

Research Article

Expertise Green Manufacturing Practices towards Sustainability

M.A.K.K. Shisara *, Y.N.S. Wijewardana

* kalindikithmina9@gmail.com

Department of Engineering Technology, Faculty of Technological Studies, Uva Wellassa University, Passara Road, Badulla, 90000, Sri Lanka.

Abstract

Green manufacturing deals with conserving natural resources for future generations and recycling materials by improving the manufacturing process to mitigate environmental pollution from manufacturing industries. The implementation of green manufacturing practices in manufacturing industries has increased with the negative environmental impacts. However, there are various barriers to the implementation of green manufacturing practices. The objectives of this study are (i) to study the barriers and their implementing techniques on green manufacturing practices and (ii) to assess stakeholders' viewpoints to implement green manufacturing practices to the manufacturing industries. An online questionnaire survey was used among 27 professionals to explore and identify the barriers, implementing techniques, and recommendations for improving green manufacturing practices. The results reveal that lack of awareness programs conducted by local institutions is the main barrier and give better advertising about green manufacturing is the main implementing technique of green manufacturing practices in the manufacturing industries. This study has been able to rank the barriers and their implementation techniques of green manufacturing practices through attitudes and perceptions of experts. Additionally, the results show that green manufacturing practices are a successful device for mitigating negative environmental impacts. This study will guide the manufacturing industries to focus on the main factors that will impact green manufacturing practices.

Keywords: *Environmental impacts, green manufacturing, barriers, implementation techniques, online questionnaire*

1. Introduction

The manufacturing sector, as the leading industry plays a major role in improving the economies of developing nations (Ganiyusufoglu, 2013) and therefore, showcase a broaden overall national strength a nation. However, the rapid growth of mechanized manufacturing has increased the use of energy in the world (Liang, 2019). The limited natural resources and high-energy demands hinder the pace of development. On the other hand, the manufacturing sector of emerging economies is attracting global attention due to the priority given for the development over natural resources and human resources, together with lack of strong environmental legislation (Ganiyusufoglu, 2013). The environment can be crucial and climate

change at any time can cause an imbalance in the world. In some cases, there is pretentious regional cooperation on environmental issues and even encourage conflicts (Tol, 2009). The International Organization for Standardization (ISO) developed the latest quality management process for products and even for the environment management process. They are mitigating the environmental damage caused by industries in the modern era. There's a desire for a new manufacturing process, and green manufacturing practices (GMP) have been identified as important aspects for sustainable development strategies (Tan *et al.*, 2002).

GMP is the latest trend in the manufacturing sector, with the main aim of mitigating the environmental damage caused by its manufacturing industries and its polities. GMP concept was produced in the 1990s. Handfield *et al.*, (1997) is stated that GM as a whole process of systems and integrated approaches that play an economically vital role in the removal, disposal of all waste related to the design, manufacturing, use, and/ or disposal of goods and materials. Under the reality of the manufacturing system, green production plans, and embrace the assembly technology program and process route with fewer resources and energy consumption, minimal environmental pollution however much as could be expected. Zero potential safety issues, zero health damages on the operators and commodity users, and waste recycling, zero environmental pollution, and waste disposal during the manufacturing process the maximum amount as possible are GM's achievable standards (Yongge *et al.*, 2009). GM is a new direction and a need across the globe. Consequently, it can be viewed as a common concept that all manufacturing engineers should use. The main advantage of GM is that they minimize unnecessary costs and promotes study and design. Its role in GM and technology has four specifications. They are sustainable manufacturing, sustainable green operation, environmental management tools, and green supply chain management (Kumar, 2017).

Sri Lanka promotes the manufacturing industries as the major driving forces for economic success without paying much attention to environmental issues. However, most of them function independently fix with barriers. Conversely, there are some barriers to implementing the GM concept concert in a perfect solution (Kulatunga *et al.*, 2013). Although, several ways are highlighted as being responsible for implementing the barriers to the use of GMP, however, these methods of implementation are also varied depending on the economic, political, and social region in which the industries operate (Nordin *et al.*, 2014). This can be large, as the implementation of GMP requires a production system that causes less environmental pollution, but the system generally requires higher operating costs and skills (Zhang *et al.*, 2017). This GM concept can be properly implemented through strategic methods as well as by minimizing the barriers to it through the integration of government and manufacturing industries (Mittal & Sangwan, 2014).

There are a few published types of research in a number of the sub-topics of GMP within the recent past. Further, there's no research or any government or privately involved project to research the barriers and their implementation techniques to manoeuvre towards GMP. This research is done to fill this gap. GMP has become a critical factor in the manufacturing industries, making it necessary to survive in the current low-cost business environment (Nordin *et al.*, 2014). The main objective of this study is to investigate the fundamentals that currently arise in the use of GMP in the manufacturing industries and to investigate whether environmental pollution can be mitigated by using this concept. Specific objectives are to (i) study the barriers and their implementing techniques on green manufacturing practices (ii) to assess stakeholders' viewpoints to implement GMP to the manufacturing industries. Also, there are significant deviations available from different manufacturing industries concerning GMP (Kulatunga *et al.*, 2013).

2. Materials and Methods

2.1 Sample Selection

The experts and other professional bodies who were employed in the Sri Lankan manufacturing industries such as Engineers, Assistant Engineers, Technicians, and Technologists have participated. The target sample was 30. The selected sample were key informants with knowledge of green manufacturing practices in their manufacturing industries.

2.2 Questionnaire Development

The primary study was used to recognizing the key barriers and implementing techniques of GMP within the manufacturing industries in Sri Lanka with different perspectives in orders. The preliminary study was involved in an online questionnaire form, which was consisted of four major sections. They are (A) company, respondent and project background, (B) current barriers for introducing GMP according to their perception ($B_1 - B_8$), (C) implementing techniques for GMP ($I_1 - I_8$), and (D) recommendations on introducing and implementing GMP. This study was commonly dependent on the quantitative analytical methods used to collect the data.

2.3 Data Collection

The methodology flow chart is shown in Figure 1. The online questionnaire was sent to selected 30 specialized experts using e-communication (e-mail, and WhatsApp) in ethical approval up to achieve the objectives of this study. The survey was conducted online from mid-June to mid-July 2020 on a representative sample. Overall, 29 online questionnaires were received from 30 respondent and 27 valid responses were selected to this study.

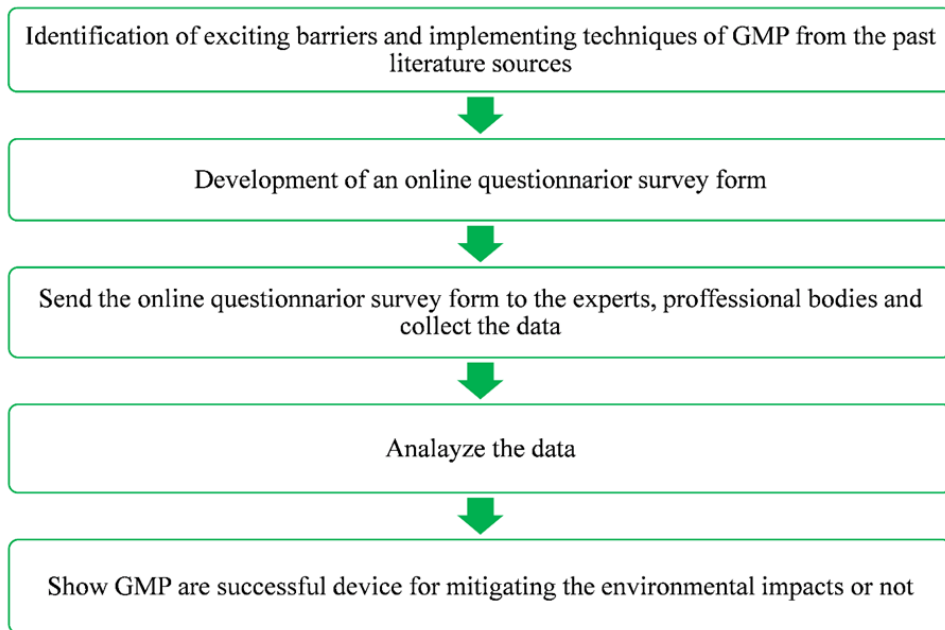


Figure 1: Flow chart of the methodology

2.4 Data Analysis

Descriptive statistics computed current barriers and implementing methods of GMP of manufacturing industries in Sri Lanka. SPSS version 20 was used to analyze data in the usage of the most effective and prominent way.

3.Results and Discussion

3.1 Background of Respondents, Organizations, and Projects

The primary perspective is to analyse the respondents' background situations, the organizations, and the projects involved. The outcomes indicate that the respondents, organizations, and projects respondents, organizations, and project's overall foundation for examples of the industry type, position in the organization, years of experience in the manufacturing field, and their ideas about GM are summarized in Table 1. The highest number of respondents (40%) in this study were from the manufacturing sector, of which 52% were engineers. The vast majority of the respondents (40%) have involved their current position between 1 to 5 years. Also, this result revealed that all the respondents have enough knowledge together with a lot of experience of GMP in their respective industries.

Table 1: The analysed frequencies and percentages of the background of respondents, companies, and projects

Background	Frequency	Percentage (%)
Industry type	27	100
Manufacturing	11	40
Telecom systems installations and servicing	1	4
Irrigation and water resources	1	4
Textile and clothing	1	4
Water resources planning and management	1	4
Maintain railway locomotive	1	4
Electricity, gas, steam and air conditioning supply	2	7
Civil construction	7	25
Building automation and IT systems	1	4
Mechanical	1	4
Position in the organization	27	100
Engineer	14	52
Assistant engineer	10	36
Technician	1	4
Technologist	1	4
Trainee	1	4
Years of the experience in field	27	100
Less than one year	4	15
1 – 5 years	11	40
6 – 10 years	8	30
11 – 15 years	1	4
Over 15 years	3	11
Have idea about GM?	27	100
Yes	27	100

3.2 Current Barriers to Introduce GMP in Manufacturing Industries

The second aspect of this study was to examine the barriers to the implementation of GMP in the manufacturing industries in Sri Lanka. The preliminary study was recognized 8 barriers of GMP after referring to past literature sources and they are summarized in Table 2.

Table 2: Summary of literature sources used to recognize the current barriers of GMP in manufacturing industries

Barriers	Literature Sources
Lack of awareness in GM concepts (B_1)	(Oosterveer <i>et al.</i> , 2006), (Singh <i>et al.</i> , 2012)
Lack of awareness programs conducted by local institution/s (B_2)	(Ghazilla <i>et al.</i> , 2015), (Kulatunga <i>et al.</i> , 2013)
Lack of awareness of local customers in green products (B_3)	(Florida <i>et al.</i> , 2001), (Singh <i>et al.</i> , 2012)
No tax benefit or other rewards from the government (B_4)	(Cousins & Pocknell, 2007), (Walker <i>et al.</i> , 2008)
Negative attitudes towards GM concepts (B_5)	(Kulatunga <i>et al.</i> , 2013)
Less support from the employees/ employer (B_6)	(Kulatunga <i>et al.</i> , 2013)
Lack of funds for green projects (B_7)	(Kulatunga <i>et al.</i> , 2013)
Difficult to operate and maintenance (B_8)	(Movahedipour <i>et al.</i> , 2017), (Kulatunga <i>et al.</i> , 2013)

Table 3 provides factor wise mean values and rank number of survey responses on a five-point Likert scale, of all current barriers to GMP to the manufacturing industries according to the responders’ knowledge and attitude.

Based on the ranks, B_2 , B_1 , and B_3 are founded as most commonly existing barriers to adapting of GMP by local firms. The listed barriers are having mean values ranging from 2.67 to 3.96, with the most important mean value at B_2 . Moreover, the study of Kulatunga *et al.* (2013) has identified the better advertising as a key barrier of GMP. The present survey results demonstrate that manufacturing industries are unable to adopt GMP because they lack in awareness of GMP, which is considered to the primary step in the successful implementation of various GMP. On the other hand, the barrier of B_5 scored the lowest mean value of 2.67, which shows that attitudes towards GM concept are contributing its role than other barriers. The overall results indicate that GMP is relatively a new concept in Sri Lanka.

Table 3: Comparison of means and ranks of responses of current barriers of GMP in manufacturing industries.

Barriers	Mean	Rank
Lack of awareness in GM concepts (B_1)	3.81	2
Lack of awareness programs conducted by local institution/s (B_2)	3.96	1
Lack of awareness of local customers in green products (B_3)	3.41	3
No tax benefit or other rewards from the government (B_4)	3.22	5
Negative attitudes towards GM concepts (B_5)	2.67	8
Less support from the employees/employer (B_6)	3.19	6
Lack of funds for green projects (B_7)	3.30	4
Difficult to operate and maintenance (B_8)	2.89	7

The responders based on their knowledge and attitudes were stated other barriers found in the GMP in Sri Lanka, which are shown in the following.

- a) Awareness programs and practical sessions should be provided to the community from the inception.
- b) Absence of awareness/ information about technological risk, and powerless enactment.
- c) Lack of adequate market and clients for green products.
- d) Lack of familiarity with the use of green products.
- e) Harmful refrigerant gases are used for the air conditioning system.
- f) More time-consuming.
- g) The GM concept should highly setup for Sri Lanka.
- h) Green issues are not a worry for top administration.
- i) No support from the government. Aware of the people and should have plans to implement business in the country.
- j) Lack of knowledge in green manufacturing to compete with other products in the market.

3.3 Implementing Techniques for GMP in Manufacturing Industries

The third aspect of this study was to examine the implementing techniques of GMP in the manufacturing industries in Sri Lanka. The preliminary study was recognized 8 implementing GMP techniques after referring to past literature sources and they are summarized in Table 4.

Table 4: Summary of literature sources used to recognize the implementing techniques of GMP in manufacturing industries.

Implementing Techniques	Literature Sources
Awareness of the GM concept (I_1)	(Singh <i>et al.</i> , 2012), (Fiksel <i>et al.</i> , 2004)
Give better advertising about GMP (I_2)	(Castle, 2017) (Arseculeratne & Yazdanifard, 2013)
Give tax benefits, promotions and regulations from government (I_3)	(Kumar & Malegeant, 2006), (Singh <i>et al.</i> , 2012)
Organize the training programs about GMP to the employees (I_4)	(Curkovic, 2003), (Singh <i>et al.</i> , 2012)
Give the award/ appreciation/ recognition in GMP (I_5)	(Paul <i>et al.</i> , 2014), (Singh <i>et al.</i> , 2012)
Perform environment management system (I_6)	(Tsui, 2014), (Pun <i>et al.</i> , 2002)
Apply new technology for all stakeholders (I_7)	(Singh <i>et al.</i> , 2012)
Establishment of funds for green projects (I_8)	(Kulatunga <i>et al.</i> , 2013)

The respondents were instructed to rank the possible implementing techniques by which GMP can be implemented in local manufacturing industries concerning their knowledge and attitudes. The following are derived Table 5 shows factor wise mean values and rank numbers of survey responses on a five-point Likert scale, of all stated implementing techniques of GMP.

Based on the ranks, I_2 , I_7 and I_1 are the most commonly existing implementing techniques which led manufacturing industries to adopt various GMP, with having a mean value ranging from 3.85 to 4.19 when responses are taken on a five-point Likert's scale. The present survey results made us confirmed that I_2 is the most suitable implementing techniques to overcome barriers in GMP. Moreover, the study of Castle (2017) has identified the better advertising as an important implementing technique of GMP. Advertising provides the society with a broad knowledge of GMP and enabling them to incline towards to GMP. In the same manner, it is also proved that I_5 and I_7 are founded with a very low level of perception with a mean value range 3.81 and 3.70 respectively. The data reveals

that responders have shown low perception, mainly because of the high cost of GMP, eco-friendly raw materials, and new technology.

Table 5: Comparison of means and ranks of responses of various implementing techniques of GMP in manufacturing industries.

Implementing Techniques	Mean	Rank
Awareness of the GM concept (<i>I</i> ₁)	3.89	3
Give better advertising about GMP (<i>I</i> ₂)	4.19	1
Give tax benefits, promotions, and regulations from the government (<i>I</i> ₃)	3.85	4
Organize the training programs about GMP to the employees (<i>I</i> ₄)	3.85	4
Give the award/ appreciation/ recognition in GMP (<i>I</i> ₅)	3.81	7
Perform environment management system (<i>I</i> ₆)	3.85	4
Apply new technology for all stakeholders (<i>I</i> ₇)	3.70	8
Establishment of funds for green projects (<i>I</i> ₈)	3.96	2

The responders based on their knowledge and attitudes were stated other implementing techniques found in the GMP in Sri Lanka, which are shown in the following.

- a) Community innovative thinking and the importance of environmentally friendly working conditions should be developed, need to begin from schools.
- b) Encourage customers by discounting of products and efficient advertising.
- c) Give support from the government.
- d) Change the regulations and policies to facilitate the use of waste.
- e) Enhance investments in research for the development of technological innovations.
- f) Awareness of the top management about GM concept.
- g) Introduction of facilitating entities.
- h) Provide dissemination actions.
- i) Reducing the price of green materials.

Figure 2 shows the percentage of respondents that believe the GMP are a device for mitigating the environmental impacts or not. Based on the results, 88.89% of responses are showing GMP are the device for mitigating the negative environmental impacts and no responses are showing GMP aren't device for

minimizing the negative environmental impacts. The results show GMP are the device for mitigating the negative environmental impacts in Sri Lanka.

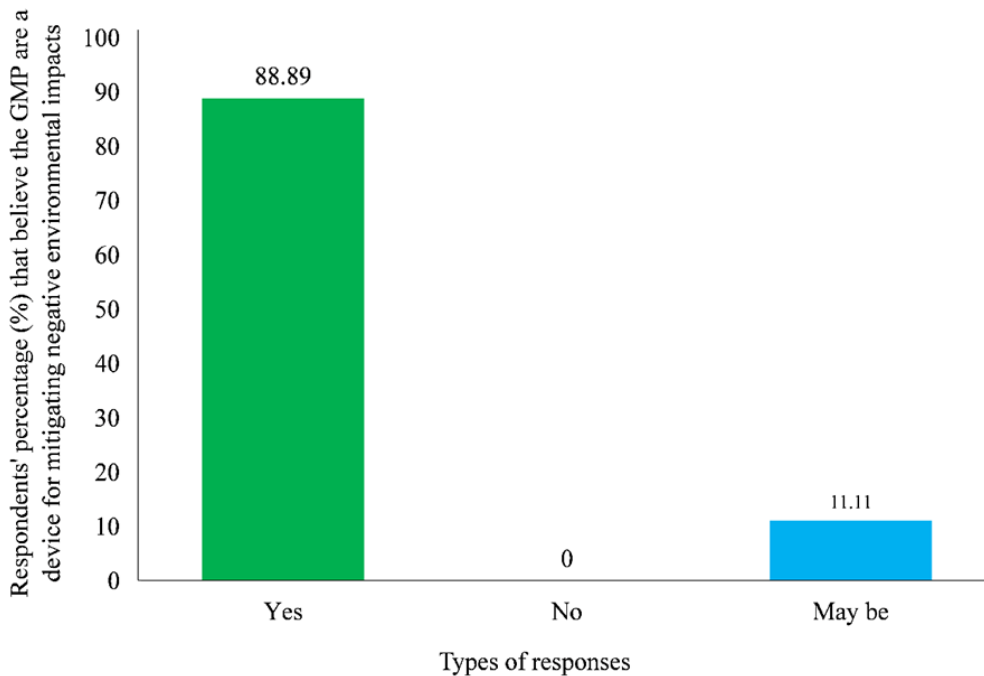


Figure 2: Respondents' percentage (%) that believe the GMP are a device for mitigating the negative environmental impacts in Sri Lanka.

The responders based on their knowledge and attitudes were stated ten recommendations for improving the GMP in Sri Lanka, which are shown in the following.

- a) Long-term loan facilities should be provided for the companies.
- b) Make it mandatory by making government regulations.
- c) Implement pilot-scale green manufacturing practices and assess its impact on the economics, environment, and society and then step forward to the large scale.
- d) Reduce production costs and continue to provide incentives for GMP.
- e) Government involvement has to been taken with the sponging hand having resources & resource persons.

- f) The legislature should construct and update the basic framework to maintain infrastructure to uphold environmental legislation effectively.
- g) The legislature should likewise set up required natural enactment with innovatively developed countries to compile the industry to put resources into green advances.
- h) Get interested for the items and afterwards manufacture exceptionally request items without harming.
- i) More awareness programs on green technologies and its positives, more focus on sustainable methods of manufacturing, minimizing the barriers for the implementation of green technology.

4. Conclusions

This empirical study investigates barriers and implementation techniques that inspire and frustrate the development of GMP in manufacturing industries in Sri Lanka. Based on the findings, experts and other professional bodies were ranked that barriers and implementing techniques of GMP regarding their knowledge and attitude. Lack of awareness programs conducted by local institution/s (B_2) is the main exciting barrier and give better advertising about GMP (I_2) is the main exciting implementing technique of these findings. Further, the majority of responders were responded as the GMP are a device for reducing environmental impacts. Thus, utilizing the discoveries of this study, it tends to be concluded that the implementation of GMP in the local manufacturing industries can greatly minimize the effect on nature. Hence, all information necessary for the pertinence of GMP has to be recognized the various overcoming obstacles. The knowledge dispersal of the social and environmental advantages emerging from the utilization of new sustainable methodologies, and major consciousness towards sustainable services.

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6. References

- Arseculeratne, D., and Yazdanifard, R., (2013). How green marketing can create a sustainable competitive advantage for a business. *International Business Research*, 7(1), 130–137.
<https://doi.org/10.5539/ibr.v7n1p130>
- Castle, A. D., (2017). Strategies for implementing advertisements in the green industry, Walden University. Retrieved from
<https://scholarworks.waldenu.edu/dissertations>

- Cousins, P. and Pocknell, L., (2007). Business environmental soundness and green supply chain management. *Manchester Business School*, 6.
- Curkovic, S., (2003). Environmentally responsible manufacturing: the development and validation of a measurement model. *European Journal of Operational Research*, 146(1), 130–155.
[https://doi.org/10.1016/S0377-2217\(02\)00182-0](https://doi.org/10.1016/S0377-2217(02)00182-0)
- Fiksel, J., Lambert, D., Artman, L., Harris, J., & Share, H. (2004). The new supply chain edge supply chain management review. *Supply Chain Management Review*, 8, 50–57.
- Florida, R., Atlas, M. and Cline, M., (2001). What makes companies green? organizational and geographical factors in the adoption of environmental practices. *Economic Geography*, 77(3), 209–224.
<https://doi.org/10.1111/j.1944-8287.2001.tb00162.x>
- Ganiyusufoglu, Ö. S., (2013). Chinese approaches to sustainable manufacturing. In G. Seliger (Ed.), *Proceedings of the 11th Global Conference on Sustainable Manufacturing* (p. 4). IRP.
- Ghazilla, R. A. R., Sakundarini, N., Abdul-Rashid, S. H., Ayub, N. S., Olugu, E. U. and Musa, S. N., (2015). Drivers and barriers analysis for green manufacturing practices in Malaysian SMEs: A Preliminary Findings. *Procedia CIRP*, 26, 658–663.
- Handfield, R. B., Walton, S. V., Seegers, L. K. and Melnyk, S. A., (1997). “Green” value chain practices in the furniture industry. *Journal of Operations Management*, 15(4), 293–315.
[https://doi.org/10.1016/S0272-6963\(97\)00004-1](https://doi.org/10.1016/S0272-6963(97)00004-1)
- Kulatunga, A. K., Jayatilaka, P. R. and Jayawickrama, M., (2013). Drivers and barriers to implement sustainable manufacturing concepts in Sri Lankan manufacturing sector. 11th Global Conference on Sustainable Manufacturing, September, 171–176. <https://doi.org/10.13140/2.1.2952.1927>
- Kumar, S., (2017). The literature review of lean and green manufacturing system. *International Journal of Theoretical and Applied Mechanics*, 12(3), 389–393.
- Kumar, S. and Malegeant, P., (2006). Strategic alliance in a closed-loop supply chain, a case of manufacturer and eco-non-profit organization. *Technovation*, 26(10), 1127–1135.
<https://doi.org/10.1016/j.technovation.2005.08.002>
- Liang, S., (2019). Development and application of green manufacturing. IOP Conference Series: *Materials Science and Engineering*, 631(3), 1–3.
<https://doi.org/10.1088/1757-899X/631/3/032010>
- Mittal, V. K. and Sangwan, K. S., (2014). Prioritizing barriers to green manufacturing: Environmental, social and economic perspectives. *Procedia CIRP*, 17, 559–564.
<https://doi.org/10.1016/j.procir.2014.01.075>

- Movahedipour, M., Zeng, J., Yang, M. and Wu, X., (2017). An ISM approach for the barrier analysis in implementing sustainable supply chain management: An empirical study. *Management Decision*, 55(8), 1824–1850.
<https://doi.org/10.1108/MD-12-2016-0898>
- Nordin, N., Ashari, H. and Hassan, M. G., (2014). Drivers and barriers in sustainable manufacturing implementation in Malaysian manufacturing firms. *IEEE International Conference on Industrial Engineering and Engineering Management*, January 2016, 687–691. <https://doi.org/10.1109/IEEM.2014.7058726>
- Oosterveer, P., Kamolsiripichaiporn, S. and Rasiah, R., (2006). The “greening” of industry and development in southeast Asia: Perspectives on industrial transformation and environmental regulation; introduction. *Environment, Development and Sustainability*, 8(2), 217–227.
<https://doi.org/10.1007/s10668-005-9015-2>
- Paul, I. D., Bhole, G. P. and Chaudhari, J. R., (2014). A review on green manufacturing: It’s important, methodology and its application. *Procedia Materials Science*, 6(2014), 1644–1649.
<https://doi.org/10.1016/j.mspro.2014.07.149>
- Pun, K. F., Hui, I. K., Lau, H. C. W., Law, H. W. and Lewis, W. G., (2002). Development of an EMS planning framework for environmental management practices. *International Journal of Quality and Reliability Management*, 19(6), 688–709.
<https://doi.org/10.1108/02656710210429573>
- Singh, A., Singh, B. and Dhingra, A. K., (2012). Drivers and barriers of green manufacturing practices: A survey of Indian industries. *International Journal of Engineering*, 01(01), 5–19.
- Tan, X. C., Liu, F., Cao, H. J. and Zhang, H., (2002). A decision-making framework model of cutting fluid selection for green manufacturing and a case study. *Journal of Materials Processing Technology*, 129(1–3), 467–470.
[https://doi.org/10.1016/S0924-0136\(02\)00614-3](https://doi.org/10.1016/S0924-0136(02)00614-3)
- Tol, R. S. J., (2009). The economic effects of climate change. *Journal of Economic Perspectives*, 23(2), 29–51.
<https://doi.org/10.1257/jep.23.2.29>
- Tsui, C. S. K., (2014). A literature review on environmental management accounting (EMA) adoption. *Web Journal of Chinese Management Review*, 17(3), 1–19.
- Walker, H., Di Sisto, L. and McBain, D., (2008). Drivers and barriers to environmental supply chain management practices: Lessons from the public and private sectors. *Journal of Purchasing and Supply Management*, 14(1), 69–85.
<https://doi.org/10.1016/j.pursup.2008.01.007>

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- Yongge, G., Jiyong, L. and Yunfeng, S. (2009). Performance evaluation of green supply chain management based on membership conversion algorithm. 2009 Second ISECS International Colloquium on Computing, Communication, Control, and Management, CCCM 2009, 3, 237–240. <https://doi.org/10.1109/CCCM.2009.5267895>
- Zhang, H., Peng, Y., Tian, G., Wang, D. and Xie, P., (2017). Green material selection for sustainability: A hybrid MCDM approach. *PLoS ONE*, 12(5). <https://doi.org/10.1371/journal.pone.0177578>