Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 232 (2024) 2001–2008

Procedia Computer Science

www.elsevier.com/locate/procedia

5th International Conference on Industry 4.0 and Smart Manufacturing

Lean green practices in Automotive Components Manufacturing

Funlade Sunmola[a,*], Onyinyechi Racheal Mbafotu[a], Memunat Lami Salihu-Yusuf[a], Hakeem Omolade Sunmola[b]

[a] *University of Hertfordshire, United Kingdom*
[c] *University of Birmingham, United Kingdom.*

Abstract

In response to the global surge in industrial competition, organizations have increasingly embraced lean green practices as an approach to identify and eliminate non-value-added waste in manufacturing processes, while ensuring sustainable practices. This research extends current literature on lean green practices in manufacturing by a) exploring current implementation of lean green practices in the automotive components manufacturing industry and b) examining the challenges encountered within its supply chain processes when implementing the practices. The evaluation utilizes the SCOR model, and a focus group of automotive components manufacturing professionals in the UK. The findings reveal that an average level of implementation of lean green practices, offering benefits such as enhanced productivity, cost reduction, and improved competitive advantage. Implementation challenges were found to be particularly faced in the sourcing and manufacturing (MAKE) processes of the supply chain, due largely to component outsourcing issues, and inefficiencies in the conversion of raw materials into finished products to meet supply chain demands.

Peer-review under responsibility of the scientific committee of the 5th International Conference on Industry 4.0 and Smart Manufacturing

Keywords: Lean manufacturing; Lean green Practices; Automotive Components Manufacturing; SCOR Model

1. Introduction

Manufacturing companies, including the automotive industries, are adopting new manufacturing management strategies in response to the growing level of competition in the global economy. The goals of these strategies for the manufacturers include to continuously increase the strength. and performance of their production processes, at the same time lowering costs whilst enhancing quality. This trend is bringing about increased awareness of lean philosophy in manufacturing with motivated adoption of practices that identifies and eliminates non-value-added activities in manufacturing processes and operations, making the to improve their efficiency and effectiveness. This in turn allows for increase in production level which can be compromise and diminish the earth's ecosystem capacity simultaneously [1]. Manufacturers are under pressure to incorporate sustainable (green) practices into product development and associated manufacturing stages.

The term "green" is used to describe the usage of energy and resource-efficient production. In this context, not embracing green i.e., the use of production systems, operations, and processes that do not hurt the environment, is no longer an option for manufacturing enterprises that wants to compete successfully. A way is to effectively combine standard lean practices with green practices, known in the literature as lean-green practice approach [2]. As small-to-medium-sized enterprises (SMEs) now must

* *Corresponding author.*
E-mail: f.sunmola@herts.ac.uk

1877-0509 © 2024 The Authors. Published by Elsevier B.V.

Peer-review under responsibility of the scientific committee of the 5th International Conference on Industry 4.0 and Smart Manufacturing
10.1016/j.procs.2024.02.022

deal with rising global competition, shortening product lifecycles, and rising customer expectations [3] while aiming to meet their sustainability objectives, they have open to them opportunities presented by lean-green philosophy. Adopting lean green practices can be very challenging to SMEs. For example, small medium enterprises require finance and technical support as they transition to a greater strategic approach during component design, manufacturing, and factory management. Sustainability is vital to increase market share while lowering environmental risks and impacts and improving environmental efficiency. The growth of the automotive industry can in some ways be aided by the adoption of lean-green practices in the production of components.

The purpose of this paper is to explore the extent of implementation of lean green practices in automotive component manufacturing. In addition, challenges faced by automotive component manufacturing supply chain in their implementation of lean green practices will be identified. In the next section, an overview of automotive components manufacturing, and its supply chains is presented. The supply chain operations reference model useful for modelling and analysing automotive components manufacturing supply chains is also described. As part of the background and review of related work documented in Section 2 is a highlight of existing work on lean and green practices. Section 3 presents the methodology adopted in this study and Section 4 contains the results of the study and its discussion. Finally, in Section 5, the paper is concluded and recommends of future work are put forward.

2. Background and Related Work

2.1 Automotive Component Manufacturing and its Supply Chain

The automotive industry is currently faced with a high level of competition on a global scale and is constantly seeking to improve its process in technology and the efficiency of its products. The automotive components industry is a key part of the automotive manufacturing sector, and it plays a vital role in the manufacture of components used in the assembly of high-quality and reliable vehicles. Its industry's growth initiatives are being aided by the widespread adoption of lean practices in the production of component parts.

The segments of the automotive components industry, as illustrated in Figure 1, are,

i. Engine parts
ii. Drive transmission and steering parts
iii. Suspension and brake parts
iv. Electrical parts
v. Body and chassis part

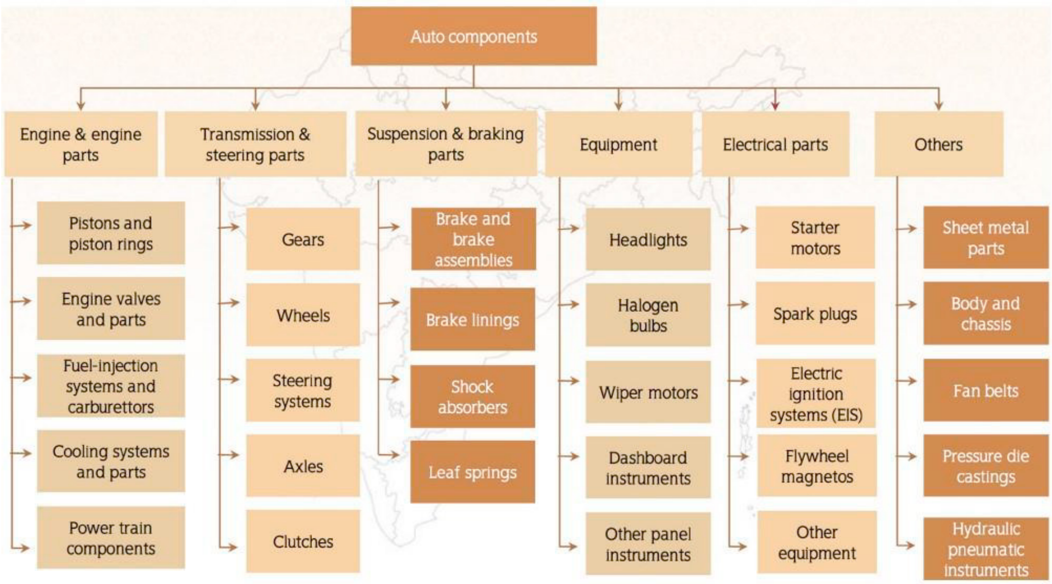


Fig 1: Product segments of the automotive components industry (Source: [4])

Currently, it is important to understand the supply chain of an organization to proffer a solution when a supply chain issue arises. The importance of component manufacturing to the automotive industry's survival and competitiveness has never been greater. According to [5], the automotive industry has a low degree of differentiation. The peculiarities of an original equipment manufacturers (OEM) supply chain and the survival of its suppliers are distinctive aspects that influence an OEM's ability to survive. The automotive component industry is classified as the supplier of the automotive industry since they supply nearly 70% of the required components [6]. The sector has been significantly impacted by the present economic crisis, which has put nearly 50% of the top 30 automotive supplier at financial risk [5]. Additionally, with highly specialised operators, considerable relationship-specific investments, and a high degree of interdependence between OEMs and suppliers, the automotive supply chains are closely connected. Therefore, it is anticipated that supplier failure will have a considerable impact on automotive OEMs and consequently the industry. Over the past ten years, the adoption of manufacturing best practices by first-tier suppliers has happened astonishingly swiftly. Businesses have been forced to invest in and focus on their supply chains because of the increased competition in international markets, the introduction of products with shorter life cycles, rising customer expectations, and ongoing developments in communications and transportation technologies. As a result, businesses are under pressure to cut expenses and raise customer service standards to remain competitive.

To meet customer needs the industry must be designed and organized appropriately [7]. Its supply chain is a key factor of competition due to the increasing number of options models. On the other hand, the evaluation of the automotive components supply chain is gaining increased attention and so the industry's characteristics and performance have been reviewed and analysed to determine the main characteristics and performance measurement for an effective model [8].

2.2 The SCOR model

This is regarded as one of the widely applied models for business analysis [9]. Therefore, to improve business systems, deal with competitiveness, and optimize supply chain efficiency, many manufacturing companies are applying the SCOR model to develop their system to be able to identify, evaluate and monitor their supply chain performance [10]. The application of SCOR model not only gives a view of how the business operates, but it's a common frame of reference and language across the supply chain.

The SCOR model's initial iteration was released by the Supply-Chain Council in 1997. In addition to analytics, best practices, and technology, it also included the supply chain stages of PLAN, MAKE, SOURCE, and DELIVER [11]. The supply chain's RETURN stage was subsequently added. According to Stewart [13], the SCOR model (version 10.0) is made up of four main parts: Performance, processes, best practices, and People. Frequently, the management of inventory and planning has been seen as the entirety of the Supply Chain. Instead of just defining a set of discrete tactics, fig 2 shows the Plan, Source, Make, Deliver, and Return framework as it defines a more strategic view of this important managerial role. Manufacturers can "configure-to-order" their supply chain using SCOR to focus on and achieve a particular competitive advantage. Plan, Source, Make, Deliver, and Return are the five separate management processes that make up the SCOR model. These are considered Level 1 processes since they are applied to all phases of the production and delivery process.

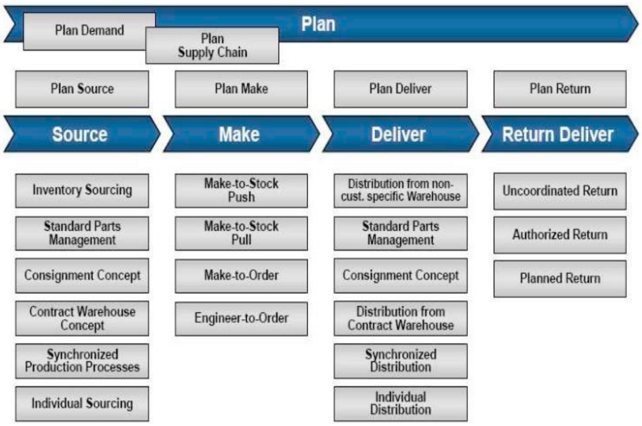


Fig 2: Standard process models – an enhancement of the SCOR model (Source: [14])

PLAN: The supply chain planning process balances overall demand and supply using data from internal and external operations to best achieve company objectives.

SOURCE: The source process includes steps for receiving, inspecting, holding, and issuing items. These steps are used to procure products and services to satisfy anticipated or actual demand. For manufacturing companies, sourcing is essential since it links suppliers and producers.

MAKE: This is the central procedure of the system where real production is carried out. It involves the tasks of making and testing the product, manufacturing it, holding it in storage, and/or eventually releasing it.

DELIVER: The operations involved in the production, upkeep, and fulfilment of customer orders through controlling demand, orders, warehousing, shipping, and, if necessary, installation.

RETURN: It deals with controlling the flow of information and materials, and damaged products. Authorizing, scheduling, receiving, verifying, discarding, and replacing or credit for the materials are all included in this.

SCOR was created to give businesses the ability to share, evaluate, and develop new or better supply-chain practices both inside and outside of their industry segment [13]. With SCOR, manufacturers can modify their internal and external supply chains, show their current supply chains, and map their processes. They can also evaluate and communicate effectively through their operations as well as themselves with a common understanding and process. Finally, they can compare their performance to that of other companies both within and outside of their sector [13].

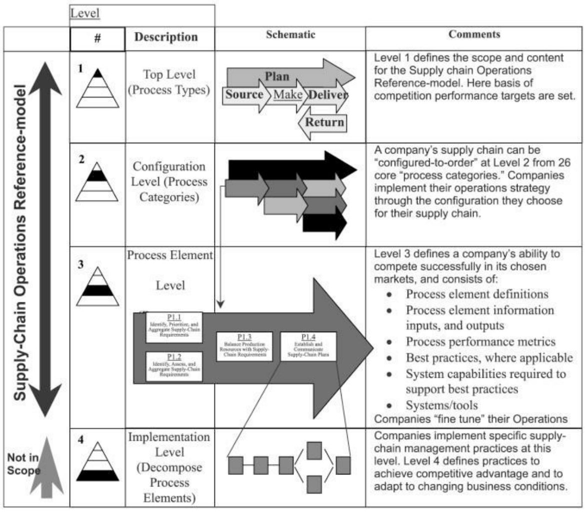


Fig 3: The SCOR Process Levels (Source: [15])

The SCOR model has 3 levels of process detail represented in fig 3. In practice, the plan, source, make, deliver, and return process types are broadly defined at Level 1, which is also the stage at which a corporation develops its supply-chain competitive goals, LEVEL 2 outlines 26 fundamental process categories that could make up a supply chain. An organization can choose from these fundamental operations to configure both its actual and ideal supply chain, LEVEL 3 provides a company with the knowledge it needs to plan and set goals for its supply-chain improvements by providing precise process element information for each level 2 category, LEVEL 4 process details are not contained in SCOR model but must be defined to implement improvements and management processes.

A company may rapidly and unambiguously explain its Supply Chain using the four SCOR model levels. This method of defining a Supply Chain allows for quick modifications and reconfiguration in response to shifting business and market needs [15].

2.3 Lean green practices

Lean manufacturing is considered the "Toyota Production System" which was founded by Taiichi Ohno and Shigeo Shingo. The Toyota production system was defined as a quantity control system by Taiichi Ohno. An objective is cost reduction based on quality, and the only way to do so is to eliminate waste. Lean Manufacturing is a production and business philosophy that reduces the time taken to deliver a product by getting rid of waste in the product's value chain [16]. Any added value beyond the minimum number of materials, machines, space, workers' time, and parts used in the production process is referred to as waste. There are seven well-known kinds of waste produced during manufacturing (Overproduction, Waiting, Motion, Inventory, Over-processing, Transportation, and Defects).

According to Bhasin and Burcher [17], the idea of lean serves as a model for manufacturing operations. There has been a wide recognition that organizations that have largely implemented lean manufacturing practices outperform those that continue to use conventional mass production in terms of cost and quality [18].

For several decades, it has been reported that lean practices have been of interest to the operational competitiveness of organizations [19]. It is proposed that lean practices should have a connection with the operations in the organization, for instance, production planning and control, materials flow, maintenance system, quality system, etc., to implement lean manufacturing systems. Lean practices are bound by some principles to identify and cut out all waste, involve the employee in continuous improvement approaches such as relating to suppliers and customers, designing products for better manufacturing, and participating in every managerial strategy to boost production. The ability to identify any process anomalies that, if unresolved, will have a significant impact on the system is one advantage of lean manufacturing. Large organizations have no trouble adopting lean practices and are more likely to implement all of them than smaller organizations [19,20]. These lean practices are listed in Table 1.

The depletion of natural resources has posed a concern to many organizations as sustainability has risen as a major issue due to a lack of social responsibility [21]. This has resulted in organizations assessing their production process to adopt environmentally friendly practices. Green Manufacturing is a production framework that merges both the design of products and processes to minimise waste, avoid costly "end-of-pipe" treatments, produce safer products, and save energy and resources. Regarding the design of processes, green manufacturing works to save resources and energy, remove the use of toxic substances, and decrease waste, whilst for products it aims to limit environmental impacts throughout the product's life cycle.

The conception of green practices was motivated by a need to set a standard for globally traded commodities. Researchers developed the framework for green practices due to the rapid increase in energy demand, the depletion of natural resources, and the rise in customer awareness of environmentally friendly products, which all compelled industrial communities to adopt green practices. Green manufacturing methods are ones that meet both consumer and environmental criteria [22]. In other words, green manufacturing processes pertain to a green design for production that aims to save energy and produce few waste products [23].

Table 1: List of lean and green practices (Source: [20,25])

LEAN PRACTICES	GREEN PRACTICES
5S	Environmental management system (EMS)
Kaizen/ Continuous improvement	Life Cycle Assessment (LCA)
Set Up time reduction/SMED	Design for environment (DfE)
Visual Control	Environmental emission Control
Value Stream Mapping	3R (reduce, reuse, and recycle
Cellular layout	Green supply chain practice
Total Productive Maintenance	Waste treatment
Kanban	Pollution prevention
Employee Training	ISO 14001
Standardize work	The use of Environmentally Friendly Raw materials
Continuous Flow	The Use of Alternate Source of Energy
Supplier relationship (SR)	
Lot Size Reduction	
Poka Yoke	
Six Sigma	

To ensure competitiveness, organizations are implementing both lean and green practices. This duo integration has emerged as a new management system to increase organizational operations [24]. Research has shown that these practices are beneficial to firms by reducing lead time, producing better product quality, boosting relationships with suppliers, and overall cost, as well as the environment [25]. Lean and green practices thrive more when implemented together and help boost organizational and environmental performance Managers find these practices as support to achieving any environmental and economic performance goal for their organization.

3. Research Methodology

To achieve the objectives of this study, a mixed method was used which included a literature review and a focus group to which a questionnaire was administered. The literature review was conducted to identify the processes of automotive components supply chains and to compile a list of relevant lean green practices in supply chains. A questionnaire-based survey was administered to a focus group to explore the extent to which the identified lean green practices have been implemented in the automotive components industry and to understand the challenges in implementing the lean green practices in different processes of the Automotive component supply chains.

To facilitate the focus group for this research, the questionnaire consists of two parts. The first section is to understand their demographic background of the survey respondents. The questions in this section include their current job position of the respondents, the size of the respondent's organization, the number of employees, and years of experience in the respondent's automotive components manufacturing company and its associated supply chain. The second section holds the key questions required to develop the analysis in this study. The first question in the section asked the respondents the level to which their automotive components manufacturing company has implementation the lean green practices identified in Section 2. A 7-point Likert scale rating is used where 1 = not aware, 2 = Aware but not implemented, 3 = considering implementation, 4 = commenced implementation, 5 = Averagely Implemented, 6 = Above average 7 = Fully Implemented. The second question asks the respondents to state the area of their supply chain process they face challenges when implementing the lean green practices. All questions had a close-ended format.

The focus group in this survey included manufacturing managers, engineering managers and supply chain managers, in UK small and medium-sized automotive components enterprises.

4. Result and Discussion

Table 1 shows the profile of the respondent companies in terms of their size, position title of participants, years of experience in automotive component manufacturing and its supply chain, and the type of automotive components they manufacture. 50% of the respondents are from small-sized enterprises and the remaining 50% were based in medium-sized enterprises. 37.50% of the respondent engage in the manufacturing of engine parts, 25% engage in the manufacturing of body and chassis, 12.50% engage in the manufacturing of Electrical parts, 12.50% engage in the manufacturing of suspension and brake parts, and 12.50% engage in the manufacturing of drive transmission and steering parts. This result corresponds with the UK Society of Motor Manufacturers and Traders' (2019) statistical fact assessment, which found that the UK is a key Engine manufacturing hub.

Table 2: Profiles of respondent companies

Position title	**Size of the organization**	**Experience in Automotive Components Manufacturing**	**Experience in Supply Chain**	**Types of Automotive Components**
Line manager (20%)	Small (50%)	3-5 years (40%)	3-5 years (20%)	Engine parts (37.50%)
Operators (40%)	Medium (50%)	6-10 years (60%)	6-10 years (80%)	Drive transmission and steering (12.50%)
Supply chain and Logistic manager (20%)				Suspension and Brakes parts (12.50%)
General Manager (20%)				Electrical and electronics (12.50%)
				Body and chassis (25%)

Out of the lean and green practices highlighted in Section 2, the result in Figure 4 below illustrates the various lean and green practices, categorized into their level of implementation. The result shows that 42% of the organisations surveyed have averagely implemented llean andgreen manufacturing practices, 50% of the organisations have just commenced the implementation of the practices and 8% reported having above average implementation of the practices.

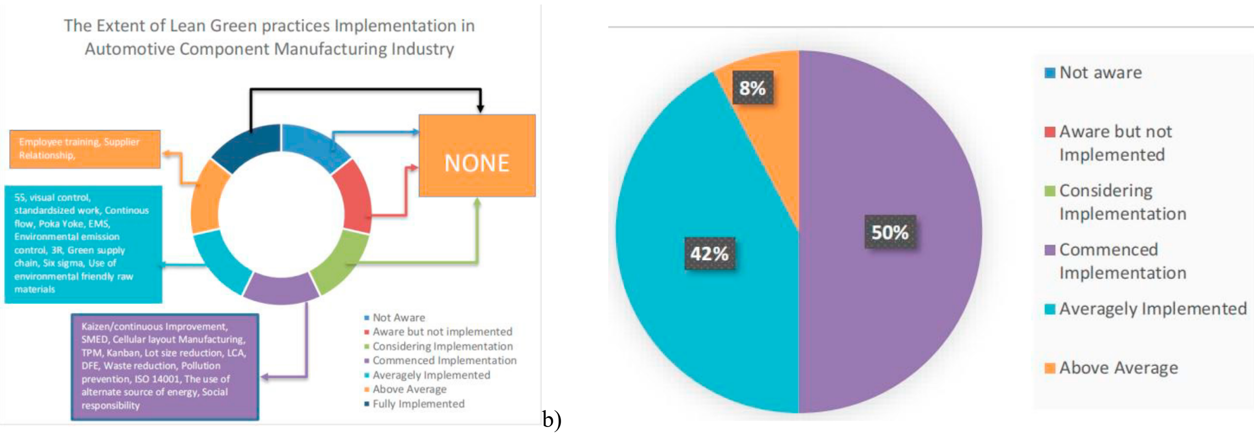
a) 

Fig 4: a) An infographic diagram showing the level of lean and green practices implemented, b) A Chart showing the percentage of lean and green practices implemented.

The result of the study identified that UK Automotive Components manufacturing industries implement lean and green practices, but their level the implementation differs. The lean practices with the highest mean score are, supplier relationship and employee training, followed by six sigma, Poka Yoke, continuous flow, value stream mapping, visual control, and 5S. The respondents believe their implementation of the practices is important for continuous improvement, creating value, reducing cycle time, and eliminating waste in their manufacturing operations and processes. The green practices with the highest mean score are the 3R (reduce, recycle, reuse), the use of environmentally friendly materials, and green environmental emission control. These lean practices were found to have been averagely implemented. Their implementation would help towards ensuring product performance and pollution reduction to the environment [26]. The use of environmentally friendly raw materials is one of the drivers of green practices. Practices involving use of environmentally friendly raw materials will help improve an organization's social and environmental performance as well as its long-term economic performance by reducing the cost of raw materials and energy [21,27]. The results indicate that none of the lean and green practices were deemed to have been fully implemented amongst the SMEs surveyed. However, there appears a strong willingness by the automotive components manufacturers surveyed to continue improving on their lean green practice implementation performance.

The overall level of implementation was analysed, and the finding suggested that, on average, 50.1% of automotive components manufacturers surveyed have averagely implement lean and green manufacturing practices. This dual implementation i.e., of lean and green practices, is a solution where everyone benefits and the manufacturers can get both operational and social benefits by increasing the growth of organizational performance in relation to reduction in cost and environmental emission, product quality improvement, reduction in customer lead time, cycle time, and overall processing time [25,28]. Integrating green and lean practices helps firms to achieve business performance as well as environmental sustainability [29].

Finally, the study found that the automotive component manufacturers sampled faces challenge mostly in their "SOURCE and MAKE" supply chain process, as shown in Figure 5.

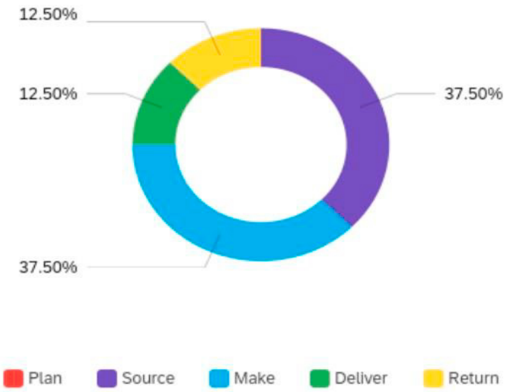


Fig 5: Chart showing the percentage rate of challenges faced in their Supply Chain SCOR process stages

Sourcing and procurement have been a challenge in the automotive sector, as many automotive companies outsource their components locally [30]. Additionally, the challenge reported in their "Make" process stage can be attributed in part to not having fully implemented TPM as a lean Practice. TPM is a major factor that can help facilitate quick and effective conversion of raw materials into completed products to satisfy supply chain demand [20].

5. Conclusion

The manufacturing SMEs including the automotive components manufacturing, small and medium enterprises, are important to both developed and emerging economies. Since resources are scarce and environmental degradation is accelerating, there is a strong need to improve the SMEs performance. This is a significant challenge to managers and decision-makers. Adopting lean and green practices is one of several strategies that are being explored to address these issues. This study shows that a higher percentage of the automotive components SMEs implements lean practices more than they do for green practices. None of the automotive components manufacturing SMEs studied have fully implemented the practices. These enterprises need to improve on their implementation of lean and green practices, increase their response to environmental issues such as pollution and degradation. This study and its results are limited to a focus group whose results covers only the space of automotive components manufacturing enterprises studied. It is important to recognise the limitations of this study, which centres on generalisability of the results and conclusions. Future work is required to validate this study's results with much larger sample size.

References

[1] Melnyk SA, Sroufe RP, Calantone R (2003) "Assessing the impact of environmental management systems on corporate and environmental performance". *Journal of Operational Management* 21(3):329–351 https://doi.org/10.1016/S0272-6963(02)00109-2

[2] Chen, D., Heyer, S., Seliger, G. and Kjellberg, T., 2012. Integrating sustainability within the factory planning process. *CIRP annals*, *61*(1), pp.463-466. https://doi.org/10.1016/j.cirp.2012.03.067

[3] Wadhwa, R.S., 2013. Traceability and Data Support in SME Manufacturing. *International Journal of Computer Science Issues (IJCSI)*, *10*(6), p.69

[4] Jadhav, J.R., Mantha, S.S. and Rane, S.B., 2015. Roadmap for Lean implementation in Indian automotive component manufacturing industry: a comparative study of UNIDO Model and ISM Model. *Journal of Industrial Engineering International*, *11*, pp.179-198. DOI 10.1007/s40092-014-0074-6

[5] Blome, C., Groetsch, V.M., Henke, M. & Tang, C.S. 2010. "Differentiating winning and losing supply chains from a supply and risk manager's perspective: A comparative study of financial and operational measures in the automotive industry", *Proceedings of 19th IPSERA Conference*, Lappeenranta, Finland, 16–19 May

[6] Nurcahyo, R. and Wibowo, A., (2015). "Manufacturing Capability, Manufacturing Strategy and Performance of Indonesia Automotive Component Manufacturer". *Procedia CIRP*, 26, pp.653- 657 doi: 10.1016/j.procir.2014.07.046

[7] Pierreval, H., Bruniaux, R. and Caux, C., 2007. A continuous simulation approach for supply chains in the automotive industry. *Simulation Modelling Practice and Theory*, *15*(2), pp.185-198. https://doi.org/10.1016/j.simpat.2006.09.019

[8] Gunasekaran, A., Patel, C. and McGaughey, R.E., 2004. A framework for supply chain performance measurement. *International journal of production economics*, *87*(3), pp.333-347 https://doi.org/10.1016/j.ijpe.2003.08.003

[9] Lemghari, R., Okar, C. and Sarsri, D., 2018. Benefits and limitations of the SCOR® model in Automotive Industries. In *MATEC Web of Conferences* (Vol. 200, p. 00019). EDP Sciences. https://doi.org/10.1051/matecconf/201820000019

[10] Stephens, S. (2001). Supply chain council & supply chain operations reference model overview, Supply Chain Council, Inc

[11] Huang, S.H., Sheoran, S.K. and Keskar, H., 2005. Computer-assisted supply chain configuration based on supply chain operations reference (SCOR) model. *Computers & Industrial Engineering*, *48*(2), pp.377-394. https://doi.org/10.1016/j.cie.2005.01.001

[12] Stewart, G. 1997 "Supply-Chain Operations Reference Model (SCOR): The first cross-industry framework for integrated supply-chain management," *Logistics Information Management*, 10(2), pp. 62–67. https://doi.org/10.1108/09576059710815716

[13] Georgise, F.B., Thoben, K.D. and Seifert, M., 2012. Adapting the SCOR model to suit the different scenarios: a literature review & research agenda. *International Journal of Business and Management*, *7*(6), p.2. doi:10.5539/ijbm.v7n6p2

[14] Lockamy, A. and McCormack, K. (2004) "Linking SCOR planning practices to supply chain performance," *International Journal of Operations & Production Management*, 24(12), pp. 1192–1218. DOI 10.1108/01443570410569010

[15] Womack, James P., Jones, Daniel T, (1996), "Lean Thinking: Banish Waste and Create Wealth in Your Corporation", Simon & Schuster, New York http://red.wutf.space/books5/?k=0743249275&b=books&d=21-05-31&l=VisitedAll&fsig=ce8e5fa&dm=dG9uaXJldmlsby5lcw==

[16] Bhasin, S. & Burcher, P. (2006). "Lean Viewed as a Philosophy". *Journal of Manufacturing Technology Management*, 17(1), 56-72. https://doi.org/10.1108/17410380610639506

[17] Pavnaskar, S.J., Gershenson, J.K. and Jambekar, A.B., 2003. Classification scheme for lean manufacturing tools. *International journal of production research*, *41*(13), pp.3075-3090. DOI: 10.1080/0020754021000049817

[18] Dües, C.M., Tan, K.H. and Lim, M., 2013. Green as the new Lean: how to use Lean practices as a catalyst to greening your supply chain. *Journal of cleaner production*, *40*, pp.93-100. http://dx.doi.org/10.1016/j.jclepro.2011.12.023

[19] White, R. E., Pearson, J. N., & Wilson, J. R. (1999). "JIT manufacturing: A survey of implementations in small and large U.S. manufacturers". *Management Science*, Vol. 45, No. 1, pp. 1-16. *https://doi.org/10.1287/mnsc.45.1.1*

[20] Shah, R., Ward, P. T (2003)., "Lean Manufacturing: Context, Practice Bundles and Performance", *Journal of Operation Management*;21:129. https://doi.org/10.1016/S0272-6963(02)00108-0

[21] Sezen, B. and Çankaya, S.Y. (2013) "Effects of green manufacturing and eco-innovation on Sustainability Performance," *Procedia - Social and Behavioural Sciences*, 99, pp. 154–163. doi: 10.1016/j.sbspro.2013.10.481

[22] Dornfeld, D.A. (2014) "Moving towards green and sustainable manufacturing". *Int. J. of Precis. Eng. and Manuf.-Green Tech.* **1**, 63–66. DOI: 10.1007/s40684-014-0010-7

[23] Paul, I.D., Bhole, G.P. and Chaudhari, J.R. (2014) "A review on green manufacturing: it's importance, methodology and its application", *Procedia Materials Science*, Vol. 6, pp.1644– 1649. doi: 10.1016/j.mspro.2014.07.14

[24] Ahmad, S., Abdullah, A. and Talib, F., 2021. Lean-green performance management in Indian SMEs: A novel perspective using the best-worst method approach. *Benchmarking: An International Journal*, *28*(2), pp.737-765. https://doi.org/10.1108/BIJ-05-2020-0255

[25] Garza-Reyes, J.A., Ates, E.M. and Kumar, V. (2015), "Measuring lean readiness through the understanding of quality practices in the Turkish automotive suppliers industry", International Journal of Productivity and Performance Management, Vol. 64 No. 8, pp. 1092-1112. DOI 10.1108/IJPPM-09-2014-0136

[26] Shen, L., Olfat, L., Govindan, K., Khodaverdi, R. and Diabat, A., 2013. A fuzzy multi criteria approach for evaluating green supplier's performance in green supply chain with linguistic preferences. *Resources, conservation and recycling*, *74*, pp.170-179. https://doi.org/10.1016/j.resconrec.2012.09.006

[27] Nunes, B. and Bennett, D. (2010) "Green operations initiatives in the automotive industry," *Benchmarking: An International Journal*, 17(3), pp. 396–420. https://doi.org/10.1108/14635771011049362

[28] Deif, A.M. (2011), "A system model for green manufacturing", *Journal of Cleaner Production*, Vol. 19 No. 14, pp. 1553-1559. https://doi.org/10.1016/j.jclepro.2011.05.022

[29] Garza-Reyes, J.A., Villarreal, B., Kumar, V. and Molina Ruiz, P. (2016), "Lean and green in the transport and logistics sector – a case study of simultaneous deployment", Production Planning and Control, Vol. 27 No. 15, pp. 1221-1232. https://doi.org/10.1080/09537287.2016.1197436

[30] Gopal, G., 2012. Challenges in Sourcing and Procurement during an Economic Downturn. *Business & Entrepreneurship Journal*, *1*(1), pp.1-2.