Journal of Transport and Supply Chain Management
ISSN: (Online) 1995-5235, (Print) 2310-8789

Drivers and barriers to green supply chain management in the South African cement industry

Authors:
Ayanda Nteta[1]
Justine Mushonga[1]

Affiliations:
[1]School of Business Leadership, Faculty of Management Sciences, University of South Africa, Midrand, South Africa

Corresponding author:
Ayanda Nteta,
ayanda@pulaconsulting.co.za

Dates:
Received: 10 Jan. 2021
Accepted: 25 Mar. 2021
Published: 26 May 2021

How to cite this article:
Nteta, A. & Mushonga, J., 2021, 'Drivers and barriers to green supply chain management in the South African cement industry', *Journal of Transport and Supply Chain Management* 15(0), a571. https://doi.org/10.4102/jtscm.v15i0.571

Background: The cement industry in South Africa is lagging behind the green supply chain management (GSCM) revolution that has influenced many sectors to re-evaluate their supply chain systems.

Objective: This study was conducted to determine the significant drivers of and barriers to the implementation of GSCM in the South African cement industry, and thus to investigate the impediments to the implementation of GSCM in the cement industry.

Method: A mixed-method approach was used to collect data from various role-players in the cement value chain. Geometric means were calculated from the scores of the survey conducted. Interviews were also conducted to confirm the results of the survey. An analytical hierarchy process technique ranked the individual drivers and barriers using the results from pairwise comparisons conducted. After ranking the drivers and barriers, a Pareto analysis was applied to determine the most significant drivers and barriers for the South African cement industry.

Results: Overall, the seven most significant sub-drivers fall into three categories of main drivers: financial performance, competitors and organisational style. Ten barriers were identified as most significant and were categorised into five themes, namely, high capital costs, poor supplier commitment, high certification costs, weak marketing positioning and lack of awareness of GSCM.

Conclusion: The identification of these drivers and barriers contributes to further research on improvements to GSCM process in the cement industry. The study shows that drivers of and barriers to the implementation of GSCM are not universally standard, and the ranking varies from one industry to another and from one country to another.

Keywords: analytical hierarchy process; cement industry; green; supply chain management; pareto analysis.

Introduction

Green supply chain management (GSCM) involves integrating environmentally friendly practices into supply chain management (SCM) to respond to stakeholders' demand for products and services that are produced through environmentally sustainable practices (Mvubu & Naude 2016). Green supply chain management is attracting increasing interest in industry, research and SCM driven by the escalating environmental degradation, for example, diminishing raw material resources, high industrial emissions and the increase in waste dumps (Srivastava 2007).

Growth of economies increases the level of energy and material consumption as the demand for products increases. The higher energy and material consumption contribute to environmental issues and natural resources depletion problems (Seman et al. 2012). In the case of South Africa, the country's economy was recording positive growth for more than two decades, except during the 2008/2009 world recession period and 2016/2017 (Statistics South Africa n.d.). South African economic growth is mainly backed by agriculture, mining, manufacturing, transport and the wholesale sectors (Statistics South Africa n.d.). These five sectors contribute close to two-thirds of economic growth (Statistics South Africa n.d.). The high-energy and resource-consuming nature of the five sectors implies that South African economic growth is associated with some negative environmental issues. Thus, South Africa is the 12th largest emitter of carbon dioxide (CO_2) in the world and is responsible for nearly half of the CO_2 emissions in Africa (Dahan et al. 2015). In their case study, Dahan et al. (2015) indicated that the total South African greenhouse gas (GHG) emissions in 2010 amounted to 579 256 gigatonnes of carbon dioxide equivalent ($GtCO_2e$), to which CO_2 contributed 80%. On the other hand, the third and latest national waste baseline conducted in 2011 showed that South Africa generated approximately 108 million tonnes of waste in 2011, of which 98 million tonnes was disposed of in landfills and only 10% was recycled (Republic of South Africa 2012).

To curb these ever-increasing environmental problems, the South African government has continuously been reviewing environmental legislation to force the industry to reduce environmental pollution. For example, in the last decade, the South African government introduced the *National Environmental Management: Waste Act* (Act 59 of 2008), the National Waste Management Strategy (DEA 2012), the *National Environmental Management: Air Quality Act* (Act No. 39 of 2004) and the Carbon Tax.

The emerging government regulations and stronger public awareness about the environment are forcing manufacturers to explore strategies that will help mitigate the environmental impacts of their supply chains (Mvubu & Naude 2016). The manufacturing industry, such as the South African cement industry, cannot afford to continue ignoring environmental concerns if it wants to remain competitive in the international market (Dhull & Nawal 2015). Consequently, it is a requirement for manufacturers to embrace GSCM because of pressure from the government and also environmental consciousness amongst customers (Srivastava 2007). Green supply chain management is defined as:

> [*I*]ntegrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life. (pp. 54–55)

Besides trying to satisfy the environmental concerns in organisations, some organisations have found a positive relationship between GSCM and economic performance. Zhu and Sarkis (2004) found that enterprises that have higher levels of GSCM practices have better positive economic performance. Chiou et al. (2011) investigated the correlation between supplier green practices and green innovation in the Taiwanese industry. They concluded that the implementation of green innovation by suppliers leads to better environmental performance and competitive advantage of the firm. Similar results were obtained by Seman et al. (2012), who concluded that green innovation is a novel approach that can contribute to differentiation from competitors which might lead to competitive advantage.

Many researchers (Diabat & Govindan 2011; Gandhi et al. 2016; Khiewnavawongsa 2011; Ojo, Mbowa & Akinlabi 2014; Rahman & Srivastava 2011; Singh, Singh & Dhingra 2012; Vachon 2008; Walker, Sisto & McBain 2008; Zhu & Sarkis 2004) have highlighted drivers and barriers that affect the implementation of GSCM in many industries around the world; therefore, it is necessary to identify these drivers and barriers in the South African cement industry context. This article identifies significant drivers of and barriers to the implementation of GSCM in the South African cement industry.

Global warming, waste management issues and depleting natural resources force governments to develop stringent environmental regulations. The manufacturing industry finds it challenging to comply with these (Ghazilla et al. 2015). Organisations therefore must find innovative ways of ensuring their supply chains comply with the environmental regulations whilst still creating value for their stakeholders (Khaksar et al. 2016).

Niemann, Hall and Oliver (2016) noted that although many studies have been conducted on the drivers of and barriers to GSCM practices, there is still conflicting information on the ranking of these drivers and barriers. This might be because of these studies having been conducted in different contexts, namely, different countries and industries (Niemann et al. 2016), and therefore, country- and industry-specific issues like legislation might influence the ranking of the drivers and barriers.

This study identifies the drivers of and barriers to the implementation of GSCM in the South African cement industry and determines the relative weights of these barriers and drivers using the analytic hierarchy process (AHP). The research objectives include the identification of factors that are critical in implementing GSCM in South African cement industry as well as ranking of these factors according to their significance in driving or providing barriers to the GSCM implementation.

As GSCM is a relatively new concept in the South African manufacturing industry, this study will help the industry understand the drivers of and barriers to GSCM implementation. The cement industry has been a slow uptaker of these concepts, as previously it was a cartel that did not necessitate marketing and sales solutions traditionally required in competitive environments. Prior to the dissolution of the cartel, the South African cement industry focused on producing cement that was sent to a centralised distribution centre before being sold to customers. As a result, issues of differentiation and competition for customers were not forefront in the South African cement industry. Consequently, customer pressure to apply GSCM principles was not a focus. However, since the unbundling of the cartel, companies producing cement have had to be more attentive to issues of customer satisfaction, efficient production processes and aspects of differentiation (Mbango & Phiri 2015).

Since 1994, the South African cement industry landscape has been dominated by six major players that are PPC Cement, AfriSam, Lafarge-Holcim, Natal Portland Cement (NPC), Sephaku and Mamba cement (Association of Cementitious Material Producers n.d.). The South African cement industry has a total of 21.7 million tonnes per annum of installed capacity although about 4 million tonnes of this installed capacity is lying idle (Electus Fund Managers 2016). This idle-installed capacity places pressure on cement industry players to adopt strategies that acquire more customers in order to attain improved return on investment, particularly in the post-cartel competitive environment. Green supply chain management practices have been recognised as a potential lever for organisations based on the positive relationship between GSCM and efficient performance. Knowledge from this study will inform strategy formulation and direction for the cement industry and other manufacturing industries towards the implementation of GSCM.

The ultimate goal is for the cement industry and the manufacturing industry to utilise the findings of this study to help implement GSCM practices. This will contribute towards South Africa's pledge to reduce GHG emissions by 42% by 2025.

Green supply chain management literature review

Green supply chain management originated from conventional SCM that involves connecting manufacturing activities from raw material supply to the delivery of the final product (Dhull & Narwal 2015). The concept of GSCM was conceived in 1990, but it was only in 1994 that the first effort of GSCM was implemented through green purchasing (Khaksar et al. 2015). However, because of increasing environmental concerns and awareness, it became necessary to implement green strategies and policies at every stage of the supply chain (Khaksar et al. 2015). Thus, as organisations drive towards sustainable SCM systems, GSCM practices are now at the centre of policy and strategy development in organisations (Luthra, Garg & Haleem 2013).

There is a considerable amount of literature relating to studies conducted in South Africa (Dos Santos, Svesson & Padin 2013; Mvubu & Naude 2016; Ojo et al. 2014; Pooe & Mhelembe 2014; Schoeman & Sanchez 2009) on GSCM implementation in South African industry. The literature reviewed in the South African context covers the construction industry (Ojo et al. 2014), transport (Schoeman & Sanchez 2009), retail (Dos Santos et al. 2013), logistics (Niemann, Hall & Oliver 2017), mining (Pooe & Mhelembe 2014) and the fast-moving consumer goods industry (Mvubu & Naude 2016).

Defining green supply chain management

The definition of GSCM ranges from green purchasing to integrated supply chains, starting from supplier to manufacturer, to customer and reverse logistics, which is closing the loop (Zhu & Sarkis 2004). Similarly, Srivastava (2007) defined GSCM as:

> [*I*]ntegrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life. (p. 14)

Mvubu and Naude (2016) reviewed the definitions suggested by Green et al. (2012) and Srivastava (2007). These definitions also focused on integrating environmentally friendly practices in SCM in response to customer demand. Many definitions converge around 'greening' the supply chain, and therefore this article defines GSCM as the integration of sustainable environmental practices into every stage of traditional supply chains. This entails 'greening' the product design, product selection, material sourcing, manufacturing and production, operation and end-of-life management.

Green supply chain management practices

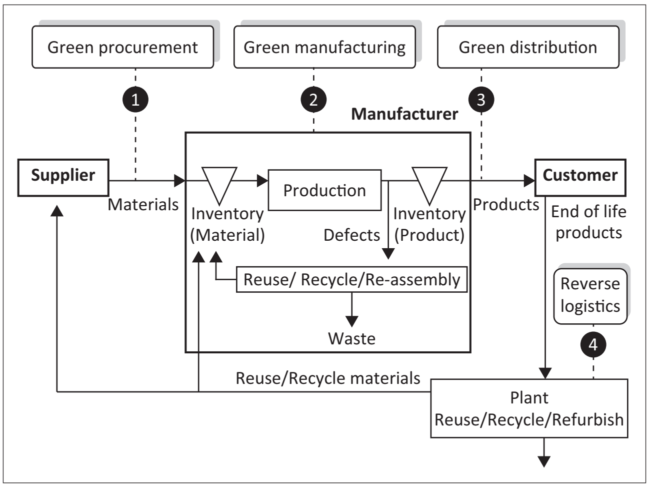
It is generally accepted that GSCM practices can be divided into four main areas, namely, green procurement, green manufacturing, green distribution and reverse logistics (Luthra et al. 2013; Ninlawan et al. 2010; Wiese et al. 2015). This is illustrated by the supply chain model in Figure 1.

Green procurement and design

Green procurement is an environmental purchasing process achieved by collaborating with suppliers to acquire inputs and services that minimise environmental impacts (Ninlawan et al. 2010). Thus, green procurement can be achieved by creating strategic partnerships with suppliers to develop environmental strategies and programmes collectively to reduce or eliminate material use (Kusi-Sarpong, Sarkis & Wang 2016).

In the Indian cement industry, Shrivastava and Shrivastava (2017) concluded that green procurement can be achieved through several practices including product recycling or reuse and remanufacturing as well as energy recovery. Thus, waste such as used tyres can be procured at a minimal fee and used in the place of fossil fuel.

To emphasise green design in the cement industry, Potgieter (2012) identified a number of alternative low-energy cement types and binders that still need more research and



Source: Ninlawan, C., Seksan, P., Tossapol, K. & Pilada, W., 2010, 'The implementation of green supply chain management practices in electronics industry', *Proceedings of the International Multi Conference of Engineers and Computer Scientists*, vol. 3, 17–19 March 2010, Hong Kong.

FIGURE 1: Green supply chain management activities model.

development to be used commercially. These include alkali-activated cements (AAC), calcium sulpho-aluminate (CSA) cement, belite cement, geopolymers, micro-defect-free (MDF) cement, Novacem, hydraulic lime and plaster of Paris, amongst others. The products are designed in collaboration with suppliers and customers.

Green manufacturing

Green manufacturing is the development of products that are energy-efficient, recyclable and easy to dispose. Thus, green manufacturing produces less overall waste during the manufacturing process (Wiese et al. 2015).

Similarly, Ninlawan et al. (2010) stated that green manufacturing is the production of environmentally friendly products using efficient processes that generate little or no environmental pollution. The ultimate goal of green manufacturing includes the reduction and minimisation of environmental impacts and resource consumption during a product life cycle (Ahmad 2015). This includes product and process design, synthesis, processing, packaging, transportation and the use of products in the manufacturing industries (Ahmad 2015).

In the cement industry, various methods have been adopted to increase energy-saving and emission mitigation (Zhang, Worrel & Crijns-Graus 2015). The methods include process optimisation, process design and integration, heat recovery from the kiln and cooler exhaust and steam generation from exhaust streams as well as energy-saving through insulation (Zhang et al. 2015).

Green distribution

Environment-friendly transportation and distribution is a process of moving a product from manufacturers to the market with a low impact on the environment (Srivastava 2007). Green distribution also involves the delivery of products directly to the end users, bulk transportation and alternative fuel vehicles, whilst green packaging involves downsizing packaging, using recycled packaging material and adopting returnable packaging methods (Ninlawan et al. 2010).

Wiese et al. (2015) also stated that green distribution can be achieved by implementing distribution rules, disciplined load planning operations and the selection of alternative environmentally friendly transport modes.

Reverse logistics

Mwaura et al. (2016:679) defined reverse logistics as 'the return of products by customers to the original company to recover and potentially generate value from any unused products or components'. Singh, Bharati and Kumar (2013) agree with Mwaura et al. (2016) when they define reverse logistics as the process of planning, implementing and controlling the efficient flow of material and related information from the end user to the original supplier to extract residual value or proper disposal.

Reverse logistics therefore represents a very important component of GSCM as this 'closes the loop' of a forward supply chain (Mwaura et al. 2016). The components of reverse logistics include reuse, re-manufacturing and recycling material to create value as well as eliminating or minimising waste, emissions and energy use.

The cement production process takes advantage of its high processing temperature (1400°C) to destroy certain types of waste, whilst in some cases encapsulating the resultant non-destructible portion safely in the final product (Potgieter 2012). This unique feature of the cement-making process has led to a variety of ways in which the cement industry can support GSCM systems through the recycling of waste from other industries.

Green supply chain management implementation strategies

To successfully implement GSCM, organisations need to develop strategies for integrating the GSCM practices, namely, green procurement, green manufacturing, green logistics and reverse logistics. Luthra et al. (2013) identified 30 strategies, categorised into four major dimensions, through which GSCM can be implemented in manufacturing organisations. According to Luthra et al. (2013), the first category is 'non-members of the supply chain', which consists of international environmental agreements (United Nations Framework Convention on Climate Change 2009), government legislation and non-government organisations. The second category is 'downstream supply chain members', which consists of collaboration with suppliers, knowledge and technology transfer and environmental auditing of suppliers. The third category, according to Luthra et al. (2013), is 'organisational perspective' which includes green practices implementation, top management initiation and commitment, quality human resources, economic interests, organisations' competitiveness and waste avoidance or minimisation. The fourth category relates to 'upward stream supply chain members', which consists of customer awareness, end-of-life management and recycling.

Other researchers (Dhull & Narwal 2015; Diabat & Govindan 2011; Gandhi et al. 2016; Kamolkittiwong & Phruksaphanrat 2015; Niemann et al. 2016) also identify government legislation, market, supplier collaboration, internal organisational innovation, logistics and stakeholder awareness as strategies for the successful implementation of GSCM in many organisations. Similarly, other researchers (Diabat & Govindan 2011; Gandhi et al. 2016; Kamolkittiwong & Phruksaphanrat 2015; Luthra et al. 2013; Niemann et al. 2016; Potgieter 2012) conclude that GSCM in the cement industry can be implemented through research and development, collaboration with suppliers and customers and innovation within the value chain.

Research and development is critical in the cement industry for GSCM implementation because several technologies that can 'green' the cement industry supply chain are still in their infancy (Potgieter 2012). These technologies therefore need to be developed further to be commercially viable. These technologies include the fluidised bed cement-making process, carbon capture and storage, and alternative cement types and binders that are less energy- and resource-intensive.

Collaboration with suppliers and customers is meant to promote closed-loop supply strategies and green design (Odeyale, Oguntola & Odeyale 2014; Potgieter 2012). Collaboration with suppliers and customers will facilitate the recycling and remanufacturing of internal process waste as well as wastes from other industries (Odeyale et al. 2014; Potgieter 2012).

Although GSCM has been topical for the last decade (Srivastava 2007), its implementation is still a challenge because of the lack of understanding and poor implementation of GSCM strategies, especially in emerging economies where research on this topic still needs to advance for companies to make real contributions to environmental management (Teixeira et al. 2016). A research gap exists in the South African cement industry to explore and rank the drivers and barriers that hinder the successful implementation of GSCM. This study therefore identifies the significant drivers and barriers that hinder the successful GSCM strategy development and implementation.

Drivers of and barriers to green supply chain management implementation

To gain more relevant insights into the drivers and barriers relating to the implementation of GSCM in South African cement industry, this literature review focuses more on studies conducted in South Africa and other developing countries. The researcher did not consider research conducted in developed countries as this study assumes that the drivers and barriers in developing countries are different from those of developed countries. This is because of differences in economic activities, legislation and technological advancement (Rahman, Ho & Rusli 2014).

The term 'drivers of GSCM' refers to the factors that motivate and enable organisations to reduce environmentally damaging substances in their SCM (Dhull & Narwal 2015).

Numerous researchers (Gandhi et al. 2016; Kamolkittiwong & Phruksaphanrat 2015; Kathiresan & Ragunathan 2016; Liu et al. 2012; Luthra et al. 2013; Niemann et al. 2016) agree that organisational strategy, support from top management, economic benefits from reverse logistics, cost reduction, organisational environmental policies and the cost and liability of harmful material disposal are all major internal drivers for the implementation of GSCM. Suppliers, government regulations and legislation, consumers, competitors, stakeholders and investor pressure are the major external drivers of GSCM.

The barriers to GSCM implementation are those that, if addressed, will enhance the implementation of GSCM in an organisation (Balaji, Velmurugan & Manikanda 2014). Various scholars (Dhull & Narwal 2015; Faisal 2015; Luthra et al. 2016; Ojo et al. 2014; Pooe & Mhelembe 2014; Wang et al. 2016) identified various barriers for the implementation of GSCM, which include the lack of infrastructure, government legislation, organisational factors, high cost and lack of knowledge.

Various researchers (Dhull & Nawal 2015; Gandhi et al. 2016; Kamolkittiwong & Phruksaphanrat 2015; Niemann et al. 2017) have identified significant drivers and barriers for the implementation of GSCM in various industries. With respect to internal drivers, the literature reviewed showed that researchers seem to concur on support from top management, economic benefits through gains of reverse logistics and cost reduction, organisational and environmental policies and the cost and liability of harmful material disposal. The researchers, however, disagree on the ranking of the internal drivers most likely because of differences in countries and industries. This study determines the significant internal drivers and ranks these drivers from a South African cement industry perspective.

The literature reviewed, as indicated in Figure 2, also identified suppliers, government regulations and legislation, consumers, competitors, stakeholders and investor pressure as being significant external drivers. This study determined external drivers from a South African cement industry perspective. Thus, this study determined the gaps between the external drivers identified in the literature. This study also ranks the external drivers according to their importance.

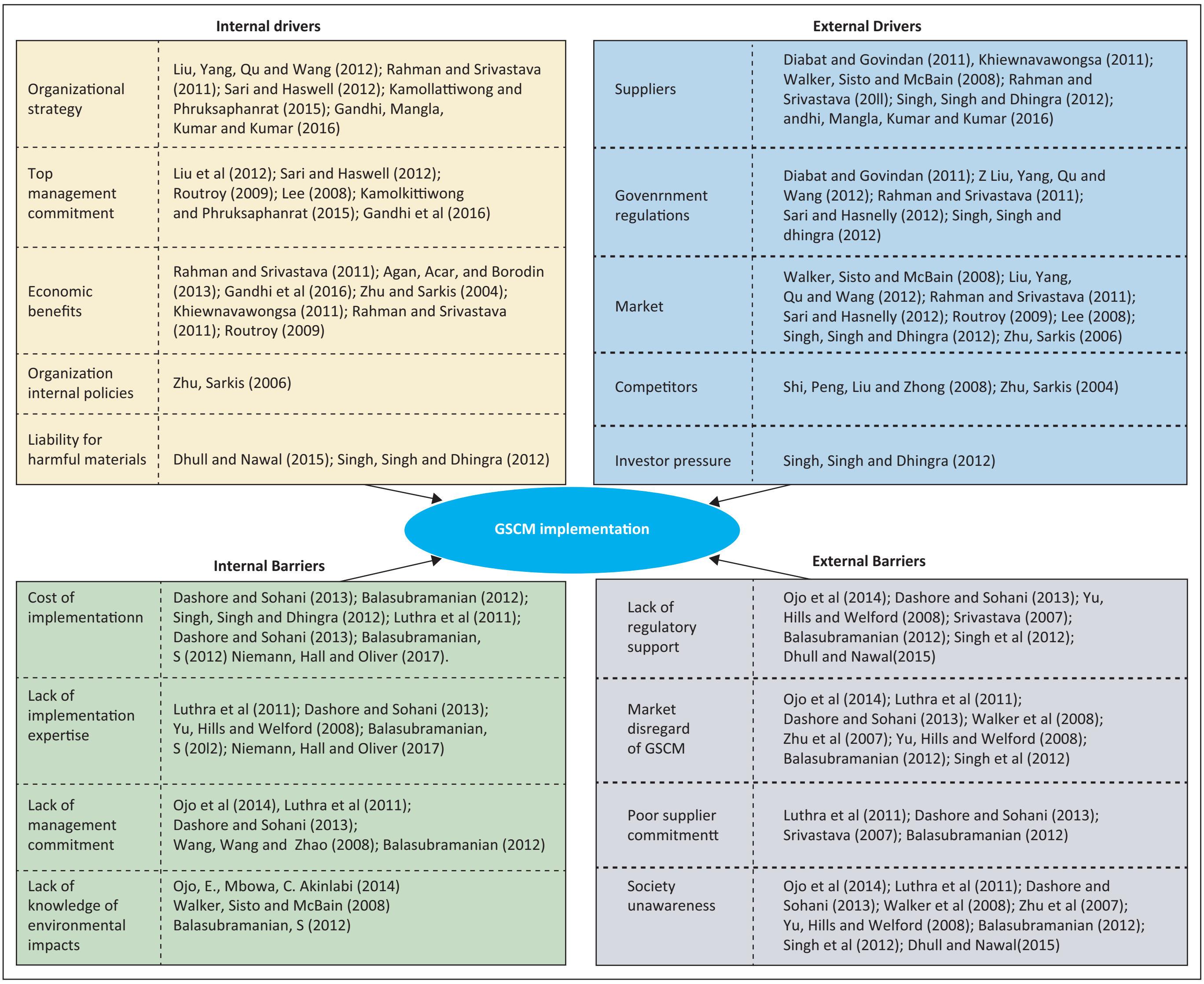
Based on the literature reviewed (Figure 2), the following were identified as being the most significant internal barriers to the successful implementation of GSCM:

- poor commitment by top management
- cost of GSCM implementation and maintenance
- lack of technical expertise
- lack of knowledge of environmental impacts.

External barriers to the successful implementation of GSCM include:

- lack of government support
- absence of suppliers' commitment to GSCM
- insufficient demand for environmentally friendly products
- limited general GSCM awareness of organisational stakeholders.

With regard to the drivers of the implementation of GSCM, the following were identified as internal drivers:



Note: Please see the full reference list of the article, Nteta, A. & Mushonga, J., 2021, 'Drivers and barriers to green supply chain management in the South African cement industry', *Journal of Transport and Supply Chain Management* 15(0), a571. https://doi.org/10.4102/jtscm.v15i0.571, for more information.

GSCM, Green supply chain management.

FIGURE 2: Drivers of and barriers to green supply chain management implementation – Literature review.

- organisational strategy and policies
- top management commitment
- economic benefits
- liability to harmful material disposal.

The external drivers were identified as:

- suppliers' commitment to GSCM practices
- government regulations that support GSCM practices
- pressure from the market for green products
- competitors
- investor pressure.

This literature review clearly shows that there is a research gap in identifying and ranking drivers of and barriers to GSCM implementation in the context of the South African cement industry in particular. This study therefore closes this gap by identifying and ranking the drivers of and barriers to GSCM implementation.

Methodology

This research started with a literature review to identify significant drivers and barriers from studies conducted in other industries and countries. Information obtained from the literature review was used to develop a questionnaire that, in turn, was used to collect quantitative data. This was followed by the collection of qualitative information through detailed interviews with specialists in SCM.

Data and information from quantitative and qualitative methods were analysed using AHP to determine the most significant drivers of and barriers to GSCM implementation.

The research methodology of this study builds on the work performed by Kamolkittiwong and Phruksaphanrat (2015), who studied the critical factors for GSCM implementation in Thailand's electronic industry. The AHP is considered to be the best analytical tool to rank the significant drivers (Figure 3) and barriers (Figure 4) in this study because of its

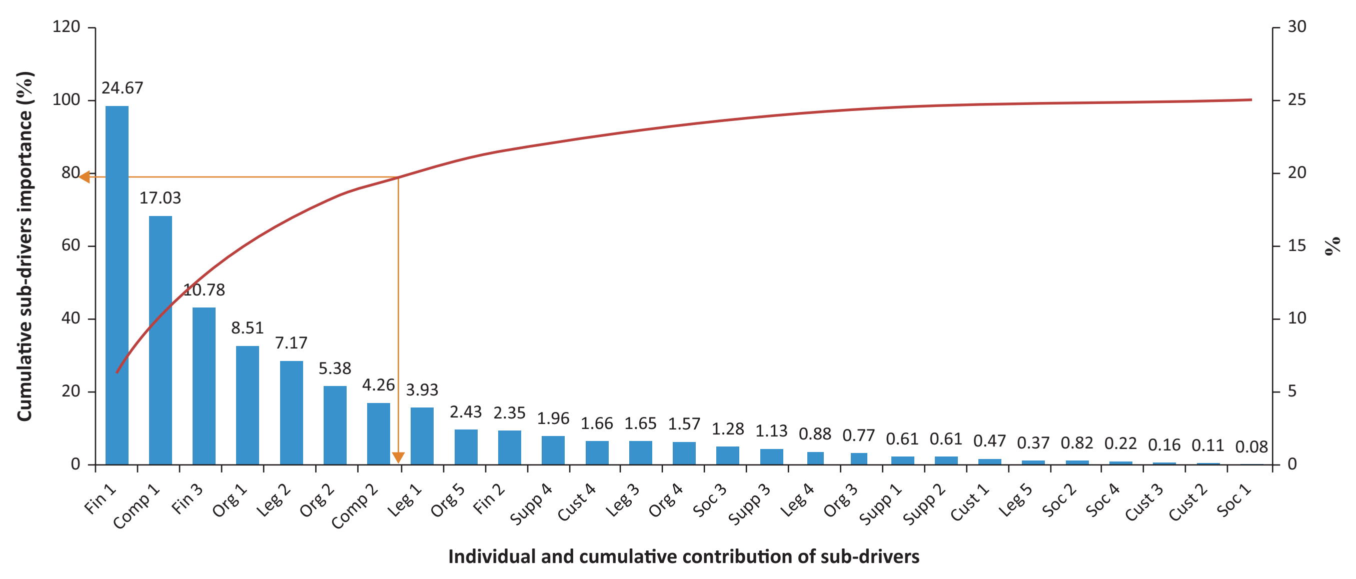


FIGURE 3: Pareto analysis for drivers.

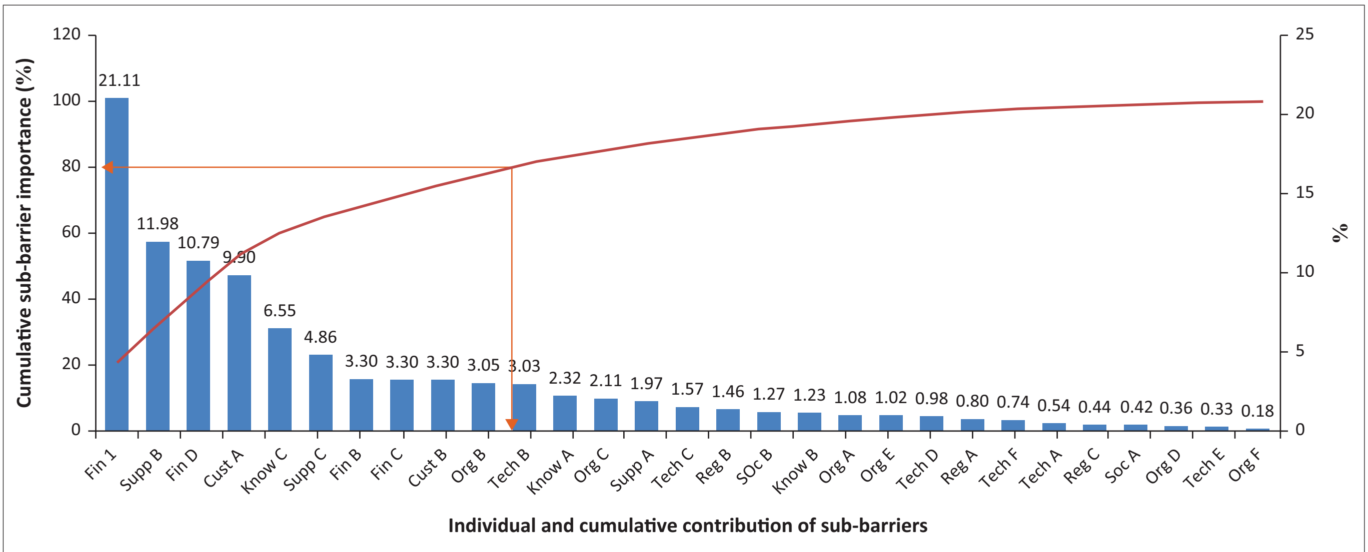


FIGURE 4: Pareto analysis for barriers.

capability to combine tangible and intangible aspects to observe the priorities associated with the alternatives of the problem (Kamolkittiwong & Phruksaphanrat 2015).

The procedure for implementing the AHP as an analytical tool is explained by Saaty (2008). The scale of absolute judgements has been developed by experts to show how dominant one element is over another element with respect to a chosen criterion.

The steps followed in the AHP are guided by Kamolkittiwong and Phruksaphanrat (2015). Furthermore, Pareto analysis was the statistical analysis employed for its appropriateness, as this technique uses the concept based on identifying the top 20% of causes that need to be addressed to resolve 80% of the problems. In this study, this analysis is used to identify 20% of drivers and barriers that contribute to the 80% successful implementation of GSCM.

Validity and ethical considerations

Internal validity

To improve the internal validity of the research, a triangulation approach was used. This involved the collection of information from the literature and thereafter using mixed-method design. Triangulation was therefore achieved by the literature review together with collecting data using both quantitative and qualitative data collection methods to address a single research question. Triangulation is the best-suited strategy in this study as different sources of data helped the researcher to gain a more comprehensive understanding of the significant drivers of and barriers to GSCM implementation.

External validity

The research sample of middle to senior managers in the supply and logistics, production, sales distribution and environment departments of the cement organisation was regarded as being representative enough to provide a clear picture of drivers and barriers to GSCM implementation in the organisation. A sample of middle and senior managers was preferred because this is the group that has a broader insight into the internal and external issues of the organisation. Their insights increased the external validity of the research.

Whilst issues of replication in a different context are yet to be tested, similar studies have been carried out in other countries and different industries. The external validity should therefore be tested against the findings of different studies in the literature to enhance the extent to which the conclusions drawn can be generalised to other contexts.

Validity of the instrument

The questionnaire used in this study was adopted from the work of Zhu and Sarkis (2004) and Gandhi et al. (2016). Panels of experts in these studies confirmed that this instrument is valid (Gandhi et al. 2016). Adopting validated questionnaires used in other studies was the most practical way of ensuring the validity of the measurement instrument for this study, particularly as GSCM is a relatively new concept in the South African cement industry. To ensure that the questionnaire was applicable to the respondents in this study, a pilot test was conducted, which further validated the instrument.

Ethical considerations

In line with the norms and standards of research ethical standards, the following steps were performed as part of this study:

- An introductory letter, with a consent form, was sent to the participants, introducing both the research and the researcher. The participants were advised that participation would be voluntary and that they could exit the research at any point in time.
- The responses were treated as confidential and anonymity was ensured, particularly as the participants of the research were employed in the organisation under consideration. Participants were assured of anonymity.

Limitations of the methodology

Green supply chain management is a relatively new concept in the South African cement industry, and, therefore, some respondents lacked in-depth knowledge of GSCM drivers and barriers or lacked interest in participating in the research. To improve the understanding of GSCM, the researcher included an introduction to the GSCM concept in the invitation e-mail sent to the respondents.

Results

Questionnaire survey

A geometric mean was used to compute the scores of each sub-driver or barrier (specific drivers and barriers) from the survey raw data. The geometric mean method is commonly used in the AHP to aggregate the individual ratings of experts (Saaty 2008). The geometric mean of individual opinions was consequently computed to determine the ranks of the factors. In this way, the pairwise assessment matrix for the main factor was analysed. Typically, the geometric means of the main drivers were represented as shown in Table 1.

The geometric mean computation and tabulation were therefore performed for all main drivers and barriers as well as their sub-drivers and sub-barriers, respectively. The geometric scores are the average scores obtained directly from the survey data for each driver or barrier. As highlighted above, these geometric mean figures would be used to develop a pairwise comparison for the above drivers.

Interviews with experts

This stage was critical because pairwise comparisons of different factors were developed, which is a crucial step in the AHP analysis. Five senior experts were selected from the original subset to determine this pairwise comparison. After careful analysis of the geometric means and using their experience, the experts agreed upon the relative importance as reflected in the geometric means, and thus the pairwise comparisons became easier to develop. A typical pairwise comparison developed is shown in Table 2.

The pairwise matrix scores were then tabulated in the form of a matrix, for example, as shown in Table 3 (drivers).

For example, referring to Table 3, 'organisational style' is twice as important as 'legislation', a '2' is entered in the 'legislation/organisational style' cell. It applies that 'organisational style/legislation' cell will have a reciprocal of '2'. All numbers in the grey-shaded area are reciprocals of non-shaded cells.

Once the matrix has been developed, the eigenvalues and eigenvectors were computed. The eigenvectors of the matrix are the relative importance weights of each driver

TABLE 1: Typical geometric mean scores calculated from survey raw data.

Drivers	Geometric mean
Legislation	3.93
Organisational style	3.97
Customers	3.44
Suppliers	3.59
Societal influences	3.40
Financial perfomances	4.13
Competitors	4.00

or barrier. The ranking was then deduced from the relative weight of each weight or barrier.

To reduce the manual computation time of the individual matrix, an available online AHP Excel sheet was used (Goepel 2016). The reliability of this online AHP Excel tool was tested by carrying out a confirmatory manual calculation on some matrices. Table 4 shows a typical pairwise matrix for sub-drivers. Sub-drivers and sub-barriers are presented in this article in short notation. For example, 'Leg 1' sub-driver represents 'Voluntary GSCM practices, regulations and standards, for example, ISO 14001'. Sub-drivers and sub-barriers notations are fully defined in Tables 1-A1 and 2-A1 in Appendix 1.

Global rankings – Drivers

The global ranking of drivers gives the overall ranking of main driver and sub-drivers. To establish the global importance weights, the relative importance of the main drivers is multiplied by the relative importance weights of sub-drivers. For example, to establish the global importance weight of sub-driver 'Leg 1', relative importance weight of legislation (as shown in Table 4) is multiplied by the relative importance weight of 'Leg 1' in Table 4 (0.140 × 0.281 = 0.0393). Global rankings of all sub-drivers are tabulated in Table 5. The sub-driver with the largest global importance weight is ranked highest.

TABLE 2: Typical pairwise comparisons.

Criteria: A	Criteria: B	i	j	More important? A or B	Scale (1–9)
Legislation	Organisational style	1	2	B	2
	Customers	1	3	A	8
	Suppliers	1	4	A	6
	Societal influences	1	5	A	9
	Financial performance	1	6	B	4
	Competitors	1	7	B	2
	-	1	8	-	-
Organisational style	Customers	2	3	A	9
	Suppliers	2	4	A	7
	Societal influences	2	5	A	9
	Financial performance	2	6	B	3
	Competitors	2	7	B	2
	-	2	8	-	-
Customers	Suppliers	3	4	B	3
	Societal influences	3	5	A	2
	Financial performance	3	6	B	9
	Competitors	3	7	B	8
	-	3	8	-	-
Suppliers	Societal influences	4	5	A	4
	Financial performance	4	6	B	8
	Competitors	4	7	B	6
	-	4	8	-	-
Societal influences	Financial performance	5	6	B	9
	Competitors	5	7	B	9
	-	5	8	-	-
Financial performance	Competitors	6	7	A	3
	-	6	8	-	-
	-	7	8	-	-

Pareto analysis of drivers

The cumulative global importance weights add up to 100%, and, therefore, Pareto analysis was used to determine the 80% most significant drivers. Figure 2 shows the Pareto analysis drivers that influence the implementation of GSCM in the cement industry. It can be seen that only seven sub-drivers out of 27 have an 80% influence on the implementation of GSCM in the South African cement industry.

The global ranking of all sub-drivers shows that 'Fin 1' (financial incentives from the government for GSCM, e.g., reduced carbon tax) is the most significant of all drivers. This highlights the need to gain financial savings from implementing GSCM. Comp 1 (better competitiveness through GSCM practices – improved company image), 'Fin 3' (economic benefits to the cement organisation from implementing GSCM), 'Org 1' (type of organisational culture supportive of GSCM) and 'Leg 2' (voluntary GSCM practices standard, e.g., ISO 14001, 9001) completed the top five of the significant drivers for the implementation of GSCM.

Sub-drivers within customers, suppliers and society main drivers were less significant in influencing GSCM implementation within the case study organisation. This means that suppliers and customers are not significantly influencing the implementation of GSCM. This points to the fact that major suppliers and customers are not applying pressure to implement GSCM, and neither are they significantly assisting to drive the implementation of GSCM.

TABLE 4: Typical pairwise matrix of legislation sub-driver.

Matrix	Leg 1	Leg 2	Leg 3	Leg 4	Leg 5	Relation importance weight	Realtive rank
Leg 1	1	1/3	4	6	9	0.281	2
Leg 2	3	1	6	8	9	0.512	1
Leg 3	1/4	1/6	1	3	7	0.118	3
Leg 4	1/6	1/8	1/3	1	5	0.063	4
Leg 5	1/9	1/9	1/7	1/5	1	0.026	5

TABLE 3: Typical pairwise matrix scores of main drivers.

Matrix	Legislation	Organisational style	Customers	Suppliers	Societal influences	Financial performance	Competitors	Relative importance weight	Rank
Legislation	1	12	8	6	9	1/4	1/2	0.140	4
Organisational style	2	1	9	7	9	1/3	1/2	0.183	3
Customers	1/8	1/9	1	1/3	2	1/9	1/8	0.024	6
Suppliers	1/6	1/7	3	1	4	1/8	1/6	0.043	5
Societal influences	1/9	1/9	1/2	1/4	1	1/9	1/9	0.019	7
Financial performance	4	3	9	8	9	1	3	0.378	1
Competitors	2	2	8	6	9	1/3	1	0.213	2

The results also show that the local community is less influential in GSCM implementation. This could be because five out of eight major operations are situated outside major cities where community pressure to comply with stringent environmental standards is lower.

Barriers

The same process as for drivers was repeated for the barriers, as indicated in Tables 6, 7 and 8. Pairwise comparisons were conducted on the main and sub-barriers and matrices developed. The relative importance weights (normalised eigenvalues) were computed, and, therefore, were the ranks of each barrier and sub-barrier.

Financial constraints, poor GSCM practices by suppliers, poor GSCM practices by customers and the lack of GSCM knowledge were the significant main barriers to GSCM implementation. Organisational, societal, technology and government regulation were broadly less significant barriers.

The most significant sub-barriers identified were as follows: 'Org B' (management's resistance towards GSCM implementation); 'Know C' (lack of awareness on GSCM practices such as reverse logistics, green manufacturing, etc., amongst supply chain members); 'Cust A' (weak market positioning for GSCM-based products or processes – green products not marketed effectively); 'Soc B' (weak public pressure towards green products or processes); 'Tech B' (lack of economically viable technologies and processes to support GSCM); 'Reg B' (lack of financial incentives from regulatory authorities on GSCM);

TABLE 7: Pairwise matrix and ranking for organisational sub-barriers.

Matrix	Org A	Org B	Org C	Org D	Org E	Org F	Relative importance weight	Relative rank
Org A	1	1/4	1/3	4	2	7	0.139	3
Org B	4	1	2	6	5	9	0.390	1
Org C	3	1/2	1	5	4	8	0.271	2
Org D	1/4	1/6	1/5	1	1/9	4	0.046	5
Org E	1/2	1/5	1/4	9	1	5	0.130	4
Org F	1/7	1/9	1/8	1/4	1/5	1	0.024	6

Org, organisation.

TABLE 5: Global rankings of drivers.

Main drivers	Relative importance weights	Sub-drivers	Relative importance weights	Relative rank	Global importance weights	Global rank
Legislation	0.140	Leg 1	0.281	2	0.0393	8
		Leg 2	0.512	1	0.0717	5
		Leg 3	0.118	3	0.0165	13
		Leg 4	0.063	4	0.0088	17
		Leg 5	0.026	5	0.0037	22
Organisational style	0.183	Org 1	0.445	1	0.0815	4
		Org 2	0.294	2	0.0338	6
		Org 3	0.042	5	0.0077	18
		Org 4	0.086	4	0.0157	14
		Org 5	0.133	3	0.0243	9
Customers	0.024	Cust 1	0.195	2	0.0047	21
		Cust 2	0.047	4	0.0011	26
		Cust 3	0.068	3	0.0016	25
		Cust 4	0.690	1	0.0166	12
Suppliers	0.043	Supp 1	0.141	3	0.0061	19
		Supp 2	0.141	3	0.0061	20
		Supp 3	0.263	2	0.0113	16
		Supp 4	0.455	1	0.0196	11
Societal influences	0.019	Soc 1	0.040	4	0.0008	27
		Soc 2	0.168	2	0.0032	23
		Soc 3	0.674	1	0.0128	15
		Soc 4	0.117	3	0.0022	24
Financial performance	0378	Fin 1	0.653	1	0.2467	1
		Fin 2	0.062	3	0.0235	10
		Fin 3	0.285	2	0.1078	3
Competitors	0.213	Comp 1	0.800	1	0.1703	2
		Comp 2	0200	2	0.0426	7

TABLE 6: Pairwise matrix and ranking of main barriers.

Matrix	Organisational	Lack of GSCM knowledge	Market or customers	Societal influences	Technology	Government regulations	Financial	Suppliers	Relative importance weight	Rank
Organisational	1	1/2	1/2	7	1	5	1/5	1/3	0.078	5
Lack of GSCM knowledge	2	1	1/2	7	2	5	1/5	1/3	0.101	4
Market or customer	2	2	1	8	2	6	1/4	1/2	0.132	3
Societal influences	1/7	1/7	1/8	1	1/6	1/3	1/9	1/8	0.017	8
Technology	1	1/2	1/2	6	1	4	1/5	1/3	0.072	6
Government regulations	1/5	1/5	1/6	3	1/4	1	1/8	1/6	0.027	7
Financial	5	5	4	9	5	8	1	4	0.385	1
Suppliers	3	3	2	8	3	6	1/4	1	0.188	2

GSCM, green supply chain management.

TABLE 8: Global ranking of green supply chain management barriers in the cement industry.

Main barriers	Relative importance weights	Sub-barriers	Relative importance weights	Relative rank	Global importance weights	Global rank
Organisational	0.078	Org A	0.139	3	0.0108	19
		Org B	0.390	1	0.0305	10
		Org C	0.271	2	0.0211	13
		Org D	0.046	5	0.0036	27
		Org E	0.130	4	0.0102	20
		Org F	0.024	6	0.0018	29
Lack of GSCM knowledge	0.101	Know A	0.230	2	0.0232	12
		Know B	0.122	3	0.0123	18
		Know C	0.648	1	0.0655	5
Market or customer	0.132	Cust A	0.750	1	0.0990	4
		Cust B	0.250	2	0.0330	9
Societal influences	0.017	Soc A	0.250	2	0.0042	26
		Soc B	0.750	1	0.0127	17
Technology	0.072	Tech A	0.075	5	0.0054	24
		Tech B	0.421	1	0.0303	11
		Tech C	0.218	2	0.0157	15
		Tech D	0.136	3	0.0098	21
		Tech E	0.047	6	0.0033	28
		Tech F	0.103	4	0.0074	23
Regulations or government	0.027	Reg A	0.297	2	0.0080	22
		Reg B	0.540	1	0.0146	16
		Reg C	0.163	3	0.0044	25
Financial	0.385	Fin A	0.548	1	0.2111	1
		Fin B	0.086	3	0.0330	7
		Fin C	0.086	3	0.0330	8
		Fin D	0.280	2	0.1079	3
Suppliers	0.188	Supp A	0.105	3	0.0197	14
		Supp B	0.637	1	0.1198	2
		Supp C	0.258	2	0.0486	6

GSCM, green supply chain management.

and ‘Fin A’ (high initial capital cost to implement GSCM projects).

Global rankings – Barriers

The relative importance weights of the individual sub-barriers were multiplied by the corresponding relative importance weights of the main barriers to calculate the global importance weights.

Pareto analysis of barriers

A similar Pareto analysis was conducted on the barriers, as was employed on the drivers, and it was deduced that only 10 out of 29 sub-barriers significantly influence the successful implementation of GSCM in the South African cement industry. ‘Fin A’ (high initial capital cost to implement GSCM projects) was found to be the most significant barrier. ‘Supp B’ (poor supplier commitment towards GSCM, e.g., power utilities using old energy-inefficient technology) was found to be the next significant barrier. ‘Fin D’ (high cost of GSCM certification or verification, e.g., ISO-integrated systems certification and CO_2 footprint verification), ‘Cust A’ (weak market positioning for GSCM-based products or processes – green products not marketed effectively) and ‘Know C’ (lack of awareness on GSCM practices such as reverse logistics, green manufacturing, etc., amongst supply chain members) made up the top five of the barriers to GSCM implementation in cement organisation. The other five most significant sub-barriers are ‘Supp C’ (problems arising from maintaining awareness of GSCM amongst suppliers [lack of collaboration with suppliers]), ‘Fin B’ (difficulties in acquiring financial capital for GSCM initiatives), ‘Fin C’ (limited financial resources within organisations), ‘Cust B’ (lack of customer preferences or demands for GSCM-based products or processes) and ‘Org B’ (management’s resistance towards GSCM implementation).

Discussion of results

Drivers

A Pareto analysis was conducted on the global ranking of the drivers. The Pareto analysis reveals that only 7 of the 27 drivers contribute 80% importance to the GSCM implementation in the cement organisation. It must be mentioned here that the significance of drivers is not static, but will keep on changing depending on the priorities and strategies of the organisation. At this stage, however, the cement industry would do well to put more effort into developing strategies that address the identified seven drivers.

The other main drivers (categories) identified in the literature – namely, customers, suppliers and societal influences – are less significant in the cement industry context. This may also change in future as the whole South African cement industry operating environment will change. Also, as the GSCM awareness increases, customers and society will demand more compliance with environmental regulations and organisations will be forced to implement GSCM practices. At that stage, these less significant drivers will become more significant.

To help understand the results of this study in the context of other studies carried out in other countries and industries, the ranking of drivers in this study is compared to what other researchers found in other studies. It was expected that there would be some similarities because many of these studies (Kamolkittiwong & Phruksaphanrat 2015; Kathiresan & Ragunathan 2016; Liu et al. 2012; Niemann et al. 2016) were carried out in developing countries with economic characteristics similar to those of South Africa. Some differences were also expected as the South African cement industry is currently facing unique challenges and opportunities compared to other industries. Some of these challenges include a contracting market, a carbon tax that has the potential to erode a significant fraction of profits and more stringent legislation amongst other challenges.

Financial incentives from the government and savings through green supply chain management (e.g. reduced carbon tax)

This was identified as the most significant driver to the implementation of GSCM. This was expected as the cement industry is a heavy emitter of CO_2 from limestone calcination and combustion processes.

It must also be noted that cement is a commodity, and, therefore, there are not many opportunities for differentiation. Competitive advantage in the South African cement market is achieved through cost leadership.

Although other studies found financial or economic benefits to be significant, it was not the most significant. Kamolkittiwong and Phruksaphanrat (2015) found government regulations, top management support, customers, organisational strategy and economic benefits (in that order) to be the top five significant drivers. In Africa (Mozambique manufacturing industry), Niemann et al. (2015) found corporate social responsibility, organisational policies, board and top management commitment and local community (society) to be the top four drivers in that order. The fact that cost saving was found to be a more significant driver in the South African cement industry points to the fact that the industry is mainly driven by lean supply chain strategies. This makes opportunities for cost-saving a high priority in the supply chain.

Better competitiveness through green supply chain management practices – Improved company image

Competitiveness through GSCM was identified as the second most significant driver for GSCM implementation in the South African cement industry. In the most recent years, particularly after the soccer world cup 2010, the South African cement market has shrunk because of reduced infrastructure developments. South African cement market has also seen two new entrants since the major soccer showpiece. Green supply chain management is therefore viewed as a great marketing tool to improve the market competitiveness; hence, it was identified as a significant driver within the South African cement industry. This concurs with studies conducted in other countries (Luthra et al. 2011; Mudgal et al. 2009).

Type of organisational culture supportive of green supply chain management

This study identified a supportive culture of GSCM as a significant driver for the implementation of GSCM. The respondents believed that a strong organisational culture of GSCM is likely to achieve quicker and sustainable GSCM implementation. Organisational culture is normally driven by top management; therefore, organisational culture and top management will be considered the same in this discussion. Kamolkittiwong and Phruksaphanrat (2015) also found organisational culture or strategy to be the fourth most significant driver in the electronic industry of Thailand. Luthra et al. (2013) found top management perspective to be the most significant in the Indian manufacturing industry. Niemann et al. (2016) found board and top management to be the third most ranked driver in the Mozambican manufacturing industry. Therefore, this study confirms what many authors found in their studies of other developing countries.

Voluntary green supply chain management practices standard (e.g. ISO 14001, 9001)

The research conducted for this article revealed that standards like ISO 14001 are critical in the implementation of GSCM practices. This is because ISO 14001 sets the basis for environmental continuous improvements which involves GSCM practices. For example, for an organisation to continuously improve in its waste management practices (ISO 14001 requirements), it might explore recycling, re-manufacturing and green design that are GSCM practices.

Gandhi et al. (2016) found environmental certifications to be the 16th most important out of 24 drivers. However, Luthra et al. (2013) found environment management systems implementation as the most significant driver amongst the innovative green practices' implementation strategy category. Therefore, it can be concluded that the varied findings amongst the different studies point to diverse priorities within industries and countries.

Organisation's environmental mission

The South African cement industry organisations' environmental missions aim at minimising the impact of environmental footprint. This creates positive environmental outcomes in the long term.

This commitment means that these organisations formulate strategies that are meant to promote positive environmental outcomes. In line with these strategies, the organisation will be encouraged to implement GSCM practices. Such practices will include using low-energy consumption products and processes; minimising waste generation using a 'cradle to cradle' waste management system; optimising logistics; and reducing carbon emissions.

The need to match competitor green strategies

Cement producers from around the world are driving towards a world standard carbon and other gaseous emissions per ton of cement produced. To achieve this, they continuously focus on green product design, invest in efficient processing equipment and optimise logistics. To match their competitors, the respondents recognise the need for the South African cement industry to implement GSCM practices in its supply chain. The need to match competitors' green strategies is therefore seen as a significant driver to the implementation of GSCM in the cement industry.

Luthra et al. (2013) found competitiveness through GSCM to be the third-ranked driver amongst the six main drivers. Gandhi et al. (2016) found competitiveness to be 10th ranked out of 24 identified drivers. Kamolkittiwong and Phruksaphanrat (2015) found competitiveness to be sixth-ranked out of 10 drivers. The ranking in this study concurs with what other researchers found in their studies.

Barriers

A Pareto analysis was also used to analyse the importance of the 29 sub-barriers. Ten barriers were identified as being the most significant barriers out of the 29 identified through literature review.

High capital costs

The high initial capital costs on large-scale GSCM projects were identified as being the most significant barrier to the implementation of GSCM in the cement industry. The suggested reason was that large-scale 'green projects' in the cement context require significant capital. For example, to reduce the carbon footprint within the value chain, the cement industry has to invest in renewable energy projects, such as solar.

Because of the high cost of large green projects, organisations seek cheaper sources of capital to complete these projects. Some organisations offer lower interest loan options compared to commercial lenders. Such organisations in South Africa, like the Industrial Development Corporation (IDC), require expected capital return to be guaranteed with certainty. It is sometimes difficult to guarantee the expected return on some green projects because of the ever-changing economic variables such as exchange rates, inflations and the market. As a result, many organisations lose out on relatively cheaper capital. Related to the high initial capital required for GSCM implementation, GSCM implementation also requires an ongoing operating capital. For example, establishing a waste recycling facility for energy requires additional operating income for consumables, labour, maintenance and logistics. This increase in costs is prohibitive, especially when every cement producer is cutting costs to be price competitive.

Poor supplier commitment

Poor supplier commitment towards GSCM (e.g. power utilities using old energy-inefficient technology) was identified as a second major barrier in this research. South Africa, like many other African countries, has energy and transport utilities monopolised by state-owned enterprises (SOEs) (Besant-Jones 2006:10). In the South African cement industry context, two critical drivers for cement organisations supply chains are power and rail logistics, and these are monopolised by Eskom and Transnet, respectively. These SOEs generally provide standardised services to their clients, and efficiency improvement projects within these SOEs generally require considerable time to plan and complete.

High cost of certification

The high cost of GSCM certification or verification (e.g. ISO-integrated systems certification and CO_2 footprint verification) was also identified as a major barrier. The cement GSCM experts consider the auditing or verification costs and employees effort required for current and future GSCM projects to be prohibitive. The costs of maintaining these certifications are high. Therefore, implementing some GSCM practices that may require consultants for implementation and verification will add to the current high costs.

Weak market positioning

The fourth major barrier is weak market positioning for GSCM-based products or processes (green products not marketed effectively). In the current price-sensitive cement market, customers are looking at short-term cost savings at the expense of long-term sustainability through green products. Therefore, cost is a primary factor considered by all players along the cement supply chain.

Lack of green supply chain management awareness

The GSCM experts believe that, despite GSCM having been talked and written about for more than 20 years now, there is generally a lack of GSCM awareness amongst cement industry employees and relevant stakeholders.

Related to general GSCM awareness along the supply chain, awareness and collaboration with suppliers in particular play a significant role in the implementation of GSCM in organisations.

Top management must set the tone for GSCM awareness. Failure to create a vibrant awareness drive is generally a huge barrier to the implementation of GSCM. Pooe and Mhelembe (2014), Luthra et al. (2011) and Ojo et al. (2014) all found top management resistance or lack of support to be a major barrier in the South African, Indian and Nigerian industries, respectively.

Conclusion

This study has shown that drivers of and barriers to the implementation of GSCM are not universally standard; rather they slightly vary according to industry and country. Thus, although significant barriers and drivers are generally similar between industries, the ranking of these drivers and barriers varies slightly from one industry to another and from one country to another. For example, most literature reviews concerning the Indian, Chinese and Malaysian manufacturing industry concluded that government regulations, customer awareness and top management are the most crucial drivers of GSCM implementation (Dhull & Narwal 2015; Ghazilla et al. 2015; Luthra et al. 2013); however, the results of this study show that financial or economic performance and the need to gain market competitive advantages are the top-ranked drivers of GSCM implementation in the South African context.

This is indicative of the different forces that influence the performance of various industries in different countries. It is therefore crucial that, before embarking on putting strategies to implement GSCM, top management review drivers and barriers relevant to their industry and country. Similarly, studies in the three countries listed above show that the lack of customer awareness and lack of top management commitment are the critical barriers to GSCM implementation (Luthra et al. 2016; Wang et al. 2016), and yet, in the South African cement industry context, high initial capital costs and the lack of supplier commitment to GSCM are the most significant barriers.

Of the 27 and 29 drivers and barriers identified in the literature, respectively, only seven drivers are significant for the South African cement industry and 10 barriers are also significant according to the 80:20 rule.

With regard to the results obtained from this study, one can conclude that the implementation of GSCM in the cement industry and any other manufacturing industry is a crucial process (Walker et al. 2008) and needs coordination between all players in the organisational value chain (staring from employees to top management) as well as external stakeholders (government, customers, suppliers, technology and financing partners).

The South African cement industry would benefit from ideas suggested in this article as it suggests critical factors for GSCM adoption. The results point to the fact that the forces from both drivers and barriers are highly significant, and they must all be considered when planning GSCM implementation. The contents of this article are part of a larger framework of environmental responsibility and the strategic implications of GSCM implementation.

Acknowledgements

Competing interests

The authors have declared that no competing interest exist.

Authors' contributions

A.N. provided conceptual, methodology, writing review and supervisory contribution. J.M. conducted the first drafting, methodology and analysis work.

Ethical considerations

This article followed all ethical standards for research without direct contact with human or animal subjects.

Funding information

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Data availability

The authors confirm that the data supporting the findings of this study are available within the article.

Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors.

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Appendix 1

TABLE 1-A1: Full definitions of sub-drivers notation.

Notation	Sub-drivers
Leg 1	Voluntary GSCM practices regulations and standard (e.g. ISO 14001)
Leg 2	Voluntary GSCM practices standard (e.g. ISO 14001, 9001)
Leg 3	Compulsory regulation mandated by the central government
Leg 4	Local municipality regulations (e.g. municipality by-laws)
Leg 5	Compulsory corporate social responsibility pushed by authorities
Org 1	Type of organizational culture supportive of GSCM
Org 2	Organisation's environmental mission
Org 3	Employee involvement or motivation
Org 4	Internal organizational capabilities to support GSCM
Org 5	Awareness of GSCM impact throughout the organisation
Cus 1	Pressure from customers to produce environmentally friendly products
Cus 2	Fear of being criticized by customers
Cus 3	Environmental awareness of customers
Cus 4	Potential to penetrate new markets
Sup 1	Suppliers capabilities to develop environmentally friendly goods
Sup 2	Supplier willingness to develop environmentally friendly goods
Sup 3	Environmental certification of suppliers
Sup 4	Green product design collaboration with suppliers
Soc 1	Public awareness to green initiatives
Soc 2	Society pressure for PPC Cement to implement GSCM practices
Soc 3	PPC Cement corporate and social responsibility requirements
Soc 4	Pressure by environmental advocacy groups to green the supply chain
Fin 1	Financial incentives from government for GSCM (e.g. reduced carbon tax)
Fin 2	High cost of disposal of harmful materials
Fin 3	Economic benefits to PPC Cement from implementing GSCM
Comp 1	Better competitiveness through GSCM practices (improved company image)
Comp 2	The need to match competitor green strategies

GSCM, green supply chain management.

TABLE 2-A1: Full definition of sub-barriers notation.

Notation	Sub-barriers
Ong A	Weak organizational structure to support GSCM
Org B	Management's resistance towards GSCM implementation
Org C	Restrictive company policies towards products or process stewardship for GSCM
Org D	Undeveloped organizational GSCM organisational culture
Org E	Disbelief regarding the benefits of GSCM
Org F	Lack of organisational technical expertise to implement GSCM
Know A	Lack of collaboration of supply chain members on green practices
Know B	Difficulties in obtaining GSCM information for potential improvements in the supply chain line
Know C	Lack of awareness on GSCM practices like reverse logistics, green manufacturing etc. among supply chain members
Cust A	Weak market positioning for GSCM-based products or processes (green products not marketed effectively)
Cust B	Lack of customer preferences or demands for GSCM based products or processes
Soc A	Low drive by society towards green practices
Soc B	Weak public pressure towards green products or processes
Tech A	Inadequate R&D within the supply chain to support GSCM practices
Tech B	Lack of economically viable technologies and processes to support GSCM
Tech C	Inadequate processes to support GSCM practices
Tech D	Unavailability of viable GSCM-based alternative solutions
Tech E	Complexity of design to support GSCM practices
Tech F	Lack of flexibility to switch overto GSCM-based systems
Reg A	Lack of environmental enforcement by the government
Reg B	Lack of financial incentives from regulatory authorities on GSCM
Reg C	Lack of clear policies from government related to GSCM
Fin A	High initial capital cost to implement GSCM projects
Fin B	Difficulties in acquiring financial capital for GSCM initiatives
Fin C	Limited financial resources within organisations
Fin D	High cost of GSCM certification or verification (e.g. ISO integrated systems certification and CO2 footprint verification)
Supp A	Suppliers difficulties in adopting green technology
Supp B	Poor supplier commitment towards GSCM (e.g. power utilities using old energy inefficient technology)
Supp C	Problems arising from maintaining awareness of GSCM among suppliers (lack of collaboration with suppliers)

GSCM, green supply chain management.