Reverse Logistics	RL1	4.269	0.445	0,908	0.835	0.882	0.714	0.845
	RL2			0,831				
	RL3			0,793				
	RL4			0,589				
	RL5			0,796				
	RL6			0,905				
Product Returns	PR4	4.109	0.49004	0.589	0.786	0.839	0.600	0.775
	PR5			0.796				
	PR6			0.905				
Legislation and Regulations	LR1	2.442	0.922	0,852	0.835	0.900	0.749	0.865
	LR2			0,893				
	LR4			0,851				
Green Training	GT1	3.965	0.628	0,852	0,931	0.948	0.785	0.886
	GT2			0,900				
	GT3			0,915				
	GT4			0,910				
	GT5			0,850				
Supply chain green capabilities	SCGC1	4.184	0.439	0,842	0.864	0.893	0.646	0.804
	SCGC2			0,848				
	SCGC3			0,719				
	SCGC4			0,861				
	SCGC5			0,738				
Supply Chain Agility	SCA1	3.947	0.402	0,808	0.811	0.842	0.555	0.745
	SCA2			0,805				
	SCA3			0,792				
	SCA4			0,649				
	SCA5			0,653				
Supply Chain Reliability	SCREL1	3.961	0.416	0,826	0.882	0.891	0.678	0.823
	SCREL2			0,835				
	SCREL3			0,825				
	SCREL4			0,819				
	SCREL5			0,813				
Supply Chain Cost	SCC1	3.988	0.4143	0,819	0.929	0.933	0.779	0.882
	SCC2			0,916				
	SCC3			0,889				
	SCC4			0,907				
	SCC5			0,878				

Source: Authors' Compilation.

**Table 2.** Correlation between theoretical constructs.

	ED	GD	GM	GP	GT	LR	PR	RL	SCA	SCC	SCGC	SCREL
ED	1.000											
GD	0,440	1.000										
GM	0,808	0,492	1.000									
GP	0,613	0,609	0,672	1.000								
GT	0,499	0,339	0,633	0,593	1.000							
LR	0,193	0,144	0,277	0,424	0,442	1.000						
PR	0,539	0,421	0,599	0,411	0,447	0,316	1.000					
RL	0,338	0,215	0,454	0,210	0,266	0,237	0,440	1.000				
SCA	0,517	0,532	0,473	0,394	0,411	0,188	0,481	0,210	1.000			
SCC	0,551	0,377	0,512	0,367	0,450	0,146	0,467	0,263	0,683	1.000		
SCGC	0,490	0,403	0,503	0,445	0,542	0,278	0,471	0,297	0,452	0,440	1.000	
SCREL	0,555	0,434	0,479	0,378	0,380	0,124	0,531	0,226	0,789	0,775	0,482	1.000

Source: Authors compilation.

variance indicated by the error components (Price et al., 2015). As shown in Table 1, all factors showed CRs greater than 0.841, which confirms the reliability of all constructs.

### Path analysis

In this study, path analysis was used to test the hypotheses based on the results obtained from PLS analysis. The study utilised the two main criteria under the PLS model to validate and confirm each hypothesis. The first criterion in the application of path analysis included checking the path coefficients, which are represented by a beta ( $\beta$ ). For a hypothesis to be supported and significant, the path coefficient must be positive or negative (Price et al., 2015). The second criterion constitutes the significant influence of the constructs. The significant influence constitutes three levels, represented by stars, also known as p-values. The levels of influence include values with at least three stars (\*\*\*), which represent p-values less than 0.001; two stars (\*\*) represent p-values less than 0.05, and one star (\*) denotes a p-value less than 0.1.

The results from Figure 2 show path coefficients ranging between -0.005 and 0.452, demonstrating the existence of relationships between the constructs. GCs have a significant influence on SCREL ( $t = 0.452$ ), SCA ( $t = 0.434$ ) and SCC ( $t = 0.415$ ). However, GP, LR RL, GD and GM have insignificant influence on GCs.

### Discussion

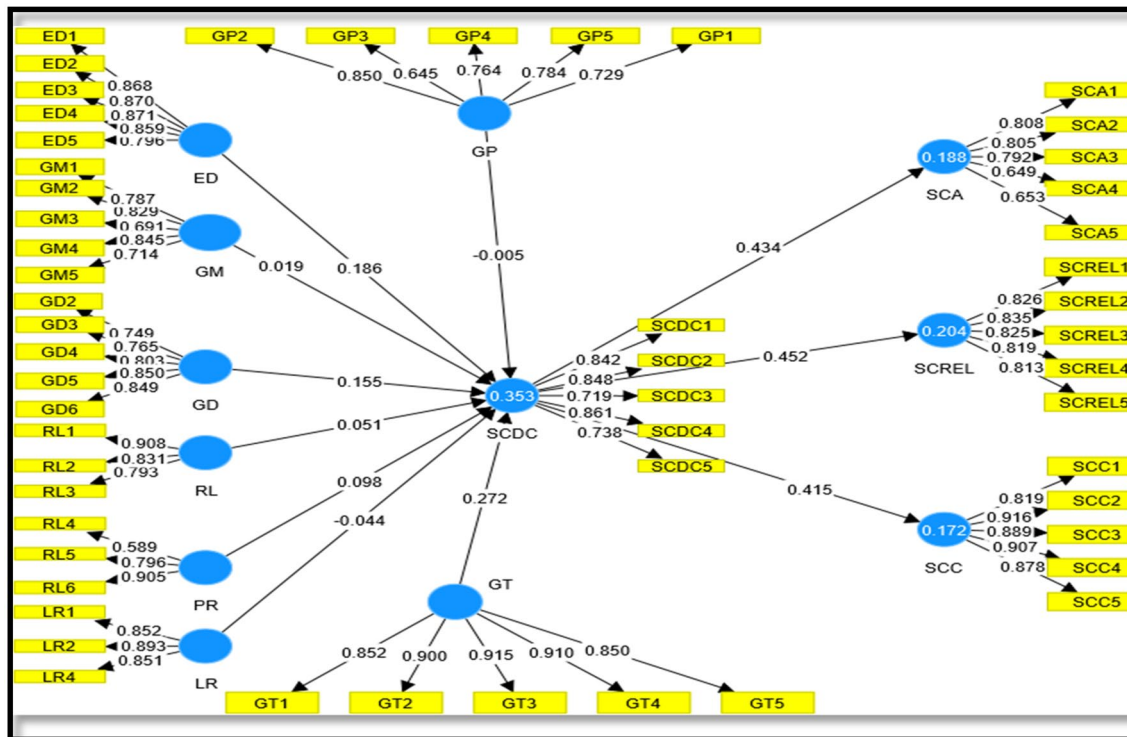
The present study tested the following objectives.

1. To examine the impact of GSCM practices on GCs
2. To determine the impact of GCs on SCP
3. To establish the mediating influence of GCs on the relationship between GSCM and SCP

The results of the study are presented in Table 3.

The results indicate that ED has a significant positive influence on GCs. ( $\beta=0.186$ ;  $t=2.729$ ;  $p=0.007$ ). This suggests that implementing ED in the South African manufacturing sector strengthens the ability of firms to innovate. This is confirmed by Habib et al. (2021), who revealed a positive and significant relationship between environmental management, which included ED and product innovation through GCs. Bag et al. (2020) also suggested that ED is one of the key resources for adopting the fourth industrial revolution innovation in the South African manufacturing sector as they provided evidence of a positive relationship between ED and innovative technologies. Li and Liu (2021) postulate that implementing green strategies requires firms to possess appropriate resources and capabilities. This may suggest that South African manufacturers had aligned their organisational strategies in a way that fits their existing resources and capabilities and thus contributed to the successful adoption and implementation of green design strategies.

Green distribution was found to have a significant positive influence on SCGC ( $\beta=0.155$ ;  $t=2.749$ ;  $p=0.006$ ). This outcome indicates that implementing GD exhibits greater GCs in the South African



**Figure 2.** Path coefficients.

Source: Authors' compilation based on data analysis results.

**Table 3.** Results of PLS hypotheses testing analysis.

Path (from-to)	Direct effect	T statistics	P values	Hypothesis Test result
H1: ED → SCGC	0,186	2.729	0.007**	Supported
H2: GD → SCGC	0,155	2.749	0.006**	Supported
H3: GM → SCGC	0,019	0.251	0.802	Not Supported
H4: GP → SCGC	-0,005	0.092	0.927	Not Supported
H5: GT → SCGC	0,272	5.002	0.000***	Supported
H6: LR → SCGC	-0,044	1.024	0.306	Not Supported
H7: PR → SCGC	0,098	1.484	0.138	Not Supported
H8: RL → SCGC	0,051	0.863	0.388	Not supported
H9: SCGC → SCA	0,434	8.962	0.000***	Supported
H10: SCGC → SCC	0,415	7.928	0.000***	Supported
H11: SCGC → SCREL	0,452	8.010	0.000***	Supported

Source: Authors' compilation.

manufacturing sector. This outcome complements the discourse of Subramanian and Abdulrahman (2017), who concluded that carbon-efficient practices, including transportation operations, positively affect the product redesign capabilities of manufacturing firms in China. Similarly, a study by Yildiz Çankaya and Sezen (2019) emphasised how GSCMPs, which include GD, positively influence environmental performance through strategic resources and capabilities in the Turkish manufacturing sector. Moreover, Novais et al. (2020) found that cloud logistics, which included transportation and distribution, positively influence supply chain integration through GCs.

This outcome may result from well-coordinated supply chain operations from up to downstream the supply chain using appropriate routing systems and technologies. Adequate coordination and cooperation among supply chain partners may have contributed to easing the timely response to customer demands as well as the distribution of products at correct quantities, scheduled time, and right locations with minimum pollution of the environment. Moreover, the cooperation may have facilitated the improvement of supply chain capabilities for a better GD. Finally, manufacturers may have been able to integrate effective and efficient handling of supply chain resources to respond to customers' needs.

Green manufacturing has an insignificant influence on GCs ( $\beta=0.019$ ;  $t=0.251$ ;  $p=0.802$ ). This result is not consistent with extant literature, which indicates that GM has a positive effect on GCs. Prior studies evidenced a relationship between the two constructs (Afum et al., 2021; Yusr et al., 2020), and it was reiterated that the adoption of green technology (GM) helps achieve product innovation in the manufacturing sector. However, this result is consistent with Nkrumah et al. (2021), who found no relationship between GM and GCs.

This result may be justified by the inability of South African manufacturing companies to establish collaborative mechanisms that promote cooperation and collaboration among supply chain partners in matters that advance innovation and green technologies. This outcome may also imply that manufacturers could not develop new competencies and redeploy resources and capabilities adequately for a sustainable competitive advantage. Furthermore, this result may suggest the complexity associated with the implementation of GM. GM strategy involves complex techniques and systems that require the deployment of resources and appropriate capabilities. South African manufacturers probably lacked this.

The results further indicate an insignificant relationship between GP and GCs ( $\beta = -0.005$ ;  $t=0.092$ ;  $p=0.927$ ). This result implies that implementing GP in the South African manufacturing sector does not influence the GCs of any given firm. The result contradicts prior studies (Brandon-Jones & Knoppen, 2018; Liu et al., 2020), which found a positive association between GP and GCs. The reason behind this unconventional result may be the cost associated with the implementation of green technology. This statement is consistent with Fang and Zhang (2018) argument, which suggests that the implementation of GP comes with extremely complex challenges that include higher cost, a lack of corporate commitment, insufficient knowledge, a lack of alternatives and reluctance to change. Furthermore, Liu et al. (2020) point out that incorporating GP into a supply chain is a complicated process since it requires not only considering traditional factors such as a supplier's cost, quality, lead time and flexibility but also environmental responsibility. It is clear that South African manufacturers may have perceived that they do not possess the capabilities required to engage in sustainable activities. Moreover, integrating suppliers into a supply chain requires exercises such as coaching, training, and monitoring, all of which consume a considerable number of resources that companies often do not possess. Another possible explanation may have been that GP does not seem to be an issue for customers due to the lack of awareness on matters related to environmental sustainability.

Hypothesis (H5) suggested a positive significant relationship between GT and GCs was established ( $\beta=0.272$ ;  $t=5.002$ ;  $p=0.000$ ). This suggests that GT exerts a significant positive influence on GCs in the South African manufacturing sector. The result aligns with Aslam et al. (2018) and Joshi and Dhar (2020), who proposed a positive relationship between GT through supply chain learning orientation and GCs. The result may indicate that South African manufacturers supported the emergence of novel capabilities through their ability to change and abandon obsolete supply chain practices. Manufacturers may have committed sufficient resources to promote GT and creativity. These capabilities may have allowed employees to better match work with their particular strength (environmental sustainability). GT is necessary to improve conditions for better GCs through knowledge creation, skills, and new capabilities. Aslam et al. (2018) postulate that learning is a fundamental part of capability development in SCM that allows firms to tackle supply chain challenges and capture niche markets.

The expected result in this study, a statistically significant positive relationship between LR and GCs, did not materialise, and did not support Hypothesis (H6) ( $\beta = -0.044$ ;  $t=1.024$ ;  $p=0.306$ ). One can conclude that the South African manufacturing sector does not believe that implementing LR influences GCs. The result of the study suggests that the ability of South African manufacturers to integrate government policies and regulatory requirements on green technology into their supply chains may not affect their ability to enhance competencies and innovate. This result contrasts the findings by Fernando et al. (2023), who revealed a positive and significant relationship between RL and GCs. While previous studies may suggest the role played by LR in improving GCs (Clemens & Douglas, 2020; Zeng et al., 2017), the result of the study claims otherwise. One possible explanation may be that manufacturers may have felt that there are too many regulations that are difficult to comply with or the proposed LR does not target manufacturing companies specifically. Moreover, the South African Government may have been less stringent regarding the implementation of GSCM because of the lack of financial support for businesses. Moreover, it may mean that manufacturers were not able to adjust their competencies and bring some effective changes to their processes as well as changes in their organisational culture.



An interesting result revealed that PR has an insignificant influence on GCs ( $\beta=0.098$ ;  $t=1.484$ ;  $p=0.138$ ). This result suggests that despite the implementation of the PR strategy by South African manufacturers, they did not perceive any improvement in their ability to recapture value from returned products. It appears clear that the relationship between PR and GCs is in dissonance with previous works, which suggests that there is an association between the two constructs. For example, the result of the study is contrary to that of Shaharudin et al. (2017), who suggested that PR promotes GCs through a closed-loop supply chain. Another study by Shaharudin et al. (2019) found a significant influence of PR on closed-loop supply chain adoption capability under the lens of GCs in the Malaysian manufacturing sector. This outcome may have resulted from inadequate environmental guidelines not being supportive of the PR strategy. It is important to point out that a poorly implemented PR strategy may hamper the prospect of green innovation through GCs. South African manufacturers may have been unable to recognise the value associated with PR and develop systems and mechanisms that exploit returned products. Shaharudin et al. (2019) point out that the ability of a firm to recapture value from PR is of great importance since a failure to exploit product returns may lead to the proliferation of industrial wastes and the depletion of natural resources. It is important that South African manufacturers invest in remanufacturing capabilities to handle PR effectively since it could facilitate the leverage of their capabilities and help improve their competitive advantage.

The results show no significant positive relationship between RL and GCs ( $\beta=0.051$ ;  $t=0.863$ ;  $p=0.388$ ). The result indicates that RL did not have a relatively greater effect on GCs in the South African manufacturing sector. This result does not espouse the work of Richey et al. (2015), who assert that committing resources to RL positively impacts the firm's ability to innovate. Additionally, Li and Liu (2021) indicated that firms that pay attention to their RL competency are more likely to achieve enhanced efficiency and effectiveness throughout their processes than those that forego RL. Bag et al. (2022) also suggest that RL adoption positively influences operations performance. A non-significant relationship between RL and GCs may be due to the lack of utilisation of RL resources, competencies, and collaboration with supply chain partners on strategic issues. It is important to point out that RL requires the exchange of goods. In this regard, collaboration with the supply chain is essential. Moreover, this outcome may mean that RL decisions were not appropriately taken, resulting in increased costs and financial losses to manufacturers. It is important that South African manufacturers possess competitive, collaborative skills, build strong relationships with their suppliers and strategic partners, and seek to develop and reconfigure their competencies in both information technology and RL.

The outcome of the path analysis and *t*-test demonstrates effectively that GCs has a positive and significant impact on SCA ( $\beta=0.434$ ;  $t=8.962$ ;  $p=0.000$ ). The result of the study suggests that GCs is more likely to improve the agility of supply chains in the South African manufacturing sector. This result corroborates the findings of Aslam et al. (2018), who found a positive relationship between GCs and SCA. A similar result was obtained by Irfan et al. (2020) in the garment manufacturing industry in Pakistan. The outcome of the study may be the result of improved efficiencies through GCs within the South African manufacturing sector. Manufacturers may have been well prepared by developing structures, technologies, and policies that allowed them to respond to customer demands effectively and efficiently. In addition, manufacturers may have been able to respond timeously to market changes and seize opportunities by adapting their resources. Aslam et al. (2018) posit that firms with well-developed GCs are more likely to improve their SCA since managers have a better understanding of operations within the supply chains. Understanding their processes may have effectively contributed to anticipating changes through the development of proactive strategies.

Another interesting result illustrates a positive and significant link between GCs and SCC ( $\beta=0.415$ ;  $t=7.928$ ;  $p=0.000$ ). This result aligns with previous studies (Aslam et al., 2018; Singhry & Abd Rahman, 2019), which establish a positive relationship between GCs and SCC. Furthermore, Chen et al. (2019) suggested that GCs enable product improvement through cost reduction, capital investment reduction and low business risks. This result demonstrates that GCs have allowed South African manufacturers to effectively manage their labour costs, material costs, management, and transportation costs, hence improving the overall cost of their supply chain. Dewi et al. (2023) postulate that firms that compete on cost can use their resources more efficiently and reap the benefits of a low-price strategy. South African manufacturers may have been able to design products and processes in a way that consumed fewer



resources by enhancing efficiency. Moreover, they may have been able to effectively coordinate resources with their supply chain partners. This result may also demonstrate that manufacturers could refine their processes and create and innovate for better performance through cost efficiency.

Lastly, a positive and significant relationship was found between GCs and SCREL variables ( $\beta=0.452$ ;  $t=8.010$ ;  $p=0.000$ ). The result of the study discloses that appropriate GCs can improve the overall supply chain through reliability in the South African manufacturing sector. The result aligns with Fernando et al. (2023), who assert that GCs improve the SCP through SCREL as well as other performance measures such as flexibility, responsiveness, and customer service. Consistently, Yusuf et al. established a positive association between GCs and operational performance, which included SCREL. The rationale behind this result may have been that South African manufacturers were able to adhere strictly to customer requirements and deliver the correct products to their customers within the prescribed timeframe. Moreover, they may have been able to prepare, respond to and recover from uncertainties such as the Covid-19 pandemic and maintain a steady state of operations at an acceptable time and cost. This assertion is supported by Yusuf et al., who ascertain that firms that do not deliver products to their customers as per the established schedule are likely to encroach on trust and loyalty, thus resulting in reduced competitive advantage. Finally, South African manufacturers may have been able to effectively eliminate non-value-added activities within their processes as well as supply chains.

### Mediation analysis

Mediation was tested to determine the significance of changes in SCGC on the relationship between each GSCM construct and each of the three SCP constructs. This mediation analysis was important since it helped to determine the significance of the indirect effects that may have existed between the predictor and outcome constructs. The results are presented in Table 4.

GC significantly and positively mediated the relationship between three GSCM practices (ED, GD, GT) and their corresponding SCP dimensions (SCA, SCC, SCREL). However, most mediating effects were weak, with the highest being observed between GT  $\rightarrow$  SCGC  $\rightarrow$  SCREL ( $\beta=0.128$ ;  $t=4.681$ ;  $p=0.000$ ). This result implies that GT emerged as the most important dimension of GSCM practices that contributed to enhancing the performance of supply chains through GCs in the South African manufacturing sector.

**Table 4.** Indirect effects.

Relationship	Mediating effect	T-value	P-value	Remark
GP $\rightarrow$ SCGC $\rightarrow$ SCA	-0.002	0.079	0.937	No mediation
GP $\rightarrow$ SCGC $\rightarrow$ SCC	-0.002	0.081	0.935	No mediation
GP $\rightarrow$ SCGC $\rightarrow$ SCREL	-0.002	0.081	0.936	No mediation
ED $\rightarrow$ SCGC $\rightarrow$ SCC	0.077	2.279	0.023	Positive mediation
ED $\rightarrow$ SCGC $\rightarrow$ SCA	0.081	2.417	0.016	Positive mediation
ED $\rightarrow$ SCGC $\rightarrow$ SCREL	0.084	2.315	0.021	Positive mediation
GM $\rightarrow$ SCGC $\rightarrow$ SCA	-0.004	0.223	0.824	No mediation
GM $\rightarrow$ SCGC $\rightarrow$ SCC	-0.004	0.225	0.822	No mediation
GM $\rightarrow$ SCGC $\rightarrow$ SCREL	-0.005	0.223	0.824	No mediation
GD $\rightarrow$ SCGC $\rightarrow$ SCC	0.068	2.632	0.009	Positive mediation
GD $\rightarrow$ SCGC $\rightarrow$ SCA	0.072	2.625	0.009	Positive mediation
GD $\rightarrow$ SCGC $\rightarrow$ SCREL	0.074	2.608	0.009	Positive mediation
RL $\rightarrow$ SCGC $\rightarrow$ SCC	0.029	0.819	0.413	No mediation
RL $\rightarrow$ SCGC $\rightarrow$ SCA	0.031	0.819	0.413	No mediation
RL $\rightarrow$ SCGC $\rightarrow$ SCREL	0.032	0.815	0.415	No mediation
PR $\rightarrow$ SCGC $\rightarrow$ SCREL	0.045	1.566	0.118	No mediation
PR $\rightarrow$ SCGC $\rightarrow$ SCC	0.041	1.568	0.117	No mediation
PR $\rightarrow$ SCGC $\rightarrow$ SCA	0.043	1.479	0.140	No mediation
PR $\rightarrow$ SCGC $\rightarrow$ SCR	0.022	1.491	0.137	No mediation
LR $\rightarrow$ SCGC $\rightarrow$ SCA	-0.017	0.987	0.324	No mediation
LR $\rightarrow$ SCGC $\rightarrow$ SCC	-0.016	1.008	0.314	No mediation
LR $\rightarrow$ SCGC $\rightarrow$ SCREL	-0.017	0.998	0.319	No mediation
GT $\rightarrow$ SCGC $\rightarrow$ SCREL	0.128	4.681	0.000	Positive mediation
GT $\rightarrow$ SCGC $\rightarrow$ SCC	0.118	4.544	0.000	Positive mediation
GT $\rightarrow$ SCGC $\rightarrow$ SCA	0.124	4.370	0.000	Positive mediation

Note:  $p < 0.05$  indicates the significance.

**GP** = Green Purchasing; **ED** = Eco-design; **GM** = Green Manufacturing; **GD** = Green Distribution; **RL** = Reverse Logistics; **PR** = Product Returns; **LR** = legislation and Regulations; **GT** = Green Training; **SCDC** = Supply Chain Green Capabilities; **SCA** = Supply Chain Agility; **SCREL** = Supply Chain Reliability; **SCC** = Supply Chain Costs; **SCR** = Supply Chain Responsiveness; **CS** = Customer Satisfaction; **SCQ** = Supply Chain Quality; **SCB** = Supply Chain Balance.

Moreover, the results suggest that manufacturing firms intending to enhance their SCP should direct greater attention to providing GT to their managers and staff, besides incorporating ED and GD. SCGC will enable such firms to reconfigure green strategies by improving their agility and resilience, enhancing the SCP, and achieving competitive advantages.

## Conclusion

This study employed SEM, based on the PLS technique, to examine the relationship between GSCM practices, GC, and SCP in the South African manufacturing sector. The study confirms that implementing GSCM practices positively contributes to GCs in the South African manufacturing sector. The study further concludes that ED, GD, and GT positively influence on GCs. Moreover, GCs are vital for improving SCA, SCC and SCREL. However, the implementation of some of the GSCM activities (i.e. GM, GP, PR, RL and LR) has an insignificant influence on the GCs in the South African manufacturing sector. SCGC significantly mediated the relationship between GT, ED and GD as well as the three SCP dimensions, namely SCA, SCC and SCREL.

The results of this study have significant implications for understanding the connections between the factors considered and how they can be used to enhance the South African manufacturing sector. Moreover, these results, which show significant relationships, provide an essential part of empirical evidence for GSCM, GCs and performance research. The study also validates research conclusions from other environments that are comparable to those of the South African manufacturing sector. The input of this study is important because it is one of the rare empirical research projects that used the measurement scales and items for appraising GSCM activities implementation among South African manufacturing companies and bid to improve the measurement items with adjustments. The study, therefore, is a reference work for future researchers on GSCM, GCs and SCP in similar environments elsewhere.

To the management and leadership in the manufacturing sector, the study suggests that implementing GSCM activities (particularly ED, GT, and GD) is vital in influencing the GCs. Correspondingly, it is imperative to implement GSCM activities in tandem with SCGCs if gains in SCP are to be realised. Management of manufacturing firms that apply GSCM activities must confirm that both the employees and the organisation achieve inclusive organisational objectives, such as cycle time reduction, cost reduction, enhanced environmental quality, and overall greater customer values, as well as individual goals of the employees. As the results of the study show, an inconsiderate approach to GSCM could actually diminish rather than improve the available financial resources and could put pressure on the external stakeholders to adopt the same GSCM practices.

To enhance the execution of IGSCM practices, modern technological resolutions should be considered. Using such technology resolutions may provide several benefits, such as a reduction in paperwork, the accuracy of information, easy integration with other functions and data access, which enables improved sustainability. Training and development programmes focusing on GSCM should be offered to all the staff to raise awareness within the manufacturing sector. A budget should be provided by firms for implementing the GSCM initiatives so that funds can be supplied when required.

It is important for management in manufacturing firms to adopt GSCM sustainability as a strategic essential and to modify existing enterprise information processes to monitor the systems and results linked to the organisation's sustainability wits prior to the implementation of the GSCM activities. Once GSCM sustainability has become strategic attention, manufacturers can instigate and implement GSCM practices with some assurance that the activities will produce not only enhanced capabilities but improved SCP. Therefore, adopting GSCM activities improves the firm's capabilities to sustain the environment and support the firm's SCP.

## Research limitations and future needs

The strength of the study lies in its reference to the full spectrum of GSCM practices. It was anchored on the widely recognised eight GSCM practices, making it an all-encompassing study. However, the study has some limitations that would offer opportunities for further studies. Firstly, the survey instrument

could be refined and reinforced. GSCM studies are still nascent in developing specific measurement items and scales on GSCM practices and SCP. Developing exclusive measurement scales on GSCM practices is significant, particularly for manufacturing firms. Manufacturing firms need self-diagnostic measurement scales to monitor their environmental management capabilities and performance. Further research should offer such indicative scales and items to support manufacturing firms in identifying their problem areas and creating solutions.

Moreover, the study chose manufacturing firms in four provinces of South Africa for data collection and analysis as this industry operates under strict environmental laws. Consequently, the study may require an expansion of its scope to improve its generalisability. This may be accomplished by repeating the study for comparative analysis in diverse industries and in other developing countries. Furthermore, the study assessed SCP using rather general factors such as agility, reliability, and costs. In future research, more specific performance measures could be utilised to assess performance, such as innovation, responsiveness, financial indices and environmental performance indicators, among others. This study attempted to explain the direct and indirect effects of GCs on the relationship between GSCM activities and SCP for manufacturing firms in South Africa. Since GSCM practices are progressively playing a significant part in improving competitive advantage, manufacturing firms should begin investigating how to leverage GSCM practices to promote capabilities and relational competencies and ultimately gain better competitiveness in the ever-changing global marketplace. Another suggestion would be for future studies to test the impact of GCs on GSCM practices. This could solve the unusual results obtained in the study where most of the GSCM practices did not influence GCs.

### Disclosure statement

No potential conflict of interest was reported by the author(s).

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