ScienceDirect

Cleaner Waste Systems
Volume 5, August 2023, 100098

A study of the barriers to the adoption of integrated sustainable-green-lean-six sigma-agile manufacturing system (ISGLSAMS) in Indian manufacturing organizations

Dharmendra Hariyani [a] [b], Sanjeev Mishra [c], Milind Kumar Sharma [d], Poonam Hariyani [e]

[a] Department of Mechanical Engineering, University Department, Rajasthan Technical University, Kota, Rajasthan, India
[b] Department of Mechanical Engineering, Swami Keshvanand Institute of Technology, Management and Gramothan, Jaipur, Rajasthan, India
[c] Professor, Department of Mechanical Engineering, University Department of Teaching, Rajasthan Technical University, Kota, Rajasthan, India
[d] Professor, Department of Production and Industrial Engineering, MBM University, Jodhpur, Rajasthan, India
[e] Associate Professor, Department of Chemistry, JECRC University, Jaipur, Rajasthan, India

Received 20 August 2022, Revised 9 March 2023, Accepted 12 May 2023, Available online 13 May 2023, Version of Record 22 May 2023.

https://doi.org/10.1016/j.clwas.2023.100098
Get rights and content

Referred to by

Corrigendum regarding previously published articles
Cleaner Waste Systems, Volume 9, December 2024, Pages 100159

View PDF

Highlights

- Technological risk and low supplier commitment is first ranked barrier construct.
- Uncertainty, misconception, and low customer demand is second ranked construct.
- Managerial complexity construct is third ranked barrier construct for ISGLSAMS.
- Design complexity construct is the fourth ranked barrier construct for ISGLSAMS.
- Barriers have a significant negative effect on the organization performance.

Abstract

The scarcity of resources and customers' demands for the product variety is causing significant research in the sustainable market-based manufacturing system, i.e. integrated sustainable-green-lean-six sigma-agile manufacturing system (ISGLSAMS). Many manufacturing organizations are opting for ISGLSAMS with partial mix or success. The objectives of this study are to analyze the effect of the various ISGLSAMS barriers constructs on the (i) adoption of ISGLSAMS, and (ii) organizational market, operational and sustainable performance in Indian manufacturing organizations. The research methodology includes the (i) design of a survey questionnaire, (ii) data collection, and (iii) analysis of the data. A total of 540 responses were received out of 3607 survey questionnaires mailed. Based on the opinion of four industry experts and two academic experts from the field of operations management ISGLSAMS barriers are grouped into ten formative constructs. The effect of the constructs on the adoption of ISGLSAMS and ISGLSAMS performance is analyzed with SmartPLS 2.0 M3. The result suggests that (i) technological risk and low supplier commitment construct, (ii) uncertainty, misconception, and low customer demand construct, (iii) managerial complexity construct, and (iv) design complexity construct are found prominent barriers in India for the ISGLSAMS. The results also suggest that ISGLSAMS barriers have a significant negative effect on the organizational operational, market, and sustainable performance. This study provides the opportunity for the policymakers and organizations to design and develop policies, and research activities for overcoming the barriers, and successful adoption of ISGLSAMS in India.

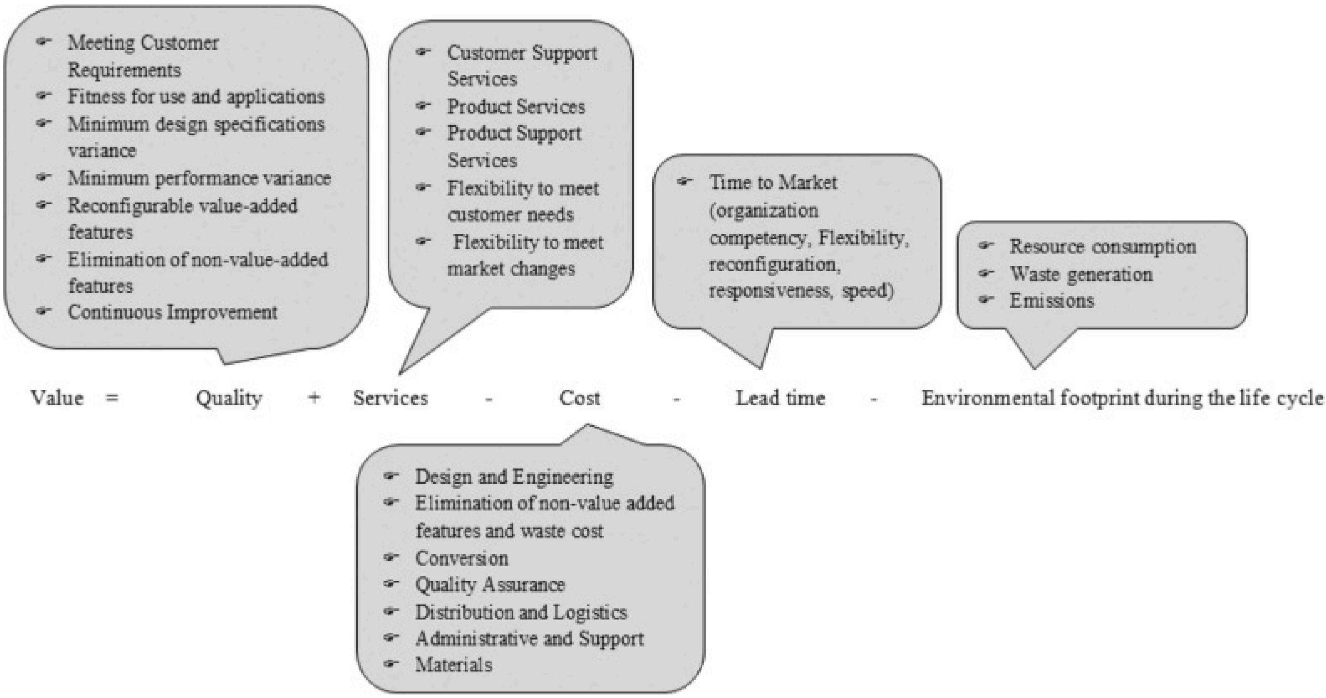
Previous Next

Keywords

Integrated sustainable-green-lean-six sigma-agile manufacturing system (ISGLSAMS); ISGLSAMS barriers; ISGLSAMS performance; Structural equation modeling of ISGLSAMS barriers; Operational, market, and sustainable performance of ISGLSAMS

1. Introduction

Due to the ecological imbalance, and ever-changing customers' demand for product variety there has been a radical change in the working environment of manufacturing organizations. With sustainable awareness, and ever-changing customer demand, customers weights the product value in terms of various characteristics, viz., quality, service, cost, lead-time (Johansson et al., 1993), and environmental footprint during the product life cycle (Dangelico and Pujari, 2010) as shown in Fig. 1. To maximize the product value (i) the cost of the product, lead time of the product, and environmental impact of the product during the product life cycle must be minimized, and (ii) product quality and organizational services must be maximized.



Download: Download high-res image (263KB)

Download: Download full-size image

Fig. 1. Total value characteristics of ISGLSA product covering ISGLSAMS dimensions (Hariyani and Mishra, 2022a).

To maximize the quality, the organization has to focus on (a) meeting customer requirements, (b) fitness for use and applications, (c) minimum design specifications variance, (d) minimum performance variance, (e) reconfigurable value-added features, (f) elimination of non-value added features, (g) continuous improvement, and (h) process integrity of the organizational activities. To maximize the services, the organization has to focus on designing (a) customer support services, (b) product services, (c) product support services, (d) flexibility to meet customer needs, and (e) flexibility to meet market changes. To minimize the cost, the organization has to focus on (i) reduction of the cost of (a) design and engineering, (b) manufacturing or conversion, (c) distribution and logistics, (d) administrative and support, and (e) materials, (ii) elimination of non-value added features and waste cost, and (iii) quality assurance of the organizational activities. To reduce the lead time, the organization has to focus on the reduction of time to market through developing (a) organization competency, (b) flexibility, (c) reconfiguration, (d) responsiveness, and (e) speed. To reduce the environmental footprint during the life cycle, the organization has to reduce (a) resource consumption, (b) waste generation, and (c) emissions during the total value chain (Mittal et al., 2017). Manufacturing organizations are continuously focusing attention to respond to meet these characteristics in the organization's product, process, system, and supply chain (Mittal et al., 2017). This will increase the organizational ecological, social, economic, and market performance (Veleva and Ellenbecker, 2001). Organizations need to manufacture the products through harmonious interaction (Wu et al., 2015) among the ecological, social, and economic dimensions (Veleva and Ellenbecker, 2001). This will ensure the balanced growth of the organization and society.

A sustainable, competitive, and compatible manufacturing strategy, harmonizing all these three dimensions makes the manufacturing organization competitive (Mittal et al., 2017). It is observed through literature that the "integrated sustainable-green-lean-six sigma-agile manufacturing system (ISGLSAMS)" (Elmoselhy, 2015; Mittal et al., 2017; Nieuwenhuis and Katsifou, 2015) meets all these business goals, and the total value characteristics as described by the Fig. 1. To generate the value-added activities in the turbulent market in a sustainable manner, integration of "sustainable, green, lean, six sigma, agile manufacturing practices" is essential. In ISGLSAMS, (i) lean, sustainability, and six sigma manufacturing practices provide the economic dimension by (a) reducing non-value-added activities (b) robust product, process, and system design (c) recover, reuse, remanufacturing, and redesigning of the product during its life cycle) and (ii) agile manufacturing practices provide quick responsiveness towards the changes in the market or customers' demand (Mittal et al., 2017, Nieuwenhuis and Katsifou, 2015). ISGLSAMS increases organizational sustainability, and market performance through low-cost, quick deliverable sustainable reconfigurable products, production systems, and supply chain (Nieuwenhuis and Katsifou, 2015). This manufacturing system is more sustainable than 6Rs-based sustainable manufacturing, as this reduces resource consumption due to modular product, process, and system design. 3Rs-based green manufacturing strictly focuses on environmental health, while 6Rs-based sustainable manufacturing focuses on environmental health, social benefits, and economic viability. In ISGLSAMS, modularity increases the opportunities for product recovery, reuse, and recycle, and reduces the production and product waste during the life cycle. This also increases the opportunities for meeting the customer variety needs for the product in the turbulent market (Mittal et al., 2017, Nieuwenhuis and Katsifou, 2015, Elmoselhy, 2013).

Despite the sustainable and market performance, organizations do not opt for ISGLSAMS either due to the (i) presence of various barriers, or (ii) lack of various drivers, or (iii) lack of various enablers, or (v) various short-term business goals; but for the business sustainability requirements and benefits of the society, adoption of ISGLSAMS is essential. The objectives of this paper are (i) to analyze the effect of the various ISGLSAMS barriers on the adoption of ISGLSAMS, and (ii) to analyze the effect of the various ISGLSAMS barriers on the organizational market, operational and sustainable performance in Indian manufacturing organizations.

1.1. Integrated sustainable-green-lean-six sigma-agile manufacturing system (ISGLSAMS)

ISGLSAMS is a sustainable quick reconfigurable manufacturing system to respond quickly to changes in the customers' demand in the market (Hariyani and Mishra, 2022a). ISGLSAMS integrates sustainable, green, lean, six sigma, and agile dimensions simultaneously under a single manufacturing house. The organization has to plan strategic level planning, covering the strengths and weaknesses of the organization, to position the organization for the competition for ISGLSAMS. Tactical level planning helps the organization to create the resources for meeting long-term strategic goals. Operational-level planning assists the organization to execute the activities in ISGLSA manner to meet the business sustainability requirements and market performance goals (Mittal et al., 2017, Nieuwenhuis and Katsifou, 2015, Elmoselhy, 2013). An integrated strategic approach helps organizations to design a new business model for competitiveness and business benchmarking (Madsen, 2020).

In ISGLSAMS, the resources are purchased and developed as per the requirements of ISGLSAMS. ISGLSAMS responds quickly to changes in the product design, and product mix in an unpredictable market sustainably (Elmoselhy, 2015; Mittal et al., 2017; Nieuwenhuis and Katsifou, 2015). The organization uses (i) information and communication technology to predict and analyze the changes in the market, (ii) a virtual network for streamlining the ISGLSAMS, (iii) quick reconfigurable robust sustainable manufacturing workstations, supply chain, and system for lead time compression, and meeting the customer's demand for quality and variety, (iv) reverse supply chain for minimizing the ecological effect of the product at the end of the product life cycle, (v) cross-trained workers trained in the concepts of ISGLSAMS, and (vi) quick reconfigurable robust product design. Table 1 highlights the various characteristics of ISGLSAMS.

Table 1. Characteristics of ISGLSAMS (Hariyani and Mishra, 2022a).

Distinguish Attributes	ISGLSAMS
Resources	Sustainable reconfigurable and clean
Market demand	Volatile and Irregular
Information collection through IT	Essential
Product variety	Medium to high or personalized
Product life cycle	Short
Customer drivers	Sustainable reconfigurable agile product
Forecast mechanism	Algorithmic or consultative
Purchasing portfolio	Hybrid Keiretsu-Kraljic
Purchasing policy	Vendor Managed Inventory
Stockout penalties	Nil
Waste elimination	Essential
Inventory Level	At strategic and bottleneck locations
Rapid reconfiguration	Essential
Outsourcing	Essential for assemble to order

Distinguish Attributes	ISGLSAMS
Virtual corporation	Essential
Mixed-Pull supply chain strategies	Essential
Cost	Market Runner-up
Sustainability and responsiveness	Market Champion
Quality	Market Runner-up
Lead time reduction	Market Runner-up
Level scheduling	Desirable
Employees training in ISGLSA	Essential
Self-organized teams	Essential
Kaizen	Essential
Visual Management	Essential
Stakeholders involvement	Essential

ISGLSAMS uses sustainable reconfigurable clean workstations or resources to quickly respond to the changes in the volatile market demand in a sustainable manner (Mittal et al., 2017, Elmoselhy, 2013). The organization has to use information technology to predict changes in the market (Krishnamurthy and Yauch, 2007, Naylor et al., 1999). Due to the agility of the ISGLSAMS, the product variety may be medium to high, or even personalized or engineered to order. Due to the turbulence in the market or ever-changing customer demand the product life cycle will be low. Due to the ever-changing customer demand and customer awareness of the sustainability issue, the sustainable reconfigurable agile product will be the main driving force for the organizations for ISGLSAMS. As the customer demand is uncertain, the organization has to use either algorithmic or consultative to forecast the demand for the market. The organization has to use a hybrid Keiretsu-Kraljic purchasing portfolio to procure the inventory through suppliers' partnerships (Elmoselhy, 2013, Elmoselhy, 2015a). It will minimize the impact of the business market on the manufacturing organization and also the supply risk. Buffer inventory is also kept at strategic and bottleneck locations, and supply chain partnerships minimize stockout penalties for the organization (Elmoselhy, 2013, Elmoselhy, 2015a). To be sustainable ISGLSAMS, must focus on the reduction of waste. Rapid reconfiguration ability will make the organization more competitive and sustainable. The organization has to adopt outsourcing of the modules for assemble to order to gain a market advantage. Virtual corporation of supply chain partners is essential to streamline the ISGLSAMS (Elmoselhy, 2015b, Krishnamurthy and Yauch, 2007, Christopher and Towill, 2000, Naylor et al., 1999). Mixed-pull supply chain strategies help the organization to better manage inventory procurement in ISGLSAMS (Elmoselhy, 2015). The organization has to focus on (i) reduction of cost and lead time, and (ii) improvement of quality, but sustainability and responsiveness of the organization will be one of the market-winning criteria for long-term business success in ISGLSAMS. For reducing the scheduling complexity organization has to use level scheduling through the heizunka box. For ISGLSA work culture practices the employees must be well-cross-trained in all aspects of ISGLSAMS (Mittal et al., 2017, Naylor et al., 1999). This will also help to develop the self-organized teams to execute the ISGLSAMS practices. For continuously improving the ISGLSAM practices kaizen work culture is essential to lead the business. Visual management of the ISGLSAMS task is essential to identify and monitor the opportunity for improving the work practices of ISGLSAMS. Stakeholders' involvement is essential for ISGLSAMS planning and design to in-build the voice of various stakeholders in the organization's value chain.

2. Research problem

Apart from the sustainable and market performance in a turbulent market, and various competitive advantages, viz. responsiveness, flexibility, quality, cost, competence, sustainability, innovation, and profitability (Elmoselhy, 2013, Elmoselhy, 2015b, Nieuwenhuis and Katsifou, 2015), better market image (Vázquez-Bustelo et al., 2007), sustainable, environmental and market performance (Mittal et al., 2017, Elmoselhy, 2015a, Nieuwenhuis and Katsifou, 2015), many organizations are not opting for ISGLSAMS.

3. Research objectives

The research objectives of this paper are (i) to analyze the effect of the various ISGLSAMS barriers on the adoption of ISGLSAMS, and (ii) to analyze the effect of the various ISGLSAMS barriers on the organizational market, operational and sustainable performance in Indian manufacturing organizations, so that a strategic approach can be planned by the government and manufacturing organizations (i) to overcome the ISGLSAMS barriers constructs, and (ii) to meet the business market, sustainability, and organizational goals.

4. Literature review

4.1. Barriers to the ISGLSAMS

There are always various barriers that prevent an organization from adopting a manufacturing strategy. Following are the various barriers to the adoption of ISGLSAMS.

4.1.1. Weak legislation

(i) The absence of environmental, social, ecological, and economic sustainability laws (Mittal and Sangwan, 2014, Asuka-Zhang, 1999), (ii) the presence of ineffective environmental legislation (Mittal and Sangwan, 2014, Asuka-Zhang, 1999), and (iii) lack of compliance with legislation (Muduli et al., 2013) make the organization or value chain partners more lenient with the sustainability, and environmental related laws and planning in ISGLSAMS (Hariyani and Mishra, 2022b).

4.1.2. Uncertain future legislation

Uncertain developments in the laws for sustainability, environmental regulations, resource conservation, resource use, resource recovery, and modular manufacturing (Iacovidou et al., 2017, Mittal and Sangwan, 2014, Nnorom and Osibanjo, 2008) make the organization or value chain partners less focused on strategic investment planning for sustainability, and environmental related projects for ISGLSAMS (Hariyani and Mishra, 2022b).

4.1.3. Lack of government support

Absence of investment aids, grants, and R&D support by the government. for ISGLSAMS products, projects, system, and supply chain design, also creates investment initiative barriers for the ISGLSAMS (Raut et al., 2018, Bhanot et al., 2016), as a high initial investment cost and long payback period for green and sustainable projects cause the organizations to seek for the government support for the investment fund for ISGLSAMS (Hariyani and Mishra, 2022b).

4.1.4. Low public and peer pressure due to lack of awareness

Absence or low pressure from local societies, NGOs, and stakeholders for ISGLSAMS due to a lack of awareness about sustainable products, processes, supply chain, and green innovation (Abdullah et al., 2016, Cherrafi et al., 2016, Ghazilla et al., 2015, Kulatunga et al., 2013, Russo and Harrison, 2005), and reconfigurable products, processes, and supply chain (Yusuf et al., 1999), etc. also influence the adoption of ISGLSA manufacturing practices in the organization's value chain (Hariyani and Mishra, 2022b).

4.1.5. The misconception of the high cost

The misconception about the huge fund required for ISGLSAMS such as a huge fund for sustainable products, processes, design, technologies, and supply chain (Abdullah et al., 2016, Govindan et al., 2014, Luthra et al., 2011), etc. also affect the organization's initiative for ISGLSAMS (Hariyani and Mishra, 2022b).

4.1.6. Uncertain financial benefits

Uncertain return on investment from sustainable supply chain (Dhull and Narwal, 2016, Jawahir et al., 2006), sustainable manufacturing (Ghazilla et al., 2015), ISGLSA manufacturing and supply chain, etc. also cause the organization to be more reluctant to take the risk (Hariyani and Mishra, 2022b).

4.1.7. Low customer demand for sustainable reconfigurable products

Lack of customer demand for sustainable (Shankar et al., 2017, Zhu and Geng, 2013) reconfigurable products affects the way the organization adopts the manufacturing practices in the business (Hariyani and Mishra, 2022b).

4.1.8. Complexity in the design of ISGLSA product, process, supply chain, and system

Complexity to in-built sustainable (Jovane et al., 2009) reconfigurable (Koren, 2010, Mehrabi et al., 2000) ISGLSA practices in the product, process, supply chain, and system affects the organization's initiative for the ISGLSAMS (Hariyani and Mishra, 2022b).

4.1.9. Management complexity

Complexity due to (i) layoff (Alefari et al., 2017), (ii) other barriers (Marodin and Saurin, 2015), (iii) involvement of various value chain partners (Lambert et al., 2005), (iv) plant size (Berger et al., 2018), (v) purchasing, and different market groups (Giunipero et al., 2012), (vi) lack of updated information and unpredictable market (Giunipero et al., 2012), (vii) design to reuse/recycle, reduced consumption of energy or resource, (viii) environmental management practices, (ix) supply chain networks (Kaur et al., 2018), and (x) system performance investigation (Zhang et al., 2017) and optimization (Nambiar, 2010), etc. make the organization management to be less prone to the adoption of ISGLSAMS (Hariyani and Mishra, 2022b).

4.1.10. Low top management commitment due to low awareness or negative attitude about ISGLSAMS

Poor management commitment in the transformation, and improvement project (Hicks and Matthews, 2010) due to poor knowledge (Kumar et al., 2016) about (a) sustainable products, and sustainable processes (Cherrafi et al., 2017, Ghazilla et al., 2015), and supply chain practices (Lee and Rhee, 2007), (b) environmental training (Ghazilla et al., 2015), (c) reconfigurable manufacturing (Potdar et al., 2017), etc. cause the poor top management commitment and support for the ISGLSAMS (Hariyani and Mishra, 2022b).

4.1.11. Lack of leadership

Poor leadership of the management (Lodgaard et al., 2016, Veiga et al., 2011) due to the lack of a strategic direction (Basu et al., 2018), and leadership behavior (Machado, 2014) desired for ISGLSAMS obstruct the adoption of ISGLSAMS (Hariyani and Mishra, 2022b).

4.1.12. Lack of ISGLSAMS technical resources and infrastructure

Lack of availability of technical resources for sustainable manufacturing (Sarkis et al., 2010, Asuka-Zhang, 1999), flexible manufacturing (Potdar et al., 2017), and ISGLSA manufacturing impede the sustainability of ISGLSAMS projects and policies (Hariyani and Mishra, 2022b).

4.1.13. Financial constraints

Lack of the fund (Brammer et al., 2012), financial resources (Abdullah et al., 2016) for sustainable (Bhanot et al., 2015) reconfigurable projects (Koren, 2010, Mehrabi et al., 2000), remanufacturing technologies innovations (Xia et al., 2015), and R&D in ISGLSAMS, etc. make the organization management less ambitious for the ISGLSAMS (Hariyani and Mishra, 2022b).

4.1.14. Lack of awareness, education, training, and rewards system for employees

Lack of awareness, education, training, and knowledge of the employees (Dhull and Narwal, 2016) about (i) sustainable manufacturing (Millar and Russell, 2011), (ii) green manufacturing, green product, and services (Dhull and Narwal, 2016), (iii) lean manufacturing (Marodin and Saurin, 2015), (iv) environmental conscious manufacturing (Cherrafi et al., 2017), (v) six sigma practices (Aboelmaged, 2011), (vi) cost savings due to (a) GSCM (Muduli et al., 2013) and (b) ISGLSAMS, etc. hamper the sustainability of ISGLSAMS practices and initiatives (Hariyani and Mishra, 2022b).

4.1.15. Technological Risk

Threat or risk due to the inharmoniousness of ISGLSAMS with the existing manufacturing processes (Mittal and Sangwan, 2014), manufacturing system (Singh et al., 2012), and management practices and tools (Singh et al., 2012) cause the poor management initiatives, and attitude towards ISGLSAMS (Hariyani and Mishra, 2022b).

4.1.16. Lack of updated information, communication, and data

Lack of updated real-time information and communication (Petrini and Pozzebon, 2009) about (i) product life data (Bey et al., 2013), (ii) process life data (Bey et al., 2013), (iii) value chain data (Zhang et al., 2017), (iv) market data (Giunipero et al., 2012), and (v) ISGLSA performance data cause the organizational barrier to manage and adopt ISGLSAMS in the organization's value chain (Hariyani and Mishra, 2022b).

4.1.17. Resistance to change

The reluctance of employees and management to adopt ISGLSA practices, sustainable practices (Raut et al., 2018), green practices (Ravi and Shankar, 2005), and ISGLSA technology causes the organizational barrier to adopt ISGLSAMS in the organization's value chain (Hariyani and Mishra, 2022b).

4.1.18. Difficulty in the evaluation of system performance

(i) Difficulty in obtaining information on environmental impact (Bey et al., 2013), (ii) absence of practical guidelines, and performance measurement and evaluation matrices for ISGLSA performance, (iii) difficulty in calculating the quality, flexibility, competitiveness, and competitive advantage (Henderson et al., 2004), (iv) difficulty in measuring and monitoring supplier's ISGLSA performance, (v) difficulty in gathering the product, process and system performance data (Rahimifard et al., 2009), and (vi) difficulty in tracing carbon footprint (Raut et al., 2018), etc. cause the organizational barrier to ISGLSAMS, as the organization finds it more difficult to manage or run the system which is difficult to measure (Hariyani and Mishra, 2022b).

4.1.19. Low employees' commitment

Low employees' commitment to the ISGLSAM practices due to (a) poor understanding, poor knowledge, (b) change inertia, (c) fear of job cutting, and (d) changes were not shared (Alefari et al., 2017). Low employees' commitments cause poor enthusiasm among employees toward the organization ISGLSAMS initiatives (Hariyani and Mishra, 2022b).

4.1.20. Undeveloped organization culture

(i) Absence of the right supportive work culture (Zhang et al., 2017), (ii) lack of a culture of respect, fair rules, and behavior, (Baumgartner and Ebner, 2010), (iii) organizational culture changes from management side (Berger et al., 2018), (iv) lack of job rotation culture (Aravindraj et al., 2013), and (v) organizational politics (Seidel et al., 2008), etc. lead to the poor organizational culture for the adoption of ISGLSAMS (Hariyani and Mishra, 2022b).

4.1.21. Poor organization structure

Poor organization structure for ISGLSA, sustainable (Raut et al., 2018), green practices (Mittal et al., 2016), and GSCM (Dhull and Narwal, 2016) cause communication problems at various levels of the hierarchy (Mittal et al., 2016). This will cause the organizational barrier to designing a system that is essential for the successful adoption of ISGLSAMS (Hariyani and Mishra, 2022b).

4.1.22. Lack of supplier commitment, awareness, and integration

Poor supplier commitment (Wyrwicka and Mrugalska, 2017, Bey et al., 2013), awareness, and integration for ISGLSAMS and practices due to lack of awareness, understanding, knowledge, and education (Dhull and Narwal, 2016) about (a) sustainability (Kulatunga et al., 2013, Millar and Russell, 2011), (b) six sigma (Aboelmaged, 2011), (c) lean (Marodin and Saurin, 2015), (d) environment (Cherrafi et al., 2017) and environmental impact (Ghazilla et al., 2015), (e) green product and services (Dhull and Narwal, 2016), (f) green (Kaur et al., 2018) and agile supply (Christopher and Towill, 2000), etc. cause the organization difficult to streamline ISGLSAMS practices and planning in the organizational total value chain (Hariyani and Mishra, 2022b).

Table 2 outlines the frequency of citation of the barriers by the other authors in the literature.

Table 2. Frequency of citation of the barriers by the other authors.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Baumgartner and Ebner (2010)																				✓		
Millar and Russell (2011)														✓								✓
Ravi and Shankar (2005)																	✓					
Abdullah et al. (2016)				✓	✓								✓									
Aboelmaged (2011)														✓								✓
Alefari et al. (2017)									✓										✓			
Aravindraj et al. (2013)																				✓		
Asuka-Zhang (1999)	✓											✓										
Basu et al. (2018)											✓											
Berger et al. (2018)									✓											✓		
Bey et al. (2013)																✓		✓				✓
Bhanot et al. (2015)													✓									
Bhanot et al. (2016)			✓																			
Brammer et al. (2012)													✓									
Cherrafi et al. (2016)				✓																		
Cherrafi et al. (2017)										✓				✓								✓
Christopher and Towill (2000)																						✓
Dhull and Narwal (2016)						✓								✓							✓	✓
Ghazilla et al. (2015)				✓		✓				✓												✓

Giunipero et al. (2012)									✓							✓						
Govindan et al. (2014)					✓																	
Hariyani and Mishra (2022c)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hariyani et al. (2022)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Henderson et al. (2004)																		✓				
Hicks and Matthews (2010)										✓												
Iacovidou et al. (2017)		✓																				
Jawahir et al. (2006)						✓																
Jovane et al. (2009)								✓														
Kaur et al. (2018)									✓													✓
Koren (2010)								✓					✓									
Kulatunga et al. (2013)				✓																		✓
Kumar et al. (2016)										✓												
Lambert et al. (2005)									✓✓													
Lee and Rhee (2007)										✓												
Lodgaard et al. (2016)											✓											
Luthra et al. (2011)					✓																	
Machado (2014)											✓											
Marodin and Saurin (2015)									✓					✓								✓
Mehrabi et al. (2000)								✓					✓									
Mittal and Sangwan (2014)	✓														✓							
Mittal et al. (2016)																					✓	
Muduli et al. (2013)	✓													✓								
Nambiar (2010)									✓													
Nnorom and Osibanjo (2008)		✓																				
Petrini and Pozzebon (2009)																✓						
Potdar et al. (2017)										✓		✓										
Rahimifard et al. (2009)																		✓				
Raut et al. (2018)			✓														✓	✓			✓	
Russo and Harrison (2005)				✓																		
Sarkis et al. (2010)												✓										
Seidel et al. (2008)																				✓		

Shankar et al. (2017)		✓							
Singh et al. (2012)						✓			
Veiga et al. (2011)				✓					
Wyrwicka and Mrugalska (2017)									✓
Xia et al. (2015)					✓				
Yusuf et al. (1999)	✓								
Zhang et al. (2017)			✓				✓	✓	
Zhu and Geng (2013)		✓							

Abbreviations: 1- Weak legislation, 2- Uncertain future legislation, 3- Lack of government support, 4- Low public and peer pressure due to lack of awareness, 5- The misconception of the high cost, 6- Uncertain financial benefits, 7- Low customer demand for sustainable reconfigurable products, 8- Complexity in the design of ISGLSA product, process, supply chain, and system, 9- Management complexity 10- Low top management commitment due to low awareness or negative attitude about ISGLSAMS, 11- Lack of leadership, 12- Lack of ISGLSAMS technical resources and infrastructure, 13- Financial constraints or lack of fund, 14- Lack of awareness, education, training, and rewards system for employees, 15- Technological risk, 16- Lack of updated information, communication, and data, 17- Resistance to change, 18- Difficulty in the evaluation of system performance, 19- Low employees' commitment, 20- Undeveloped organization culture, 21- Poor organization structure, 22- Lack of supplier commitment, awareness, and integration

5. Research questions

Although the organizations are opting for various manufacturing strategies, viz., sustainable, lean, green, six-sigma, and agile to achieve sustainability and business goals, still they are not able to meet these goals in an unpredictable market either due to the lack of suitable manufacturing strategy or due to the various barriers to it. It is observed from the literature, that an integrated sustainable-green-lean-six sigma-agile manufacturing system (ISGLSAMS) provides a solid platform for this Many organizations are opting for this strategy in a partial mix or success. The study of the ISGLSAMS barriers' formative constructs on the adoption of ISGLSAMS, from the practitioners' point of view, is missing in the literature. This leads to the research question: "What is the effect of the ISGLSAMS barriers' formative constructs on the adoption of ISGLSAMS in India? Based on the opinion of four industry experts and two academic experts from the field of operations management (a) ISGLSAMS barriers were grouped into ten formative constructs, i.e., (i) design complexity construct, (ii) managerial complexity construct, (iii) lack of top management commitment and leadership construct, (iv) poor organizational structure and culture construct, (v) uncertainty, misconception, and low customer demand construct, (vi) financial constraint construct, (vii) technological risk and low supplier commitment construct, (viii) low legislative and social pressure construct, (ix) lack of resources, and updated product information construct, (x) employees barrier construct, and (b) ISGLSAMS organizational performance items were grouped into three formative performance constructs (i) operational performance, (ii) market performance, and (iii) sustainable performance.

Based on the experts' opinions following research questions were designed:

- RQ1: What is the significance and contribution of design complexity barrier construct in ISGLSAMS?
- RQ2: What is the significance and contribution of managerial complexity barrier construct in ISGLSAMS?
- RQ3: What is the significance and contribution of the lack of top management commitment and leadership barrier construct in ISGLSAMS?
- RQ4: What is the significance and contribution of poor organizational structure and culture barrier construct in ISGLSAMS?
- RQ5: What is the significance and contribution of uncertainty, misconception, and low customer demand barrier construct in ISGLSAMS?
- RQ6: What is the significance and contribution of the financial constraint barrier construct in ISGLSAMS?
- RQ7: What is the significance and contribution of technological risk and low supplier commitment barrier construct in ISGLSAMS?
- RQ8: What is the significance and contribution of the low legislative and social pressure barrier construct in ISGLSAMS?
- RQ9: What is the significance and contribution of the lack of resources and updated product information barrier construct in ISGLSAMS?
- RQ10: What is the significance and contribution of employees' barrier construct in ISGLSAMS?
- RQ11: What is the impact of ISGLSAMS barriers on organizational operational performance?
- RQ12: What is the impact of ISGLSAMS barriers on organizational market performance?
- RQ13: What is the impact of ISGLSAMS barriers on organizational sustainable performance?

So that a strategic approach can be planned by the government and manufacturing organizations (i) to overcome the ISGLSAMS barriers constructs, and (ii) to meet the business market, sustainability, and organizational goals.

6. Research methodology

6.1. Development of hypotheses

As the barriers constructs create a significant impact on the adoption of any manufacturing strategy. The following null (H_{0i}) and alternate (H_{ai}) hypotheses (Table 3) are formulated to get the answer to the research questions:

Table 3. Research question and associated null (H_0i) and alternate or research (H_{ai}) hypotheses.

S. No.	Research question	Null (H_{0i}) hypotheses	Alternate (H_{ai}) hypotheses
RQ1	What is the significance and contribution of the design complexity barrier construct in ISGLSAMS?	H_{01}: The design complexity construct is not a significant barrier construct for ISGLSAMS.	H_{a1}: The design complexity construct is a significant barrier construct for ISGLSAMS.
RQ2	What is the significance and contribution of the managerial complexity barrier construct in ISGLSAMS?	H_{02}: Managerial complexity construct is not a significant barrier construct for ISGLSAMS.	H_{a2}: Managerial complexity construct is a significant barrier construct for ISGLSAMS.
RQ3	What is the significance and contribution of the lack of top management commitment and leadership barrier construct in ISGLSAMS?	H_{03}: Lack of top management commitment and leadership construct is not a significant barrier construct for ISGLSAMS.	H_{a3}: Lack of top management commitment and leadership construct is a significant barrier construct for ISGLSAMS.
RQ4	What is the significance and contribution of poor organizational structure and culture barrier construct in ISGLSAMS?	H_{04}: Poor organizational structure and culture construct is not a significant barrier construct for ISGLSAMS.	H_{a4}: Poor organizational structure and culture construct is a significant barrier construct for ISGLSAMS.
RQ5	What is the significance and contribution of uncertainty, misconception and low customer demand barrier construct in ISGLSAMS?	H_{05}: Uncertainty, misconception, and low customer demand construct is not a significant barrier construct for ISGLSAMS.	H_{a5}: Uncertainty, misconception, and low customer demand construct is a significant barrier construct for ISGLSAMS.
RQ6	What is the significance and contribution of the financial constraint barrier construct in ISGLSAMS?	H_{06}: Financial constraint construct is not a significant barrier construct for ISGLSAMS.	H_{a6}: Financial constraint construct is a significant barrier construct for ISGLSAMS.
RQ7	What is the significance and contribution of technological risk and low supplier commitment barrier construct in ISGLSAMS?	H_{07}: Technological risk and low supplier commitment construct is not a significant barrier construct for ISGLSAMS.	H_{a7}: Technological risk and low supplier commitment construct is a significant barrier construct for ISGLSAMS.
RQ8	What is the significance and contribution of the low legislative and social pressure barrier construct in ISGLSAMS?	H_{08}: Low legislative and social pressure construct is not a significant barrier construct for ISGLSAMS.	H_{a8}: Low legislative and social pressure construct is a significant barrier construct for ISGLSAMS.

S. No.	Research question	Null (H_{0i}) hypotheses	Alternate (H_{ai}) hypotheses
RQ9	What is the significance and contribution of the lack of resources and updated product information barrier construct in ISGLSAMS?	H_{09}: Lack of resources and updated product information (UPI) construct is not a significant barrier construct for ISGLSAMS.	H_{a9}: Lack of resources and updated product information (UPI) construct is a significant barrier construct for ISGLSAMS.
RQ10	What is the significance and contribution of employees' barrier construct in ISGLSAMS?	H_{010}: Employees' barrier construct is not a significant barrier construct for ISGLSAMS.	H_{a10}: Employees' barrier construct is a significant barrier construct for ISGLSAMS.
RQ11	What is the impact of ISGLSAMS barriers on organizational operational performance?	H_{011}: ISGLSAMS barriers do not have a significant impact on organizational operational performance.	H_{a11}: ISGLSAMS barriers have a significant impact on organizational operational performance.
RQ12	What is the impact of ISGLSAMS barriers on the organizational market performance?	H_{012}: ISGLSAMS barriers do not have a significant impact on organizational market performance.	H_{a12}: ISGLSAMS barriers have a significant impact on organizational market performance.
RQ13	What is the impact of ISGLSAMS barriers on organizational sustainable performance?	H_{013}: ISGLSAMS barriers do not have a significant impact on organizational sustainable performance.	H_{a13}: ISGLSAMS barriers have a significant impact on organizational sustainable performance.

6.2. Data collection method

A survey questionnaire is used to collect data from Indian manufacturing organizations. A five-point Likert scale was used to measure the barriers with ratings of “strongly disagree”, “disagree”, “neutral”, “agree”, and “strongly agree”. The questionnaire (Appendix – A) was designed and revised based on the viewpoints of four industry experts and two academic experts from the expertise background in operations management, green manufacturing, sustainable manufacturing, agile manufacturing, six sigma, and lean manufacturing.

For conducting the survey, we took data on the manufacturing organizations from the Confederation of Indian Industries (CII) database. Survey questionnaires were mailed to 3607 Indian manufacturing organizations. Senior-level management having significant experience in production and operations management, production planning and control, design, supply chain management and logistics, and strategic planning are requested to fill out the questionnaire. Out of the 3607 manufacturing organizations we received 540 responses, a response rate (of 14.97%). Although the response rate (14.97%) is low, it is still acceptable as (i) Micheli et al. (2020) employed 5.54% response rate to study the green supply chain management practices, (ii) Ward and Zhou (2006) employed 6.7% response rate to study the effect of information technology and lean practices on lead time. The sample covers automobiles industries, machine components industries, electronic and electrical industries, pumps, iron and steel, fasteners, gears, valves, bearings, motors, LED technologies, security systems, computers, furniture industries, renewable technology industries, chemical and process industries, textile industries, engineering services, etc.

6.3. Structural equation modeling of ISGLSAMS barriers and ISGLSAMS performance

To test the null hypotheses H_{01} to H_{013} structural equation modeling is used. Table 4 shows the various ISGLSAMS barriers constructs, ISGLSAMS performance constructs, and associated measured items and abbreviations used for the items.

Table 4. ISGLSAMS Barriers Constructs and ISGLSAMS Performance Constructs.

Barrier Constructs	Measured Items	Description	Abbreviation used
Complexity barrier	- Complexity in ISGLSA product design. - Complexity in ISGLSA process design. - Complexity in ISGLA system design	- Complexity in the design of ISGLSA product.	- CompxProdD_B
		- Complexity in the design of ISGLSAMS process.	- CompxProcD_B
		- Complexity in the design of ISGLSAMS system.	- CompxSysD_B
Managerial complexity	- Difficulty in the measuring and evaluating the system performance throughout the life cycle	- Difficulty in the measuring and evaluating the system performance throughout the life cycle either due to unavailability of performance evaluation matrix or product and process data during the life cycle.	- DiffSysEva_B
	- Management complexity	- Complexity to manage and integrate ISGLSAMS.	- MgmtCompx_B
Lack of top management commitment (TMC) and leadership	- Low top management - commitment.	- ISGLSAMS has low priority for the management due to conflicting business objectives, failure to take the risk, the threat of incompactibility of new	- LowTMC_B

Barrier Constructs	Measured Items	Description	Abbreviation used
		manufacturing technology or system with existing one.	
	- Lack of leadership	- Lack of streamlined ISGLSAMS among the whole supply chain.	- LowLedr_B
Structural and culture	- Undeveloped organization culture	- Lack of company's shared beliefs hinders the changes required for ISGLSAMS.	- UndCul_B
	- Organization structure	- Too many organization levels delay decision making which is one of the key aspects of agility in ISGLSAMS.	- OrgStr_B
Uncertainty and misconception, and low customer demand	- The misconception of the high cost	- The misconception of high investment for ISGLSAMS.	- MiscHiCost_B
	- Uncertain financial benefits	- Uncertain return on investment and other benefits on ISGLSAMS.	- UncFinBene_B
	- Low customer demand for sustainable and reconfigurable products	- Planet concern does not carry enough weight for customers.	- LowCusD_B
Financial constraint	- Financial constraints or lack of fund	- Unavailability of the fund to encourage ISGLSA products, processes, systems, and supply chain.	- FinCons_B

Barrier Constructs	Measured Items	Description	Abbreviation used
	- Lack of government support	- Absence of investment aids, Grant, R&D support by govt. for ISGLSAMS.	- GovtSup_B
Techno. risk and low supplier commit.	- Low supplier commitment	- Poor attitude of the suppliers towards ISGLSAMS.	- LowSuppCom_B
	- Technological Risk	- Threat due to the inharmoniousness of ISGLSAMS with the existing system.	- TechRsk_B
Low legislative and social pressure	- Weak legislation	- Absence of environmental, social, ecological, and economic sustainability laws.	- WeLg_B
	- Uncertain future - legislation	- Uncertain developments in the laws for sustainability withhold the organizational investments for future development for sustainability.	- FutLg_B
	- Low public and peer pressure	- Absence of pressure from local societies, NGOs, and stakeholders for ISGLSAMS.	- LowPubPr_B
Lack of resources and updated product information	- Lack of organizational resources	- Lack of sustainable reconfigurable manufacturing facilities and infrastructure to meet the quality, cost, service level, variety, ecological and social needs.	- LackOfReso_B
	- Lack of updated information,	- Lack of updated product life data, supply chain data, market trend data, best practice benchmarking	- LackOfUPI_B

Barrier Constructs	Measured Items	Description	Abbreviation used
	communication, and data	data, and lack of communication for ISGLSAMS.	
Employees' barrier	- Lack of training and knowledge	- Lack of awareness, education, and knowledge of the employees about sustainability, six sigma, lean, environment, green product and services, and GSCM.	- LackOfTrn_B
	- Low employees commitment	- Poor employees' attitude towards ISGLSAMS.	- LowEmpCom_B
	- Resistance to change	- Act of opposing changes for ISGLSAMS as employees assumes that it alters the status quo.	- RTC_B

Performance Constructs	Measured Items	Abbreviation used
Operational performance	- Significant reduction in overall cost.	- Red_Ovr_Cost_PO
	- Significant reduction in lead time.	- Red_LT_PO
	- Significant improvement in product quality.	- Imp_Q_PO
	- Significant waste reduction.	- Red_Wast_PO
	- An average annual increase of turnover.	- Inc_Tur_Ovr_PO
	- Increase in labor productivity.	- Inc_Lab_Pro_PO
	- Increase equipment utilization.	- Inc_Eqp_Util_PO
	- Meet delivery promises.	- Imp_Delv_Prom_PO
	- Increase in more customized products and services to meet customer needs.	- Mor_Cust_Prod_PO
	- Increase in new product development success.	- Inc_Prod_Dev_PO
		- Red_Sou_Con_PO
		- Inc_ROI_PO

Barrier Constructs	Measured Items	Description	Abbreviation used
	- Significant reduction in resource consumption. - More return on investment or profit.		
Market performance	- Significant improvement in product performance. - Increase in sales volume - Significant improvement in market performance - Improvement in responsiveness to changes in competitive conditions - Increased customer loyalty - Improvement in the competitive position - Improvement in global market position		- Imp_Prod_Per_PO - Incr_Sal_PO - Imp_Mrk_Per_PO - Imp_Respo_PO - Inc_Cus_Loy_PO - Imp_Comp_Pos_PO - Imp_Glo_Mar_Pos_PO
Sustainable performance	- Sustainable products. - Sustainable production system. - Improvement in the social image. - Improvement in employees' morale and satisfaction. - Improvement in investment subsidies, Grant, R&D support by govt.		- Sus_Prod_PO - Sus_Prodn_Sys_PO - Imp_Soc_Img_PO - Imp_Emp_Mor_PO - Imp_In_Inv_Subs_PO

Table 5 shows the barrier's indicator weights and their t-values for formative constructs after running the bootstrapping algorithm in SmartPLS 2.0 M3. The path coefficients of the model calculated by SmartPLS are shown in Table 6. The bootstrap procedure is used to calculate t-statistics to ensure the significance of each exogenous variable. The results of the parameter estimation are shown in Fig. 2 and Fig. 3.

Table 5. indicator weights and t-values.

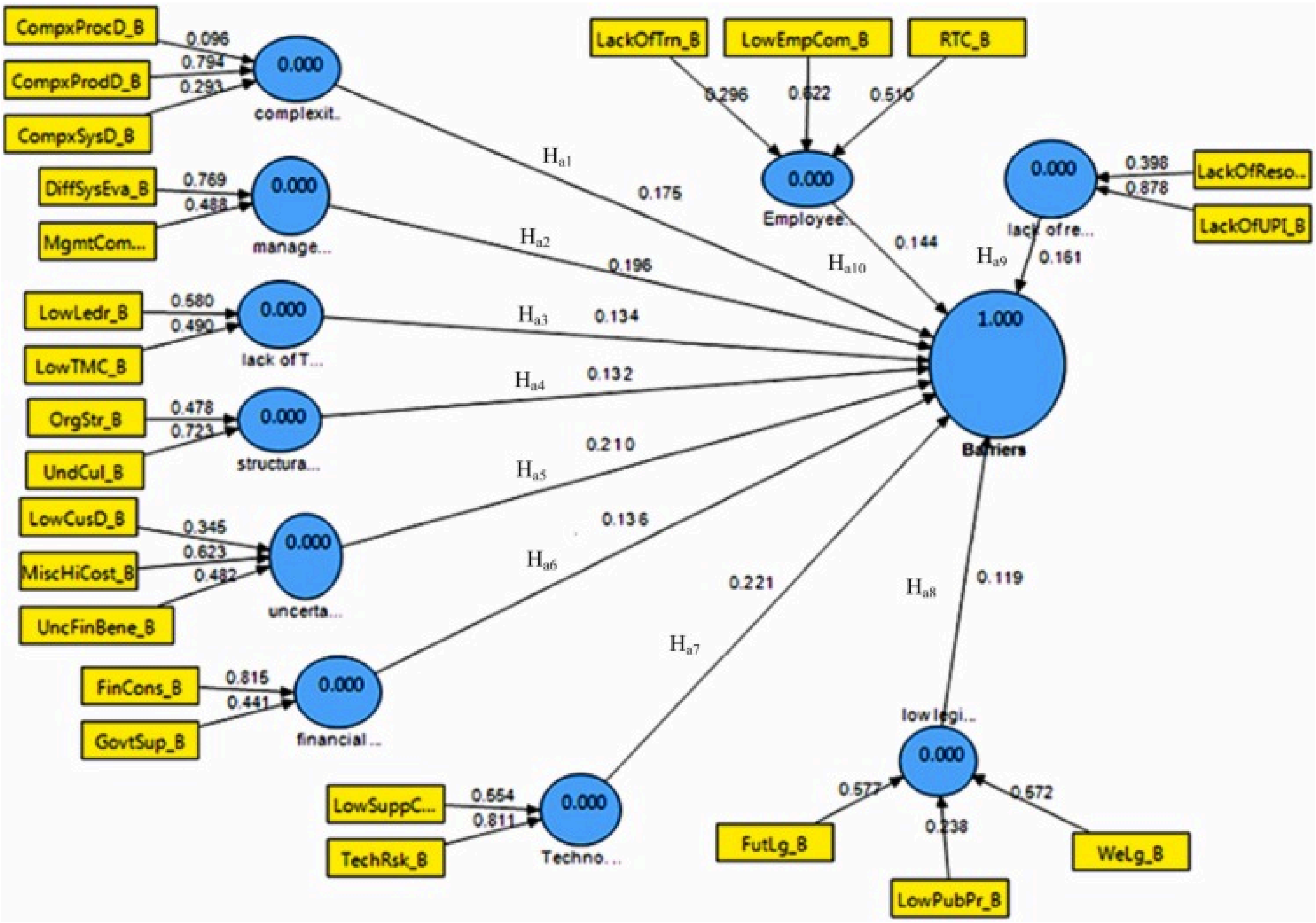
	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	Standard Error (STERR)	T Statistics (|O/STERR|)
CompxProcD_B = >complexity barrier	0.0957	0.0915	0.1701	0.1701	0.5628
CompxProdD_B = >complexity barrier	0.7942	0.7823	0.1199	0.1199	6.6247
CompxSysD_B = >complexity barrier	0.2933	0.2862	0.1838	0.1838	1.5959
LowPubPr_B = >low legislative and social pressure	0.2378	0.2316	0.1424	0.1424	1.6706
WeLg_B = >low legislative and social pressure	0.5718	0.5664	0.104	0.104	5.4959
FutLg_B = >low legislative and social pressure	0.5769	0.5678	0.1097	0.1097	5.2593
DiffSysEva_B = >managerial complexity	0.7685	0.7689	0.0512	0.0512	15.0143
MgmtCompx_B = >managerial complexity	0.4878	0.4844	0.0645	0.0645	7.5686
LackOfUPI_B = >lack of resources, and UPI	0.878	0.8761	0.041	0.041	21.4374
LackOfReso_B = >lack of resources, and UPI	0.3976	0.3954	0.0702	0.0702	5.6601
FinCons_B = >financial constraint	0.8152	0.8036	0.0921	0.0921	8.8477
GovtSup_B = >financial constraint	0.4413	0.442	0.1351	0.1351	3.2671
LackOfTrn_B = >employees' barrier	0.2959	0.2925	0.0477	0.0477	6.1993
LowEmpCom_B = >employees' barrier	0.6221	0.622	0.0575	0.0575	10.8158
RTC_B = >employees' barrier	0.5101	0.509	0.0513	0.0513	9.9452
LowCusD_B = >uncertainty and misconception and low customer demand	0.3448	0.3292	0.1351	0.1351	2.5528
MiscHiCost_B = >uncertainty and misconception and low	0.6234	0.6212	0.1028	0.1028	6.0625

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	Standard Error (STERR)	T Statistics (|O/STERR|)
customer demand					
UncFinBene_B = >uncertainty and misconception and low customer demand	0.4822	0.4735	0.1133	0.1133	4.2568
LowTMC_B = >lack of TMC, and leadership	0.4899	0.4877	0.1476	0.1476	3.319
LowLedr_B = >lack of TMC, and leadership	0.5797	0.5762	0.144	0.144	4.0244
LowSuppCom_B = >techno. risk, and low supplier commitment	0.5538	0.5557	0.1163	0.1163	4.7608
TechRsk_B = >techno. risk, and low supplier commitment	0.8113	0.798	0.0885	0.0885	9.1711
OrgStr_B = >structural, and culture	0.4776	0.4763	0.0871	0.0871	5.4809
UndCul_B = >structural, and culture	0.7229	0.7201	0.0727	0.0727	9.9462

Table 6. Path Coefficients (Mean, STDV, T-Values) and hypothesis.

Research Hypotheses	Path	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	Standard Error (STERR)	T Statistics (|O/STERR|)	Result
H_{a1}	Complexity barrier = > Barriers	0.1754	0.1743	0.0111	0.0111	15.8617	Accepted
H_{a2}	Managerial complexity = > Barriers	0.1964	0.1946	0.0084	0.0084	23.3841	Accepted
H_{a3}	Lack of top management commitment, and leadership = > Barriers	0.1344	0.1338	0.0139	0.0139	9.635	Accepted
H_{a4}	Structural, and culture = > Barriers	0.1317	0.1311	0.012	0.012	11.0139	Accepted
H_{a5}	Uncertainty and misconception and low	0.2095	0.2078	0.0082	0.0082	25.6162	Accepted

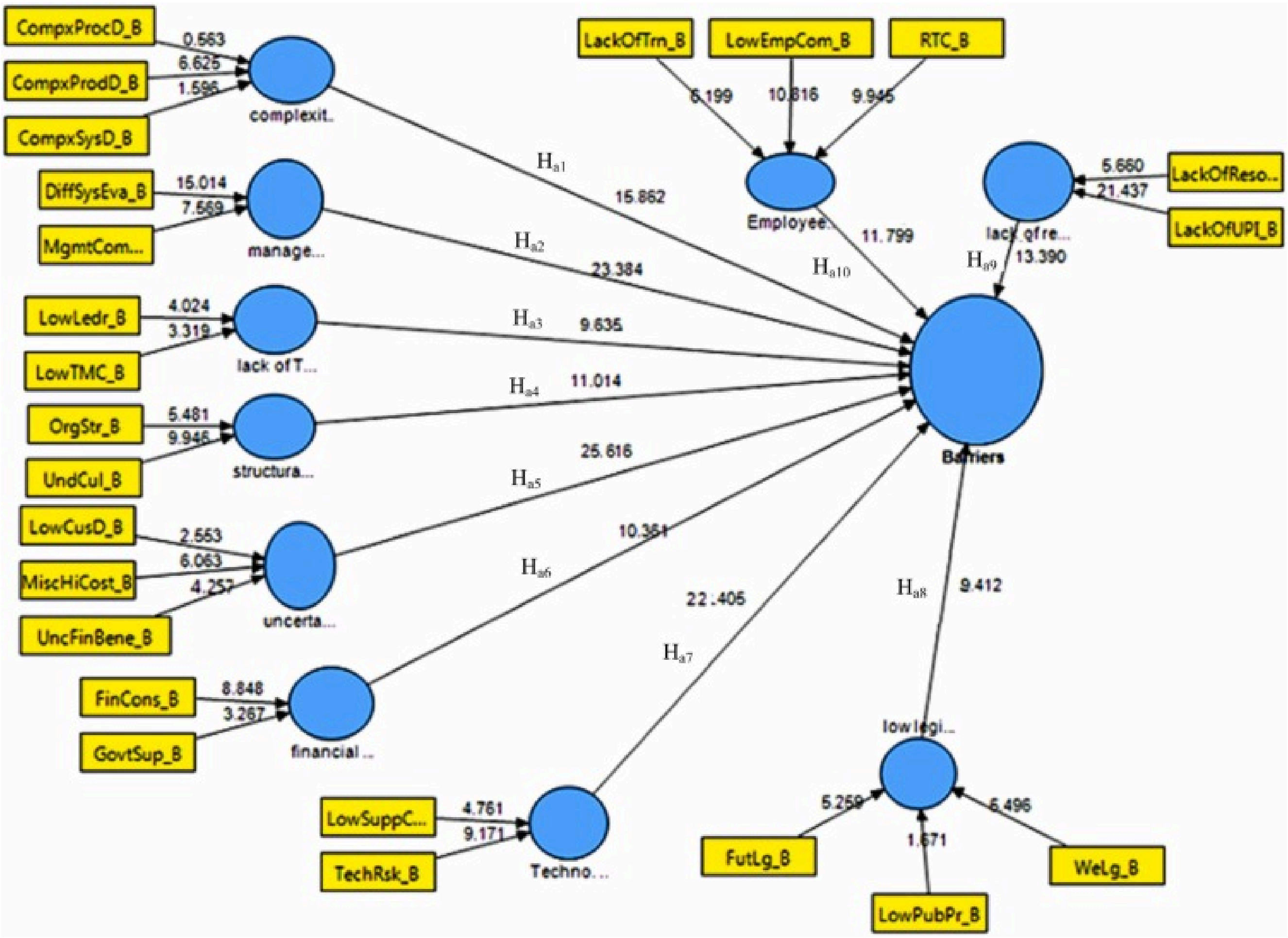
Research Hypotheses	Path	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	Standard Error (STERR)	T Statistics (|O/STERR|)	Result
	customer demand = > Barriers						
H_{a6}	Financial constraint = > Barriers	0.1364	0.1352	0.0132	0.0132	10.361	Accepted
H_{a7}	Technological Risk, and low supplier commitment = > Barriers	0.221	0.2195	0.0099	0.0099	22.4051	Accepted
H_{a8}	Low legislative and social pressure = > Barriers	0.1189	0.12	0.0126	0.0126	9.4115	Accepted
H_{a9}	Lack of resources, and updated product information = > Barriers	0.1606	0.159	0.012	0.012	13.3897	Accepted
H_{a10}	Employees' barrier = > Barriers	0.1437	0.1438	0.0122	0.0122	11.799	Accepted



Download: Download high-res image (413KB)

Download: Download full-size image

Fig. 2. Path Coefficients of Barriers Model.



Download: Download high-res image (401KB)

Download: Download full-size image

Fig. 3. t-Values of the Paths.

These results provide empirical support for all ten alternate or research hypotheses, i.e., H_{a1}:H_{a10}. The effect of all the barrier constructs on the ISGLSAMS barriers in totality is significant at the 95% confidence level (t values>1.96). The detailed analysis of Table 6 highlights the following findings:

1. The findings of structural equation modeling provide empirical support for all the ten alternate hypotheses (H_{a1} to H_{a10}) at the 5% level of significance, i.e.,

    a. H_{a1}: Complexity barrier construct is a significant barrier construct for the adoption of ISGLSAMS, (path coefficient 0.1754, t value 15.8617).

    b. H_{a2}: Managerial complexity barrier construct is a significant barrier construct for the adoption of ISGLSAMS, (path coefficient 0.1964, t value 23.3841).

    c. H_{a3}: Lack of top management commitment, and leadership barrier construct is a significant barrier construct for the adoption of ISGLSAMS, (path coefficient 0.1344, t value 9.635).

    d. H_{a4}: Structural, and culture barrier construct is a significant barrier construct for the adoption of ISGLSAMS, (path coefficient 0.1317, t value 11.0139).

e. H_{a5}: Uncertainty and misconception and low customer demand barrier construct is a significant barrier construct for the adoption of ISGLSAMS, (path coefficient 0.2095, t value 25.6162).

f. H_{a6}: Financial constraint barrier construct is a significant barrier construct for the adoption of ISGLSAMS, (path coefficient 0.1364, t value 10.361).

g. H_{a7}: Technological risk and low supplier commitment barrier construct is a significant barrier construct for the adoption of ISGLSAMS, (path coefficient 0.221, t value 22.4051).

h. H_{a8}: Low legislative and social pressure barrier construct is a significant barrier construct for the adoption of ISGLSAMS, (path coefficient 0.1189, t value 9.4115).

i. H_{a9}: Lack of resources and updated product information (UPI) barrier construct is a significant barrier construct for the adoption of ISGLSAMS, (path coefficient 0.1606, t value 13.3897).

j. H_{a10}: Employees' barrier construct is a significant barrier construct for the adoption of ISGLSAMS, (path coefficient 0.1437, t value 11.799).

2. The contributions of each construct in the ISGLSAMS barrier are in the predicted direction and are found significant at a 5% level of significance.

3. The ISGLSAMS barriers constructs can be prioritized based on their beta coefficients or contribution, as (i) technological risk, and low supplier commitment construct (0.221), (ii) uncertainty, misconception, and low customer demand construct (0.2095), (iii) managerial complexity construct (0.1964), (iv) design complexity construct (0.1754), (v) lack of resources, and updated product information construct (0.1606), (vi) employees' barrier construct (0.1437), (vii) financial constraint construct (0.1364), (viii) lack of top management commitment, and leadership (0.1344), (ix) Poor organizational structure, and culture construct (0.1317), (x) low legislative and social pressure construct (0.1189) in India for the adoption of ISGLSAMS.

Table 7 shows the indicators' outer weights and their t-values for ISGLSAMS' various performance constructs after running the bootstrapping algorithm. The path coefficients of the barrier-performance model are shown in Table 8. The results of the parameter estimation barrier-performance model are shown in Fig. 4 and Fig. 5.

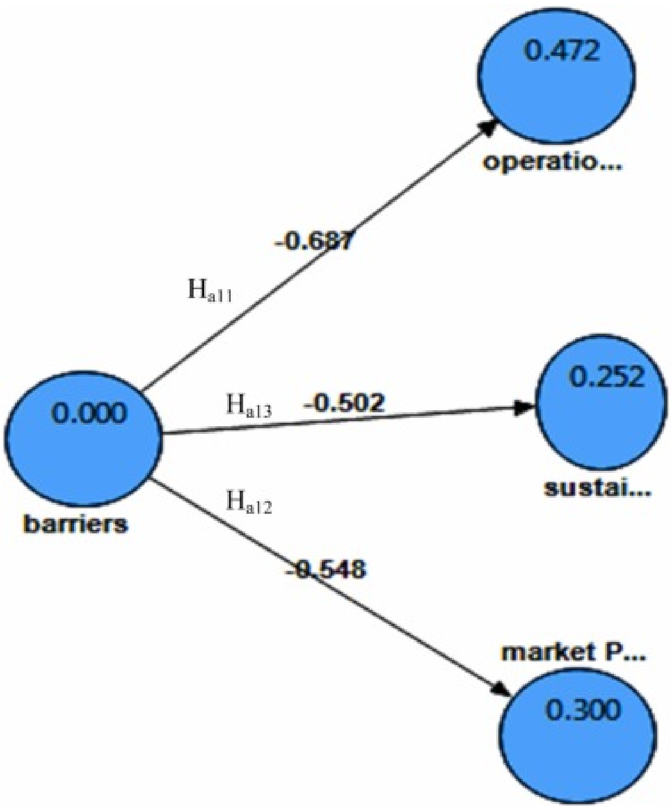
Table 7. Performance Indicator weights and t-values.

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	Standard Error (STERR)	T Statistics (|O/STERR|)
Imp_Delv_Prom_PO = > operational	0.1906	0.1895	0.1369	0.1369	1.392
Imp_Q_PO = > operational	0.8952	0.8047	0.1778	0.1778	5.0478
Imp_Respo_PO = > operational	0.1162	0.1169	0.1131	0.1131	1.0268
Inc_Eqp_Util_PO = > operational	0.4546	0.4019	0.1471	0.1471	3.0898
Inc_Lab_Pro_PO = > operational	0.4954	0.4496	0.1392	0.1392	3.5599
Inc_Prod_Dev_PO = > operational	0.1499	0.1333	0.1446	0.1446	1.0362
Inc_ROI_PO = > operational	0.0711	0.0386	0.1754	0.1754	0.4055
Inc_Tur_Ovr_PO = > operational	0.0369	0.0382	0.1097	0.1097	0.336
Mor_Cust_Prod_PO = > operational	0.2769	0.263	0.1154	0.1154	2.3997
Red_LT_PO = > operational	0.2258	0.2176	0.1359	0.1359	1.6617
Red_Ovr_Cost_PO = > operational	0.2094	0.2181	0.1713	0.1713	1.2226
Red_Sou_Con_PO = > operational	0.4413	0.4021	0.1407	0.1407	3.1372
Red_Wast_PO = > operational	0.1622	0.155	0.1023	0.1023	1.5859
Imp_Comp_Pos_PO = > market Per	0.087	0.0905	0.1419	0.1419	0.6132
Imp_Glo_Mar_Pos_PO = > market Per	0.0593	0.0537	0.1473	0.1473	0.4028
Imp_Mrk_Per_PO = > market Per	0.201	0.1959	0.2352	0.2352	0.8549
Imp_Prod_Per_PO = > market Per	0.8907	0.7443	0.4115	0.4115	2.1646
Imp_Respo_PO = > market Per	0.2963	0.2446	0.1842	0.1842	1.6086

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	Standard Error (STERR)	T Statistics (|O/STERR|)
Inc_Cus_Loy_PO = > market Per	0.1875	0.1496	0.1533	0.1533	1.2235
Incr_Sal_PO = > market Per	0.1197	0.0854	0.1796	0.1796	0.6666
Imp_Emp_Mor_PO = > sustainable	0.1515	0.1403	0.176	0.176	0.861
Imp_In_Inv_Subs_PO = > sustainable	0.4205	0.3986	0.1309	0.1309	3.2116
Imp_Soc_Img_PO = > sustainable	0.7871	0.726	0.1946	0.1946	4.0444
Sus_Prod_PO = > sustainable	0.0844	0.0601	0.1565	0.1565	0.5393
Sus_Prodn_Sys_PO = > sustainable	0.757	0.7284	0.1985	0.1985	3.8142

Table 8. ISGLSAMS Barriers-Performance Path Coefficients (Mean, STDV, T-Values) and hypothesis.

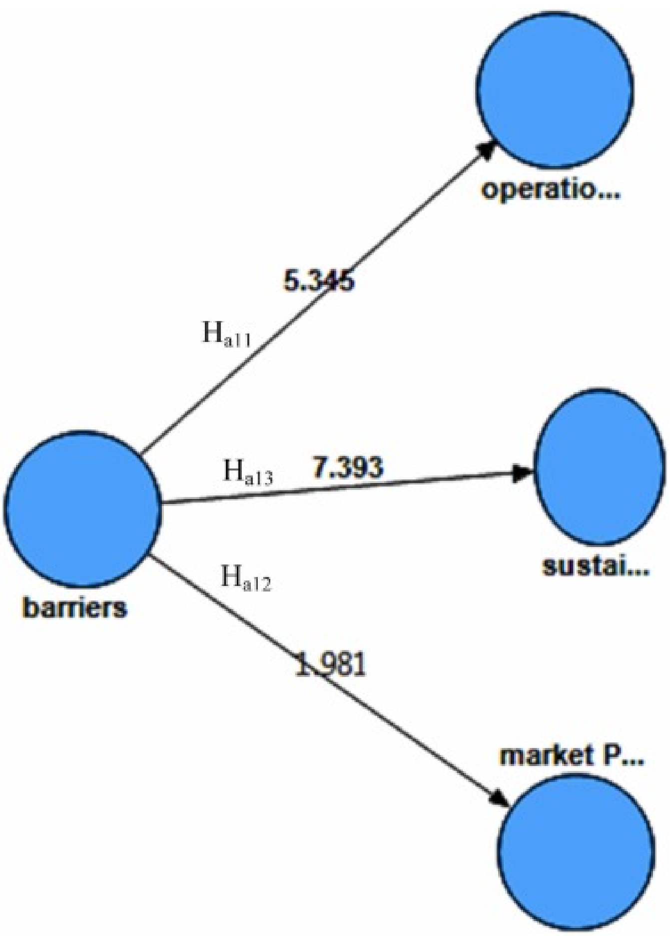
Research Hypotheses	Path	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	Standard Error (STERR)	T Statistics (|O/STERR|)	Result
H_{a11}	ISGLSAMS Barriers = > operational performance	-0.6868	-0.6958	0.1285	0.1285	5.3455	Accepted
H_{a12}	ISGLSAMS Barriers = > market performance	-0.5481	-0.5022	0.2767	0.2767	1.9805	Accepted
H_{a13}	ISGLSAMS Barriers = > sustainable performance	-0.5017	-0.5193	0.0679	0.0679	7.3928	Accepted



Download: Download high-res image (99KB)

Download: Download full-size image

Fig. 4. Path coefficients of the Performance model.



Download: Download high-res image (96KB)

Download: Download full-size image

Fig. 5. t - values of the ISGLSAMS Barriers-Performance paths.

As observed in Table 8, the results provide empirical support for all three research hypotheses (H_{a11} to H_{a13}). ISGLSAMS barriers have a significant negative effect on the organizational operational, market, and sustainable performance.

The detailed analysis of Table 8 highlights the following findings:

1. The findings of structural equation modeling provide empirical support for all three hypotheses (H_{a11} to H_{a13}) at the 5% level of significance, i.e.,

a. H_{a11}: ISGLSAMS barriers have a negative effect on organizational operational performance (path coefficient −0.6868, t value 5.3455).

b. H_{a12}: ISGLSAMS barriers have a negative effect on organizational market performance (path coefficient −0.5481, t value 1.9805).

c. H_{a13}: ISGLSAMS barriers have a negative effect on organizational sustainable performance (path coefficient −0.5017, t value 7.3928).

2. Based on the effect of ISGLSAMS barriers on ISGLSAMS performance, it is observed that ISGLSAMS barriers influence the organizational operational performance most, then market performance, and then sustainable performance.

Thus, this study contributes to the knowledge of practitioners, policymakers, academicians, and researchers on the implementation of ISGLSAMS. Through the (i) analyses of the contribution of various barriers constructs in the ISGLSAMS barriers in totality, and (ii) their impact on the organizational operational, market, and sustainable performance, governments, stakeholders, organizations, and policymakers may plan the strategy to overcome the barriers and successfully adopt and implement ISGLSAMS in the Indian manufacturing organizations.

6.4. Research findings

The research findings provide empirical support for all ten hypotheses, i.e., H_{a1}:H_{a10}. The contributions of each barrier construct in the ISGLSAMS barrier are found relevant and significant in Indian manufacturing organizations, at a 5% level of significance. Based on the path coefficients, ISGLSAMS barriers constructs can be prioritized as (i) technological risk, and low supplier commitment construct (path coefficient, 0.221), (ii) uncertainty, misconception, and low customer demand construct (0.2095), (iii) managerial complexity construct (0.1964), (iv) design complexity construct (0.1754), (v) lack of resources, and updated product information construct (0.1606), (vi) employees' barrier construct (0.1437), (vii) financial constraint construct (0.1364), (viii) lack of top management commitment, and leadership (0.1344), (ix) poor organizational structure, and culture construct (0.1317), (x) low legislative and social pressure construct (0.1189) in Indian manufacturing organizations for the adoption of ISGLSAMS.

The research findings also provide empirical support for all three hypotheses (H_{a11} to H_{a13}). It is observed that ISGLSAMS barriers have a significant negative effect on the organizational operational performance (path coefficient −0.6868, t value 5.3455), market performance (path coefficient −0.5481, t value 1.9805), and sustainable performance (path coefficient −0.5017, t value 7.3928) in Indian manufacturing organizations.

7. Discussion

As observed from the literature to meet the turbulent market demands and organization sustainability requirements, the adoption of an integrated sustainable-green-lean-six sigma-agile manufacturing system is essential. Many organizations are opting for this strategy in a partial mix or full manner. The objectives of this paper are to analyze the effect of ISGLSAMS barriers on the adoption of ISGLSAMS, and on the organizational market, operational, and sustainable performance in Indian manufacturing organizations. The findings suggest that the effect of each barrier construct is significant and is in the predicted direction at the 5% level of significance. T-values provide empirical support for all thirteen hypotheses, i.e., H_{a1} to H_{a13}. The technological risk and low supplier commitment construct is found the first major contributing barrier construct (path coefficient, 0.221) for ISGLSAMS, in India. This shows that the combined effect of (i) technological risk, i.e., the threat due to the inharmoniousness of ISGLSAMS with the existing management and manufacturing system, and processes, and uncertainties related to the radical changes due to ISGLSAMS, (ii) low supplier commitment for ISGLSAMS prevent the Indian manufacturing organizations to adopt for ISGLSAMS. To minimize the technological risk, a strategic streamlined approach must be planned by the organizations, and policymakers to design tools and practices associated with the organizational context to implement ISGLSAMS in the organizational value chain. Training and education programs must be planned for the top management or higher executives to implement ISGLSAMS in their organization (Elmoselhy, 2013, Elmoselhy, 2015b, Nieuwenhuis and Katsifou, 2015) with visible learning platforms from other organizations (Rehman et al., 2016). To overcome the low supplier commitment for ISGLSAMS, organizations, and policymakers must design training and education programs for the supply chain partners to understand the core principle and various market and organizational benefits to them. Training and education will make them more resource-effective, efficient, and ecologically and agile sustainable with the requirements of the ISGLAMS (Hariyani and Mishra, 2022a, Hsu and Hu, 2008).

Next to the technological risk, and low supplier commitment construct, the second barrier construct is the combined effect of (i) uncertain return on investment from ISGLSAMS, (ii) misconception of the large outlay required by ISGLSAMS such as high outlay for green design, green product, green manufacturing technologies, GSCM, green practices, green labeling, hazardous waste disposal, environmental quality framework, environmental programs, green certification, penalties, green purchasing, (iii) low customer demand for sustainable, and reconfigurable products (path coefficient 0.2095, t value 25.6162). The return on investment from ISGLSAMS, can be assured by enhancing the customer demand for ISGLSA products. Development of the potential regulatory laws, and enhancing the customers' awareness regarding the benefits of ISGLSAMS for satisfying their needs along with meeting the requirements of their future generation will surely boost their demand for ISGLSA products, processes, systems, and supply chain (Hariyani and Mishra, 2022a, Dangelico and Pujari, 2010, Johansson et al., 1993).

The combined effect of (i) management complexity, i.e., the complexity to manage and integrate ISGLSAMS, (ii) difficulty in measuring and evaluating the system performance throughout the life cycle either due to unavailability of performance evaluation matrix or product and process data during the life cycle, is found the third major contributing barrier construct for ISGLSAMS in India. Availability of the updated product, process, and system performance data throughout the total life cycle (Rahimifard et al., 2009), and the design of the standard work task elements make the organization to effectively monitor the system performance, and identify the system improvement opportunity for benchmarking the ISGLSAMS (Salleh et al., 2012, Johansson and Winroth, 2009).

The combined effect of (i) complexity in the ISGLSA product design, (ii) process design, and (iii) system design is found the fourth major contributing barrier construct (path coefficient 0.1964, t value 23.3841) for ISGLSAMS in India. Organizations and policymakers must design products, processes, systems, and supply chains through the early involvement of the customers and stakeholders, this reduces the complexity of the design and makes the design more likely to be successful for the ISGLSAMS (Hariyani and Mishra, 2022a, Udokporo et al., 2020).

The influence of the ISGLSAMS barriers is found more prominent on the organizational operational performance (path coefficient −0.6868, t value 5.3455), then the market performance (path coefficient −0.5481, t value 1.9805), and then the sustainable performance (path coefficient −0.5017, t value 7.3928) in India. This shows that barriers affect operational performance the most, as barriers directly affect the implementation of ISGLSAMS in the organizational value chain. The effect of ISGLSAMS barriers on market performance will be more due to the reason that it will affect the market image of the organization to run the business.

8. Conclusion

As observed from the literature to remain sustainable in the turbulent market, the adoption of the integrated sustainable-green-lean-six sigma-agile manufacturing system is essential. This study analyzes the effect of ISGLSAMS barriers constructs on the adoption of ISGLSAMS. The study also analyzes the effect of the various ISGLSAMS barriers on the organizational market, operational, and sustainable performance in Indian manufacturing organizations. The effect of each barrier construct in the ISGLSAMS barrier is found significant and in the predicted direction at the 5% level of significance. T-values provide empirical support for all thirteen hypotheses, i.e., H_{a1} to H_{a13}.

Based on the path coefficients, ISGLSAMS barriers constructs can be prioritized as (i) technological risk, and low supplier commitment construct (path coefficient, 0.221), (ii) uncertainty, misconception, and low customer demand construct (0.2095), (iii) managerial complexity construct (0.1964), (iv) design complexity construct (0.1754), (v) lack of resources, and updated product information construct (0.1606), (vi) employees' barrier construct (0.1437), (vii) financial constraint construct (0.1364), (viii) lack of top management commitment, and leadership (0.1344), (ix) Poor organizational structure, and culture construct (0.1317), (x) low legislative and social pressure construct (0.1189) in Indian manufacturing organizations for the adoption of ISGLSAMS.

The influence of the ISGLSAMS barriers is found more prominent on the organizational operational performance (path coefficient −0.6868, t value 5.3455), then the market performance (path coefficient −0.5481, t value 1.9805), and then the sustainable performance (path coefficient −0.5017, t value 7.3928) in India.

Organizations that are looking for the successful adoption and competitive advantages of ISGLSAMS must focus on designing the strategic roadmap, tools, tactics, strategies, and management behavior to overcome the ISGLSAMS barriers.

Policymakers must focus on enforcement of the sustainability legislation in manufacturing and supply chain along with (i) research and development in ISGLSA manufacturing technologies and supply chain, (ii) development of industry-specific ISGLSAMS implementation guidelines, framework, and performance evaluation matrix, (iii) training and awareness programs for the value chain partners, customers, and stakeholders, (iv) provision of incentives for the adoption of ISGLSAMS and supply chain, (v) development of means for getting updated information regarding the product, process, system, and supply chain performance, and (vi) development of management tools and practices for ISGLSAMS.

The managerial implication of this study is that it contributes to the governments, policymakers, and organizations, a thoughtful knowledge of the ISGLSAMS barrier constructs for the adoption of ISGLSAMS. Through the knowledge of ISGLSAMS barriers in Indian manufacturing organizations, policymakers, governments, organizations, and operational managers may design and develop the policies, framework, and research and development activities to (i) overcome the ISGLSAMS barriers, (ii) develop the resources and training programs for successful adoption of ISGLSAMS in the organizational total value chain, and (iii) improve organizational operational, market, and sustainable performance in India.

The novelty of this study are (i) it explores the influence of the ISGLSAMS barriers' formative constructs on the adoption of ISGLSAMS in Indian manufacturing organizations, (ii) the study contributes to the literature on ISGLSAMS barriers, (iii) the study helps the practitioners, manufacturing organizations, and government (a) a better understanding of ISGLSAMS barriers constructs and critically assessing them, and (b) provides a scope of research (i) to design a roadmap or enablers or methodologies to (a) overcome the ISGLSAMS barriers constructs, and to (b) meet the organizational sustainability, market, and business goals, and (ii) to design an circular economy and industrial symbiosis system through the adoption of ISGLSAMS.

Thus, ISGLSAMS provides opportunities to the organizations, and value chain partners to develop the organizational strategies and value chain (i) to reduce resource consumption, and waste generation, and (ii) to promote the circular economy of the product, and optimize the management and use of the resources. ISGLSAMS is an innovative manufacturing system for cleaner production to reduce waste at the end of the product life, through the use of circular economy and industrial symbiosis. It also helps organizations, value chain partners, and policymakers to develop policies and solutions to manage product waste at the end of product life.

8.1. Future research directions and Limitations

Following few research directions concerning ISGLSAMS barriers constructs are identified that require further exploration:

(1) Identification and prioritization of the key industry-specific barriers constructs and their effects on the adoption of ISGLSAMS.

(2) Identification and prioritization of key industry-specific barriers for the control groups based on plant size, age, market, customer, demographic, and political region.

(3) Study of the effects of key industry-specific barriers constructs on the organizational various performance outcomes.

(4) Development of ISGLSAMS technologies to overcome key industry-specific ISGLSAMS barriers constructs.

(5) Development of ISGLSAMS management practices or approach to overcome ISGLSAMS barriers constructs for the industrial symbiosis and industrial ecology.

(6) Development of ISGLSAMS management practices or approach to overcome ISGLSAMS barriers constructs to enhance industrial symbiosis, and industrial ecology of the total value chain.

(7) Development of organizational learnings and training modules to overcome ISGLSAMS barriers constructs in the organization's value chain.

(8) Structural equation modeling of the coupling effect of ISGLSAMS barriers constructs on the adoption of ISGLSAMS.

(9) Structural equation modeling of the mediating effect of ISGLSAMS barriers constructs on the adoption of ISGLSAMS.

(10) Structural equation modeling of the coupling effect of ISGLSAMS barriers constructs on the organizational operational, market, and sustainable performance.

(11) Structural equation modeling of the mediating effect of ISGLSAMS barriers constructs on the organizational operational, market, and sustainable performance.

As the foundation of this research is the industrial surveys, for the generalization of results, more longitudinal, industry-specific, and demographic-based studies must be carried out, to study (i) the effect of barriers on the adoption of ISGLSAMS, and (ii) the effect of barriers on the organizational operational, market, and sustainable performance.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

APPENDIX – A. Barriers to the Adoption of INTEGRATED Sustainable-Green-Lean-Six sigma-Agile Manufacturing System (ISGLSAMS)

OPTIONAL

Name: ____Name of the

Organization: ____

Designation: ____

Kindly rate the following Barriers on a scale of 1–5 which hinder the company for Adoption of INTEGRATED Sustainable-Green-Lean-Six sigma-Agile Manufacturing System (ISGLSAMS); where (5 – Strongly Agree, 4 – Agree, 3 – Neither agree nor disagree, 2 – Disagree, 1 – Strongly Disagree): by " y or √" mark in the appropriate box)		Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree
Barrier	**Description**	**5**	**4**	**3**	**2**	**1**
Weak legislation	Absence of effective planet protection and conserving natural resources laws.					
Lack of government support	Absence of investment subsidies, Grant, R&D support by govt for this strategy.					
Uncertain future legislation	Uncertain developments in Govt. laws; withhold investments for future regulations.					
Low public pressure	Absence of pressure from local communities for this strategy.					
The misconception of high cost	The misconception of high investment for this strategy.					
Uncertain financial benefits	Uncertain return on investment on this manufacturing strategy.					
Low customer demand for sustainable products	Planet concern does not carry enough weight for customers.					
Complexity in designing ISGLSA Product, Process, and System	Complexity in the design of ISGLSA product.					
	Complexity in the design of ISGLSAM process.					
	Complexity in the design of ISGLSAM system.					
Difficult to management	Difficult to manage and integrate this strategy.					
Lack of leadership	Lack to streamline this strategy in the supply chain.					
Low management commitment	This strategy has low priority for the management due to					

	conflicting business objectives.
Lack of organizational resources	Lack of skilled staff, methodologies, experts, tools, and technology for this strategy.
Financial constraints	Unavailability of the fund to encourage ISGLSA products, processes, and system.
Lack of training and knowledge	Lack of training and knowledge for developing staff in this strategy.
Technological Risk	Threat due to incompatibility of this strategy with the existing system.
Lack of updated information and data	Lack of updated product life data, supply chain data, market trend data, and competition data for this strategy.
Organization structure	Too many organizational levels delay decision-making.
Resistance to change	Act of opposing changes that alter the status quo.
Difficulty in the evaluation of system performance throughout the life cycle	Difficulty in the evaluation of system performance due to the unavailability of performance evaluation matrix, product, and process data during the life cycle.
Low supplier commitment	Poor attitude of the suppliers towards this strategy.
Low employees' commitment	Poor attitude of the employees towards this strategy.
Undeveloped organization culture	The lack of the company's shared beliefs hinders the changes required for this strategy.
Missing Barriers (if any):	
Any implementation issues, which you want to share	
Any Comment (s):	

Performance Outcomes of ISGLSAMS.

Kindly rate the following Performance outcomes of your company on a scale of 1–5 based on the Adoption of an INTEGRATED Sustainable-Green-Lean-Six sigma-Agile Manufacturing System (ISGLSAMS); where: (5 – Strongly Agree, 4 – Agree, 3 – Neither agree nor disagree, 2 – Disagree, 1 – Strongly Disagree): by " y or √ " mark in the appropriate box)	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree
Performance outcomes	**5**	**4**	**3**	**2**	**1**
Significant reduction in overall cost					
Significant reduction in lead time					
Significant improvement in product quality					
Significant improvement in product performance					
Increase in sales volume					
Significant improvement in market performance					
Improvement in responsiveness to changes in competitive conditions					
Significant reduction in waste					
An average annual increase in turnover					
Increase in labour productivity					
Increase equipment utilization					
Meet delivery promises					
Increase in more customized products and services to meet customer needs					
Sustainable products					
Sustainable production system					
Increased customer loyalty					
Increase in new product development success					
Significant reduction in resource consumption					
More return on investment or profit					
Improvement in the competitive position					
Improvement in social image					
Improvement in global market position					
Improvement in employees' morale and satisfaction					

Improvement in investment subsidies, Grant, R&D support by govt.

Missing Performance outcomes (if any):

Any Comment(s):

Recommended articles

Data availability

The data that has been used is confidential.

References

Abdullah et al., 2016 M. Abdullah, S. Zailani, M. Iranmanesh, K. Jayaraman
Barriers to green innovation initiatives among manufacturers: the Malaysian case
Rev. Manag. Sci., 10 (2016), pp. 683-709, 10.1007/s11846-015-0173-9 ↗
View in Scopus ↗ Google Scholar ↗

Aboelmaged, 2011 M.G. Aboelmaged
Reconstructing Six Sigma barriers in manufacturing and service organizations: The effects of organizational parameters
Int. J. Qual. Reliab. Manag, 28 (2011), pp. 519-541, 10.1108/02656711111132562 ↗
View in Scopus ↗ Google Scholar ↗

Alefari et al., 2017 M. Alefari, K. Salonitis, Y. Xu
The role of leadership in implementing lean manufacturing
Procedia CIRP, 63 (2017), pp. 756-761, 10.1016/j.procir.2017.03.169 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Aravindraj et al., 2013 S. Aravindraj, A. Sudheer, S. Vinodh, G. Anand
A mathematical model to evaluate the role of agility enablers and criteria in a manufacturing environment
Int. J. Prod. Res, 51 (2013), pp. 5971-5984, 10.1080/00207543.2013.825381 ↗
View in Scopus ↗ Google Scholar ↗

Asuka-Zhang, 1999 S. Asuka-Zhang
Transfer of environmentally sound technologies from japan to china
Environ. Impact Assess. Rev., 19 (1999), pp. 553-567, 10.1016/S0195-9255(99)00028-1 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Basu et al., 2018 P. Basu, I. Ghosh, P.K. Dan
Using structural equation modelling to integrate human resources with internal practices for lean manufacturing implementation
Manag. Sci. Lett., 8 (2018), pp. 51-68, 10.5267/j.msl.2017.10.001 ↗
View in Scopus ↗ Google Scholar ↗

Baumgartner and Ebner, 2010 R.J. Baumgartner, D. Ebner
Corporate sustainability strategies: Sustainability profiles and maturity levels
Sustain. Dev., 18 (2010), pp. 76-89, 10.1002/sd.447 ↗
View in Scopus ↗ Google Scholar ↗

Berger et al., 2018 S.L.T. Berger, G.L. Tortorella, C.M.T. Rodriguez
Lean Supply Chain Management: A Systematic Literature Review of Practices, Barriers and Contextual Factors Inherent to Its Implementation
Springer International Publishing (2018), pp. 39-68, 10.1007/978-3-319-73648-8_2 ↗
Google Scholar ↗

Bey et al., 2013 N. Bey, M.Z. Hauschild, T.C. McAloone
Drivers and barriers for implementation of environmental strategies in manufacturing companies
CIRP Ann. - Manuf. Technol., 62 (2013), pp. 43-46, 10.1016/j.cirp.2013.03.001 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Bhanot et al., 2015 N. Bhanot, P.V. Rao, S.G. Deshmukh
Enablers and barriers of sustainable manufacturing: results from a survey of researchers and industry professionals
Procedia CIRP, 29 (2015), pp. 562-567, 10.1016/j.procir.2015.01.036 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Bhanot et al., 2016 N. Bhanot, P.V. Rao, S.G. Deshmukh
An integrated approach for analysing the enablers and barriers of sustainable manufacturing
J. Clean. Prod., 142 (2016), pp. 4412-4439, 10.1016/j.jclepro.2016.11.123 ↗
Google Scholar ↗

Brammer et al., 2012 S. Brammer, S. Hoejmose, K. Marchant
Environmental management in SMEs in the UK: practices, pressures and perceived benefits
Bus. Strateg. Environ., 21 (2012), pp. 423-434, 10.1002/bse.717 ↗
View in Scopus ↗ Google Scholar ↗

Cherrafi et al., 2016 A. Cherrafi, S. Elfezazi, A. Chiarini, A. Mokhlis, K. Benhida
The integration of lean manufacturing, Six Sigma and sustainability: A literature review and future research directions for developing a specific model
J. Clean. Prod., 139 (2016), pp. 828-846, 10.1016/j.jclepro.2016.08.101 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Cherrafi et al., 2017 A. Cherrafi, S. Elfezazi, J.A. Garza-Reyes, K. Benhida, A. Mokhlis
Barriers in Green Lean implementation: a combined systematic literature review and interpretive structural modelling approach
Prod. Plan. Control, 28 (2017), pp. 829-842, 10.1080/09537287.2017.1324184 ↗
View in Scopus ↗ Google Scholar ↗

Christopher and Towill, 2000 M. Christopher, D.R. Towill
Supply chain migration from lean and functional to agile and customised
Supply Chain Manag, 5 (2000), pp. 206-213, 10.1108/13598540010347334 ↗
View in Scopus ↗ Google Scholar ↗

Dangelico and Pujari, 2010 R.M. Dangelico, D. Pujari
Mainstreaming green product innovation: why and how companies integrate environmental sustainability
J. Bus. Ethics, 95 (2010), pp. 471-486, 10.1007/s10551-010-0434-0 ↗
View in Scopus ↗ Google Scholar ↗

Dhull and Narwal, 2016 S. Dhull, M.S. Narwal
Drivers and barriers in green supply chain management adaptation: A state-of-art review
Uncertain. Supply Chain Manag., 4 (2016), pp. 61-76, 10.5267/j.uscm.2015.7.003 ↗
View in Scopus ↗ Google Scholar ↗

Elmoselhy, 2015a S.A. Elmoselhy
Implementing the hybrid lean-agile manufacturing system strategically in automotive sector
SAE Int. J. Mater. Manuf., 8 (2015), pp. 2015-01–9083, 10.4271/2015-01-9083 ↗
Google Scholar ↗

Elmoselhy, 2015b S.A. Elmoselhy
Hybrid lean-agile manufacturing system strategic facet in automotive sector
SAE Int. J. Mater. Manuf., 8 (2015), pp. 2014-01–9104, 10.4271/2014-01-9104 ↗
Google Scholar ↗

Elmoselhy, 2013 S.A.M. Elmoselhy
Hybrid lean-agile manufacturing system technical facet, in automotive sector
J. Manuf. Syst., 32 (2013), pp. 598-619, 10.1016/j.jmsy.2013.05.011 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Ghazilla et al., 2015 R.A.R. Ghazilla, N. Sakundarini, S.H. Abdul-Rashid, N.S. Ayub, E.U. Olugu, S.N. Musa
Drivers and barriers analysis for green manufacturing practices in Malaysian SMEs: A preliminary findings
Procedia CIRP, 26 (2015), pp. 658-663, 10.1016/j.procir.2015.02.085 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Giunipero et al., 2012 L.C. Giunipero, R.E. Hooker, D. Denslow
Purchasing and supply management sustainability: Drivers and barriers
J. Purch. Supply Manag, 18 (2012), pp. 258-269, 10.1016/j.pursup.2012.06.003 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Govindan et al., 2014 K. Govindan, M. Kaliyan, D. Kannan, A.N. Haq
Barriers analysis for green supply chain management implementation in Indian industries using analytic hierarchy process
Int. J. Prod. Econ., 147 (2014), pp. 555-568, 10.1016/j.ijpe.2013.08.018 ↗

View PDF View article View in Scopus ↗ Google Scholar ↗

Hariyani and Mishra, 2022a D. Hariyani, S. Mishra
Drivers for the adoption of integrated sustainable green lean six sigma agile manufacturing system (ISGLSAMS) and research directions
Clean. Eng. Technol., 7 (2022), Article 100449, 10.1016/j.clet.2022.100449 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Hariyani and Mishra, 2022b D. Hariyani, S. Mishra
Barriers to the adoption of integrated sustainable-green-lean-six sigma-agile manufacturing system (ISGLSAMS): a literature review
Benchmark Int. J. Ahead--p (2022), 10.1108/BIJ-10-2021-0585 ↗
Google Scholar ↗

Hariyani et al., 2022 D. Hariyani, S. Mishra, M.K. Sharma
A descriptive statistical analysis of barriers to the adoption of integrated sustainable-green-lean-six sigma-agile manufacturing system (ISGLSAMS) in Indian manufacturing industries
Benchmark Int. J. Ahead p (2022), 10.1108/BIJ-11-2021-0701 ↗
Google Scholar ↗

Henderson et al., 2004 S.C. Henderson, P.M. Swamidass, T.A. Byrd
Empirical models of the effect of integrated manufacturing on manufacturing performance and return on investment
Int. J. Prod. Res, 42 (2004), pp. 1933-1954, 10.1080/00207540310001645138 ↗
View in Scopus ↗ Google Scholar ↗

Hicks and Matthews, 2010 B.J. Hicks, J. Matthews
The barriers to realising sustainable process improvement: A root cause analysis of paradigms for manufacturing systems improvement
Int. J. Comput. Integr. Manuf., 23 (2010), pp. 585-602, 10.1080/0951192X.2010.485754 ↗
View in Scopus ↗ Google Scholar ↗

Hsu and Hu, 2008 C.W. Hsu, A.H. Hu
Green supply chain management in the electronic industry
Int. J. Environ. Sci. Technol., 5 (2008), pp. 205-216, 10.1007/BF03326014 ↗
View in Scopus ↗ Google Scholar ↗

Iacovidou et al., 2017 E. Iacovidou, J. Millward-Hopkins, J. Busch, P. Purnell, C.A. Velis, J.N. Hahladakis, O. Zwirner, A. Brown
A pathway to circular economy: Developing a conceptual framework for complex value assessment of resources recovered from waste
J. Clean. Prod., 168 (2017), pp. 1279-1288, 10.1016/j.jclepro.2017.09.002 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Jawahir et al., 2006 Jawahir, I.S., Dillon, O.W., Rouch, K.E., Joshi, K.J., Jaafar, I.H., 2006. Total Life-Cycle Considerations In Product Design For Sustainability: A Framework For Comprehensive

Evaluation, in: 10th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology." Barcelona-Lloret de Mar, Spain, pp. 11–15.
Google Scholar ↗

Johansson and Winroth, 2009 Johansson, G., Winroth, M., 2009. Lean vs. Green manufacturing: Similarities and differences. Conf. 16th Int. Annu. EurOMA Conf. 1–10.
Google Scholar ↗

Johansson et al., 1993 H.J. Johansson, P. McHugh, A.J. Pendlebury, Wheeler
Business Process Reengineering: Breakpoint Strategies for Market Dominance
Wiley,, Chichester, UK (1993)
Google Scholar ↗

Jovane et al., 2009 F. Jovane, E. Westkämper, D. Williams
The Manufuture Road: Towards Competitive and Sustainable High-Adding-Value Manufacturing
Springer,, Berlin (2009)
Google Scholar ↗

Kaur et al., 2018 J. Kaur, R. Sidhu, A. Awasthi, S. Chauhan, S. Goyal
A DEMATEL based approach for investigating barriers in green supply chain management in Canadian manufacturing firms
Int. J. Prod. Res, 56 (2018), pp. 312-332, 10.1080/00207543.2017.1395522 ↗
View in Scopus ↗ Google Scholar ↗

Koren, 2010 Y. Koren
The Global Manufacturing Revolution: Product-process-business Integration and Reconfigurable Systems
Wiley,, New Jersey (2010)
Google Scholar ↗

Krishnamurthy and Yauch, 2007 R. Krishnamurthy, C.A. Yauch
Leagile manufacturing: A proposed corporate infrastructure
Int. J. Oper. Prod. Manag, 27 (2007), pp. 588-604, 10.1108/01443570710750277 ↗
View in Scopus ↗ Google Scholar ↗

Kulatunga et al., 2013 Kulatunga, A.K., Jayatilaka, P.R., Jayawickrama, M., 2013. Drivers and barriers to implement sustainable manufacturing concepts in Sri Lankan manufacturing sector. 11th Glob. Conf. Sustain. Manuf. 171–176. https://doi.org/10.13140/2.1.2952.1927 ↗.
Google Scholar ↗

Kumar et al., 2016 S. Kumar, S. Luthra, K. Govindan, N. Kumar, A. Haleem
Barriers in green lean six sigma product development process: An ISM approach
Prod. Plan. Control, 27 (2016), pp. 604-620, 10.1080/09537287.2016.1165307 ↗
View in Scopus ↗ Google Scholar ↗

Lambert et al., 2005 D.M. Lambert, S.J. García-Dastugue, K.L. Croxton
An evaluation of process-oriented supply chain management frameworks
J. Bus. Logist., 26 (2005), pp. 25-51, 10.1002/j.2158-1592.2005.tb00193.x ↗

View in Scopus ↗ Google Scholar ↗

Lee and Rhee, 2007 S.Y. Lee, S.K. Rhee
The change in corporate environmental strategies: A longitudinal empirical study
Manag. Decis., 45 (2007), pp. 196-216, 10.1108/00251740710727241 ↗
View in Scopus ↗ Google Scholar ↗

Lodgaard et al., 2016 E. Lodgaard, J.A. Ingvaldsen, I. Gamme, S. Aschehoug
Barriers to lean implementation: perceptions of top managers, middle managers and workers
Procedia CIRP, 57 (2016), pp. 595-600, 10.1016/j.procir.2016.11.103 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Luthra et al., 2011 S. Luthra, V. Kumar, S. Kumar, A. Haleem
Barriers to implement green supply chain management in automobile industry using interpretive structural modeling technique-an Indian perspective
J. Ind. Eng. Manag, 4 (2011), pp. 231-257, 10.3926/jiem.2011.v4n2.p231-257 ↗
View in Scopus ↗ Google Scholar ↗

Machado, 2014 S.D.V.C. Machado
Exploring barriers in lean implementation
Int. J. Lean Six. Sigma, 5 (2014), pp. 122-148, 10.1108/EL-01-2017-0019 ↗
Google Scholar ↗

Madsen, 2020 H.L. Madsen
Business model innovation and the global ecosystem for sustainable development
J. Clean. Prod., 247 (2020), Article 119102, 10.1016/j.jclepro.2019.119102 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Marodin and Saurin, 2015 G.A. Marodin, T.A. Saurin
Managing barriers to lean production implementation: context matters
Int. J. Prod. Res, 53 (2015), pp. 3947-3962, 10.1080/00207543.2014.980454 ↗
Google Scholar ↗

Mehrabi et al., 2000 M.G. Mehrabi, A.G. Ulsoy, Y. Koren
Reconfigurable manufacturing systems: key to future manufacturing
J. Intell. Manuf., 11 (2000), pp. 403-419, 10.1023/A:1008930403506 ↗
View in Scopus ↗ Google Scholar ↗

Micheli et al., 2020 G.J.L. Micheli, E. Cagno, G. Mustillo, A. Trianni
Green supply chain management drivers, practices and performance: A comprehensive study on the moderators
J. Clean. Prod., 259 (2020), Article 121024, 10.1016/j.jclepro.2020.121024 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Millar and Russell, 2011 H.H. Millar, S.N. Russell
The adoption of sustainable manufacturing practices in the caribbean
Bus. Strateg. Environ., 20 (2011), pp. 512-526, 10.1002/bse.707 ↗
View in Scopus ↗ Google Scholar ↗

Mittal and Sangwan, 2014 V.K. Mittal, K.S. Sangwan
Prioritizing barriers to green manufacturing: Environmental, social and economic perspectives
Procedia CIRP, 17 (2014), pp. 559-564, 10.1016/j.procir.2014.01.075 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Mittal et al., 2017 V.K. Mittal, R. Sindhwani, V. Kalsariya, F. Salroo, K.S. Sangwan, P.L. Singh
Adoption of integrated lean-green-agile strategies for modern manufacturing systems
Procedia CIRP, 61 (2017), pp. 463-468, 10.1016/j.procir.2016.11.189 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Mittal et al., 2016 V.K. Mittal, R. Sindhwani, P.K. Kapur
Two-way assessment of barriers to Lean–Green Manufacturing System: insights from India
Int. J. Syst. Assur. Eng. Manag, 7 (2016), pp. 400-407, 10.1007/s13198-016-0461-z ↗
View in Scopus ↗ Google Scholar ↗

Muduli et al., 2013 K. Muduli, K. Govindan, A. Barve, Y. Geng
Barriers to green supply chain management in Indian mining industries: A graph theoretic approach
J. Clean. Prod., 47 (2013), pp. 335-344, 10.1016/j.jclepro.2012.10.030 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Nambiar, 2010 Nambiar, A., 2010. Challenges in Sustainable Manufacturing. Proc. 2010 Int. Conf. Ind. Eng. Oper. Manag. Dhaka, Bangladesh 10–15. https://doi.org/10.5539/jsd.v4n6p36 ↗.
Google Scholar ↗

Naylor et al., 1999 J.B. Naylor, M.M. Naim, D. Berry
Leagility: Integrating the lean and agile manufacturing paradigms in the total supply chain
Int. J. Prod. Econ., 62 (1999), pp. 107-118, 10.1016/S0925-5273(98)00223-0 ↗
Google Scholar ↗

Nieuwenhuis and Katsifou, 2015 P. Nieuwenhuis, E. Katsifou
More sustainable automotive production through understanding decoupling points in leagile manufacturing
J. Clean. Prod., 95 (2015), pp. 232-241, 10.1016/j.jclepro.2015.02.084 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Nnorom and Osibanjo, 2008 I.C. Nnorom, O. Osibanjo
Overview of electronic waste (e-waste) management practices and legislations, and their poor applications in the developing countries
Resour. Conserv. Recycl., 52 (2008), pp. 843-858, 10.1016/j.resconrec.2008.01.004 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Petrini and Pozzebon, 2009 M. Petrini, M. Pozzebon

Managing sustainability with the support of business intelligence: Integrating socio-environmental indicators and organisational context
J. Strateg. Inf. Syst., 18 (2009), pp. 178-191, 10.1016/j.jsis.2009.06.001 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Potdar et al., 2017 P.K. Potdar, S. Routroy, A. Behera
Analyzing the agile manufacturing barriers using fuzzy DEMATEL
Benchmark Int. J., 24 (2017), pp. 1912-1936, 10.1108/BIJ-02-2016-0024 ↗
View in Scopus ↗ Google Scholar ↗

Rahimifard et al., 2009 S. Rahimifard, G. Coates, T. Staikos, C. Edwards, M. Abu-Bakar
Barriers, drivers and challenges for sustainable product recovery and recycling
Int. J. Sustain. Eng., 2 (2009), pp. 80-90, 10.1080/19397030903019766 ↗
View in Scopus ↗ Google Scholar ↗

Raut et al., 2018 R. Raut, B.E. Narkhede, B.B. Gardas, H.T. Luong
An ISM approach for the barrier analysis in implementing sustainable practices
Benchmark Int. J., 25 (2018), pp. 1245-1271, 10.1108/BIJ-05-2016-0073 ↗
View in Scopus ↗ Google Scholar ↗

Ravi and Shankar, 2005 V. Ravi, R. Shankar
Analysis of interactions among the barriers of reverse logistics
Technol. Forecast. Soc. Change, 72 (2005), pp. 1011-1029, 10.1016/j.techfore.2004.07.002 ↗
View PDF View article Google Scholar ↗

Rehman et al., 2016 M.A. Rehman, D. Seth, R.L. Shrivastava
Impact of green manufacturing practices on organisational performance in Indian context: An empirical study
J. Clean. Prod., 137 (2016), pp. 427-448, 10.1016/j.jclepro.2016.07.106 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Russo and Harrison, 2005 M.V. Russo, N.S. Harrison
Organizational design and environmental performance: Clues from the electronics industry
Acad. Manag. J., 48 (2005), pp. 582-593, 10.5465/AMJ.2005.17843939 ↗
View in Scopus ↗ Google Scholar ↗

Salleh et al., 2012 N.A.M. Salleh, S. Kasolang, A. Jaffar
Green lean TQM human resource management practices in malaysian automotive companies
Int. J. Mech. Aerospace, Ind. Mechatron. Manuf. Eng., 6 (2012), pp. 2065-2068, 10.1016/j.proeng.2012.07.372 ↗
Google Scholar ↗

Sarkis et al., 2010 J. Sarkis, M.M. Helms, A.A. Hervani
Reverse logistics and social sustainability
Corp. Soc. Responsib. Environ. Manag., 17 (2010), pp. 337-354, 10.1002/csr.220 ↗
View in Scopus ↗ Google Scholar ↗

Seidel et al., 2008 M. Seidel, R. Seidel, D. Tedford, R. Cross, L. Wait
A systems modeling approach to support environmentally sustainable business development in manufacturing SMEs
World Acad. Sci. Eng. Technol., 24 (2008), pp. 121-129
Google Scholar ↗

Shankar et al., 2017 K.M. Shankar, D. Kannan, P.U. Kumar
Analyzing sustainable manufacturing practices – A case study in Indian context
J. Clean. Prod., 164 (2017), pp. 1332-1343, 10.1016/j.jclepro.2017.05.097 ↗
Google Scholar ↗

Singh et al., 2012 A. Singh, B. Singh, A.K. Dhingra
Drivers and barriers of green manufacturing practices a survey of indian industries
Int. J. Eng., 1 (2012), pp. 5-19
View in Scopus ↗ Google Scholar ↗

Udokporo et al., 2020 C. Udokporo, A. Anosike, M. Lim
A decision-support framework for Lean, Agile and Green practices in product life cycle stages
Prod. Plan. Control (2020), pp. 1-22, 10.1080/09537287.2020.1764124 ↗
Google Scholar ↗

Vázquez-Bustelo et al., 2007 D. Vázquez-Bustelo, L. Avella, E. Fernández
Agility drivers, enablers and outcomes: Empirical test of an integrated agile manufacturing model
Int. J. Oper. Prod. Manag, 27 (2007), pp. 1303-1332, 10.1108/01443570710835633 ↗
View in Scopus ↗ Google Scholar ↗

Veiga et al., 2011 G.L. Veiga, E.P. Lima, J.J. Angelis, S.E.G. Costa
The strategic role of lean a discussion
Braz. J. Oper. Prod. Manag, 8 (2011), pp. 9-30, 10.4322/bjopm.2011.001 ↗
Google Scholar ↗

Veleva and Ellenbecker, 2001 V. Veleva, M. Ellenbecker
Indicators of sustainable production: framework and methodology
J. Clean. Prod., 9 (2001), pp. 519-549, 10.1016/S0959-6526(01)00010-5 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Ward and Zhou, 2006 P. Ward, H. Zhou
Impact of information technology integration and lean / JIT practices on lead time performance. Decis
Sci, 32 (2006), pp. 177-203, 10.1111/j.1540-5915.2006.00121.x ↗
View in Scopus ↗ Google Scholar ↗

Wu et al., 2015 L. Wu, N. Subramanian, M.D. Abdulrahman, C. Liu, K. hung Lai, K.S. Pawar
The impact of integrated practices of lean, green, and social management systems on firm sustainability performance-evidence from Chinese fashion auto-parts

suppliers
Sustain, 7 (2015), pp. 3838-3858, 10.3390/su7043838 ↗
View in Scopus ↗ Google Scholar ↗

Wyrwicka and Mrugalska, 2017 M.K. Wyrwicka, B. Mrugalska
Mirages of lean manufacturing in practice
Procedia Eng., 182 (2017), pp. 780-785, 10.1016/j.proeng.2017.03.200 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Xia et al., 2015 X. Xia, K. Govindan, Q. Zhu
Analyzing internal barriers for automotive parts remanufacturers in China using grey-DEMATEL approach
J. Clean. Prod., 87 (2015), pp. 811-825, 10.1016/j.jclepro.2014.09.044 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Yusuf et al., 1999 Y. Yusuf, M. Sarhadi, A. Gunasekaran
Agile manufacturing: The drivers, concepts and attributes
Int. J. Prod. Econ., 62 (1999), pp. 33-43, 10.1016/S0925-5273(98)00219-9 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Zhang et al., 2017 L. Zhang, B.E. Narkhede, A.P. Chaple
Evaluating lean manufacturing barriers: an interpretive process
J. Manuf. Technol. Manag, 28 (2017), pp. 1086-1114, 10.1108/JMTM-04-2017-0071 ↗
View in Scopus ↗ Google Scholar ↗

Zhu and Geng, 2013 Q. Zhu, Y. Geng
Drivers and barriers of extended supply chain practices for energy saving and emission reduction among Chinese manufacturers
J. Clean. Prod., 40 (2013), pp. 6-12, 10.1016/j.jclepro.2010.09.017 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

Cited by (2)

Stakeholders' perspectives and performance outcomes of sustainable market-focused manufacturing system in Indian manufacturing organizations

2024, Cleaner Logistics and Supply Chain

Show abstract

Green Lean Six Sigma practice in the industrial and service sectors: from the systematic literature review to an integration diagram ↗

2024, Production Planning and Control