**Analysis and Prioritization of Lean Six Sigma Enablers with Environmental facets using Best Worst Method: A Case of Indian MSMEs**

**Mahipal Singh1,** **Rajeev Rathi1\*,** [**Jose Arturo Garza-Reyes**](https://www.sciencedirect.com/science/article/pii/S0959652615004394#!)**2**

1School of Mechanical Engineering, Lovely Professional University, Phagwara, Punjab, India-144411

2Centre for Supply Chain Improvement, The University of Derby, Kedleston Road Campus, Derby, DE22 1GB, UK

\*Corresponding Author: [rathi.415@gmail.com](mailto:rathi.415@gmail.com)

**Abstract**

Micro-Small and Medium Enterprises (MSMEs) play a prominent role in economic growth because of their significant contribution in terms of manufacturing, sales, and development in any country. Improvements in product quality, waste reduction, environmental measures, green product development, and cost optimization have enforced MSMEs to adopt sustainable development approaches. Lean Six Sigma (LSS) is one of the robust methods that reduce waste, variation, emission, and energy in any system. It is indispensable to relook the enablers of environmental LSS to assess sustainability through the successful implementation of this eco-friendly approach. In this context, the present study aims to investigate and prioritize the enablers which facilitate the effective implementation of environmental LSS in MSMEs. Extensive literature and expert’s opinion are used to investigate the environmental LSS enablers and grouped them as per their appropriate traits using Exploratory Factor Analysis. The final screening of grouped enablers is done through Importance-index analysis and corrected item minus total correlation method. For prioritization of finalized enablers, a robust decision-making technique, Best Worst Method, is employed with a practical case of Indian MSMEs. The research outcomes reveal that strategic based enablers are leading in nature, followed by environmental-based enablers. Moreover, current results are validated through the Analytical Hierarchy Process and Analytical Network Process. The present study outcomes are also in good agreement with case organization officials. This study expedites the managers of case organization with prominent enablers, which will help in planning and successful execution of environmental LSS.

**Keywords:** Environmental Lean Six Sigma; Enablers; Best Worst Method; MSMEs; Green Manufacturing.

**1. Introduction**

Micro-Small and Medium Enterprises (MSMEs) are the main contributors to industrial evolution and the development of any economy (Seth et al., 2018b). The MSMEs are widening their domain by producing a diverse range of products and services to meet the demands of domestic as well as global market (Singh et al., 2019). The ministry of MSMEs, Government of India (GOI), classified the industries into three categories based upon investment on the plant, machinery, and equipment (refer Table 1).

**Table 1: Classification of Indian MSMEs *(Source: Annual Report Fy 2017-18 MSMEs, GOI)***

|  |  |  |
| --- | --- | --- |
| Classification of MSMEs | Investment in Million (M) | |
| Manufacturing MSMEs | Service MSMEs |
| Micro | Less than 2.5 M | Up to 1 M |
| Small | 2.5 M to 50 M | 1 M to 20 M |
| Medium | 50 M to 100 M | 20 M to 50 M |

In the Indian industrial scenario, MSMEs contribute about 45% of total manufacturing output and 40% of total exports (International Energy Agency, 2018). Additionally, the contribution of MSMEs in the Indian GDP is measured as 16% and it provides more than 80 M employment opportunities (Seth et al., 2018b). The said contributions of MSMEs prove its effectiveness in Indian economic development. Despite its huge role in economic growth, it faces dynamic challenges relevant to environmental, competitiveness, and continuous improvement (Gandhi et al., 2018). As an environmental perceptive, MSMEs are highly responsible for carbon emission (Redmond et al., 2016; Singh and Rathi, 2019). Globally, this sector is responsible for 70% of industrial pollution and 13% of energy consumption annually (Haeri and Rezaei, 2019). MSMEs are the leading source of CO2 emission (158.98 million tons/year) in India as compared to big corporations (Ministry of the Environment, 2019). The competitiveness of MSMEs is also trapped due to limited financial and managing capabilities, resource constraints, poor monitoring obligations, and quality (Antony et al., 2016; Sunder et al., 2018). These issues become more pertinent for developing countries like India due to its lower position in the global competitive index (40 ranks amongst 137 participating nations) (Forum, 2018).

Several researchers have focused on Indian MSMEs improvement by providing innovative solutions like reducing delivery time, manufacturing cycle time, operational and technological factors, vendor rationalization, etc. (Khurana et al., 2019; Thakur and Mangla, 2019; Seth and Rastogi, 2019). Such studies had provided some good insights into the growth and development of specific areas in MSMEs. But these studies are limited to solve individual issues and unable to provide solutions for continuous improvement and environmental issues under one roof comprehensively. Thus, there is a significant need for such approaches that work for sustainable development and continuous improvement without compromising environmental stewardship.

As per Environmental Protection Agency (EPA) U.S.A, LSS approach with the environmental aspect provides operational and environmental benefits by creating eco-friendly processes (Fercoq et al., 2016; Ruiz-Benitez et al., 2017). LSS, with the synergy of the environmental aspect, diminishes the negative environmental impact in manufacturing and services, results in cleaner production, and healthy environment (Sagnak and Kazancoglu, 2016; Kaswan and Rathi, 2019). Despite the evolution of environmental LSS, MSMEs managers are still hesitant to adopt this strategy in their core business due to lack of readiness measures, limited resources, and fear of failure (Thanki and Thakkar, 2018). Also, MSMEs managers are more insecure to adopt new technologies without working on their enablers (Alhuraish et al., 2017). Enablers or readiness measures can drive the system smoothly and efficiently (Raval et al., 2018; Caldera et al., 2019). There is an immense need to adopt the enablers according to their impact and driving characteristics for the successful adoption of environmental LSS in MSMEs.

The present research investigates and prioritizes the enablers, which significantly influence the managers to take fruitful initiatives for the adoption of environmental LSS in Indian MSMEs. Initially, thirty enablers are extracted through extensive literature and expert’s opinions. Further, twenty-two enablers are finalized by using the Importance-index analysis and Corrected Item-Minus Total Correlation (CIMTC) method. Finalized enablers are highly interlinked to each other, thus possess more inter-dependency. In such situations, the selection of driving enablers is a challenging task and such kind of problems cannot be solved without adopting Multi-Criteria Decision Making (MCDM) techniques (Gupta and Barua, 2016). The literature exhibits various MCDM approaches such as Analytical Hierarchy Process (AHP) (Rathi et al., 2015a; Das et al., 2016), Technique for Order of Preference by Similarity in Ideal Solution (TOPSIS) (Rathi et al., 2017), VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) (Rathi et al., 2015b), Analytical Network Process (ANP) (Alexander et al., 2019), Decision Making Trial and Evaluation Laboratory (DEMATEL) (Luthra et al., 2019; Yadav et al., 2020), etc. The above-mentioned techniques have been implemented for prioritizing the alternatives in different areas. Amongst these techniques, Best Worst Method (BWM) is the quite prominent approach for ranking such kinds of complex decisions (Rezaei, 2015). BWM requires the least pairwise comparisons among criteria which provides more consistent results than other decision-making techniques (Rezaei et al., 2015). Therefore, in the present study, BWM is adopted for prioritizing the environmental LSS enablers with the help of a case study. The obtained results are compared with AHP and ANP results to check and validate the accuracy of the results.

The remaining paper is organized as follows: Section 2 presents the background of environmental aspects, LSS, MSMEs, and BWM. Section 3 highlights the exploration, statistical analysis, and reliability testing of environmental LSS enablers. Section 4 exhibits the detail of the method adopted in the current case study. Section 5 includes the case study conducted in selected MSMEs in India. Section 6 highlights the key points of the result and discussion of a case study with managerial implications. Section 7 discusses the conclusion, limitations, and future scope of the present research.

* 1. *Research Question of the present study*

***RQ1:*** Which are the key enablers responsible for the successful implementation of environmental LSS in Indian MSMEs?

***RQ2:*** How to prioritize the identified enablers as environmental, strategy, resources, cultures, and linkage perceptive?

***RQ3:*** How the ranking of environmental LSS enablers is beneficial in the following context: Indian MSMEs, researchers, government agencies, and society?

**2. Related Work**

In this section, the literature search methodology and the summary of literature existing on LSS, environmental aspects, BWM, and MSMEs are discussed.

*2.1 Literature Search Methodology*

In the present study, a Systematic Literature Review (SLR) is adopted as a search methodology that consists of three phases as plan review, conduct review, and document review. In the first phase, articles from 2000 to 2020 are considered to find out the fundamentals related to environmental LSS, MSMEs, and BWM. The pertinent research papers are downloaded from renowned databases such as Elsevier, Springer, Emerald, Taylor & Francis, and Inderscience. In the second phase, the articles with keywords like LSS, environmental, MSMEs, BWM, and enablers are included. The research papers before the year 2000, books, reports, conferences, and other than the English language are not considered in this article. In the document review phase, 30 pertinent enablers of environmental LSS are extracted from the literature.

*2.2 Manufacturing Policy Initiatives and Environmental Sustainability*

As per National Manufacturing Policy-2025, the manufacturing sector should be provided 100 M job opportunities and raise its shares in GDP from 16% to 25% by 2025. The Nationally Determined Contribution (NDC) under the Paris pact agreement also sets the prime target to reduce carbon emission at least 40% by 2030 (European Commission, 2018). The GOI took initiatives to achieve the said targets through Make in India plan, Automotive Mission Plan-2026, National Action Plan on Climate Change (NAPCC-2018), etc. Some provisions also made to protect the environment from industrial pollution through environmental act 1987 (Effectively Integrating Industrial Growth and Environmental Sustainability, 2017). Such proclaimed acts and regulations are now outdated and lack in uttering the integration of environmental aspects and improvement strategy in core business (Ruben et al., 2018; Shashi et al., 2018). In developed countries, the manufacturing sector has rigorous policies and a well clear road map to ensure the effective integration of environmental and improvement strategies (Cai et al., 2019; Belhadi et al., 2018). But, in developing countries, the implementation of such integrated strategies is still in its early phase, especially in MSMEs due to limited resources, lack of awareness, and loop falls in government policies (Thanki et al., 2016; Thanki and Thakkar, 2018).

*2.3 Lean Six Sigma with Environmental Facets*

LSS is a powerful business improvement approach that can resolve the ongoing economic uncertainty and stimulating market circumstances (van de Kaa et al., 2017). It has the capability to meet the company’s expectations and delicate customer requirements (Sreedharan V and Sunder M, 2018). The adoption of the LSS approach facilitates the organizations to move from a cost-based system to a quality-based system to attain excellence (Raval et al., 2018). Some past studies reported that LSS adoption offered good results in MSMEs' performance improvement (Antony et al., 2016; Chaurasia et al., 2019). Literature also reveals that the adoption of LSS approach can reduce defects and system inconsistencies in the context of Indian Small and Medium Enterprises (SMEs) (Pandey et al., 2018; Nallusamy et al., 2018). In the present scenario, the industries are more sensible for environmental quality development and carbon emission reduction with continuous improvement (Redmond et al., 2016). These goals are enforcing the industries towards the adoption of environmental-based continuous improvement strategies to achieve economical and sustainable growth (Pandey et al., 2018). Literature also exhibits that the integration of LSS and environmental facets can reduce waste and process variation with a sustainable environment (Cherrafi et al., 2016; Ruben et al., 2018). In literature, few studies highlighted the integration of environmental aspects with Lean, Six Sigma, LSS and explored the benefits of their amalgamation (Kumar et al., 2015; Siegel et al., 2019). Presently, environmental LSS has been successfully initiated in some big corporations like Malaysian Automotive industry to assess the organizational performance (Habidin and Yusof, 2012), to solve public sector supply chain management issues (Raja Sreedharan et al., 2018), to reduce medication delivery time in the USA healthcare sector (Zhu et al., 2018), to enhance performance in North African manufacturing company (Belhadi et al., 2020), etc. Apart from this, environmental LSS has been initiated in the Indian automotive sector for productive environment improvement (Ben Ruben et al., 2017). Further, researchers in the past also worked on enablers of Six Sigma (Soti et al., 2010), Lean (Khaba and Bhar, 2018), LSS (Yadav and Desai, 2017a), and environmental facets (Kaswan and Rathi, 2019) individually and highlighted their mutual relationships (Yadav and Desai, 2017; Raval et al., 2018). The exploration of environmental LSS enablers has been reported (Pandey et al., 2018), but it was conventional in nature and not focused on the MSMEs. For successful adoption and implementation of environmental LSS in MSMEs, there is a massive need to devise and investigate the enablers.

*2.4 Linkage among MSMEs, environmental LSS and BWM*

In terms of production, sales, and development, MSMEs have a significant role in the economic growth of any nation (Alexander et al., 2019). According to the World Bank report (2019), 600 M jobs should be provided by 2030 to absorb the growing global workforce, which makes MSMEs development at a high priority for governments and industrialists worldwide. Despite this, MSMEs are also one of the major contributors to carbon emission (Redmond et al., 2016). In such circumstances, environmental LSS is the most robust approach which can improve the existing process by reducing the adverse effect on the environment (Ruben et al., 2018). Generally, MSMEs possess a culture of resistance to change against the incorporation of a new approach (Chaurasia et al., 2019). Hence, it is essential to focus on environmental LSS enablers before actual execution in the MSMEs context (Lande et al., 2016). The investigation of key environmental LSS enablers is a complex decision-making problem and can be solved by using an advanced decision-making approach. Currently, BWM has been evolved as one of the best complex decision-making approaches and adopted worldwide in such complex situations (T. and K.P., 2018).

*2.5 Application of Best Worst Method in Indian and Global Context*

BWM is a novel MCDM technique developed by Rezaei to prioritize and select the best alternative among a set of alternatives (Rezaei et al., 2015). In this technique, fewer pairwise comparisons among criteria are required as compared to other MCDM i.e., AHP, ANP, etc. (Rezaei, 2016). Due to the popularity and novelty of BWM, it has been implemented for numerous applications in Indian context like identification of prime enablers of technological innovation for MSMEs (Gupta and Barua, 2016), supplier selection among small manufacturing enterprises based on green innovation ability (Gupta and Barua, 2017), ranking the barriers of energy efficiency (Gupta et al., 2017), the ranking of low back pain risk factors among industrial workers (Khan et al., 2019), etc. The BWM has been adopted for the selection of biomass thermochemical techniques (van de Kaa et al., 2017), and evaluation of external force affecting the sustainability of the oil and gas supply chain (Wan Ahmad et al., 2017). Further, it has been used for the evaluation of Research & Development (R&D) performance inside the organization (Salimi and Rezaei, 2018), and the optimal combination of power plant alternatives (Omrani et al., 2018). It has also been adopted for the evaluation of user activity-oriented service required for the smart product-service system (Chen et al., 2020) and risk evaluation in failure mode and effect analysis at supercritical water gasification (Yazdi et al., 2020). Overall, literature is lacking to express any evidence to adopt BWM for the assessment of environmental LSS enablers.

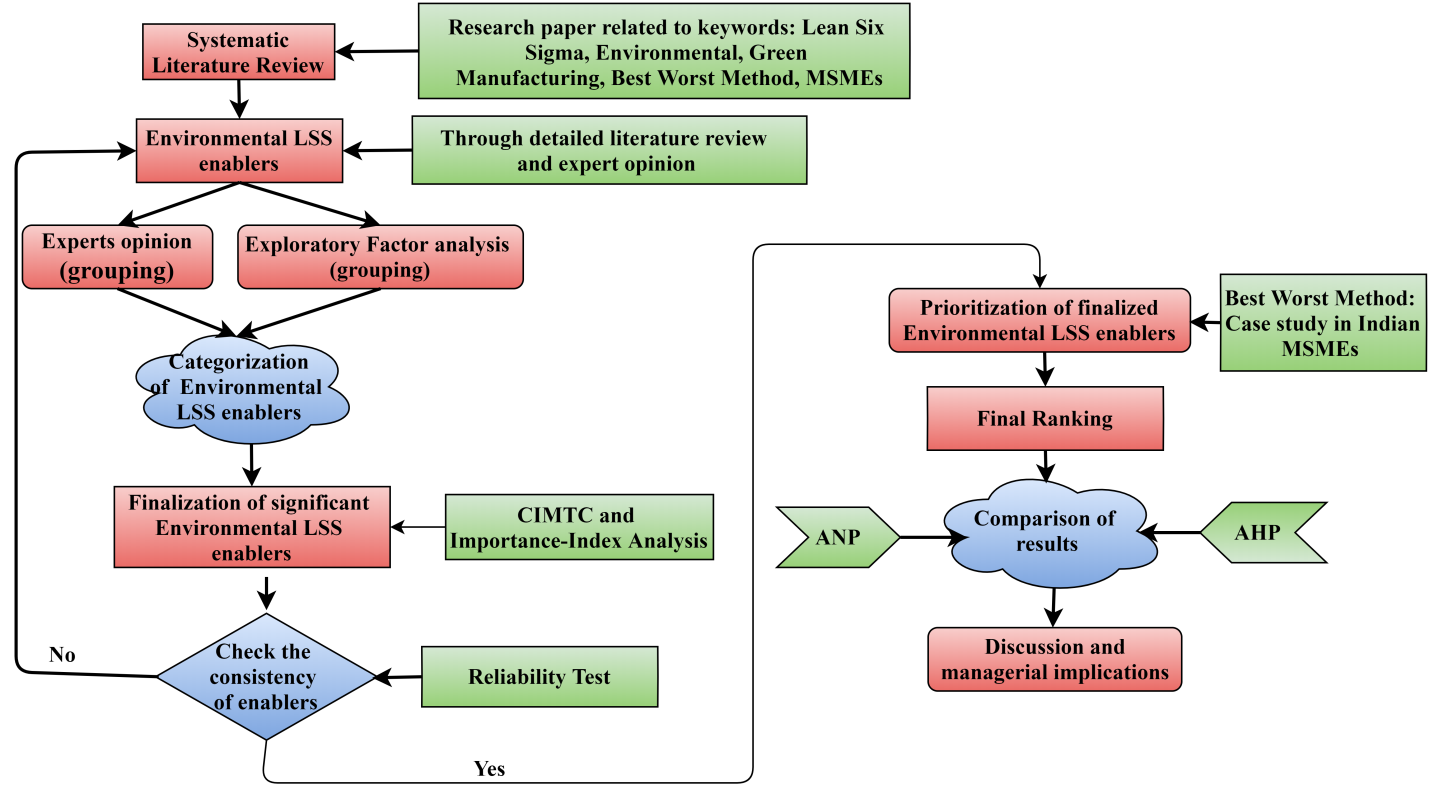
*2.6 Research Gaps*

In the past, researchers and practitioners provide some insights about the linkage of LSS with environmental facets for industrial developments (Ruben et al., 2018). The framework and performance measures of environmental LSS have also been proposed by some researchers (Kumar et al., 2015; Siegel et al., 2019). The evolution of environmental LSS has been considered at SMEs (Cherrafi et al., 2016). Still, MSMEs managers are hesitant to introduce environmental LSS concepts within their business due to the non-availability of critical enablers that may lead to success (Thanki and Thakkar, 2018). Even several efforts have been made in the past to identify and prioritize enablers of Lean, Six Sigma, and environmental aspects individually. Moreover, the mutual relationship has also been developed among enablers (Yadav and Desai, 2017b; Raval et al., 2018). Still, no evidence has been reported for identification and prioritization of environmental LSS enablers in MSMEs and practical case to strengthen the finding also missing. As per the author’s knowledge, no study has been reported which reveals the adoption of BWM for the assessment of environmental LSS enablers. These gaps in the literature provide an impetus to conduct the present research work.

**3. Environmental Lean Six Sigma Enablers**

*3.1 Research Design*

The research design adopted in the current study is organized and accessible in Figure 1. Initially, the research papers are collected from the reputed databases such as Elsevier, Springer, Science Direct, Taylor & Francis, Emerald, Sage, etc. Through the detailed literature review and visiting MSMEs, a list of enablers is framed, which influences the environmental LSS implementation in MSMEs. For the categorization of listed environmental LSS enablers, expert’s opinion and Exploratory Factor Analysis are adopted. The classified enablers are further analyzed through statistical tools like Importance-index analysis and CIMTC method. The consistency of finalized enablers is computed through Cronbach’s alpha approach using the Statistical Package for Social Sciences (SPSS) software. The validated environmental LSS enablers are prioritized using the BWM approach with the help of a practical case. To get accuracy in results, comparisons are made with AHP and ANP methods. The discussion is explored with practical and managerial implications along with concluded remarks.

****

**Figure 1: Research design of case study**

*3.2 Extraction of* environmental *LSS enablers*

Thirty environmental LSS enablers are extracted through the detailed literature review and industrial visit. Each enabler is having individual characteristics and implementation areas in the organization for successful environmental LSS execution. Hence, the enablers are categorized as per their appropriate traits through fundamentally as well as statistically. For fundamental categorization, the experts are selected from an industrial and academic background. The detailed description of experts is provided in Table 2. Through the expert’s input, the extracted enablers are grouped into five categories as environmental-based enablers (ELSSE), strategy based enablers (SLSSE), culture-based enablers (CLSSE), resources based enablers (RLSSE) and linkage based enablers (LLSSE) as shown in Table 3.

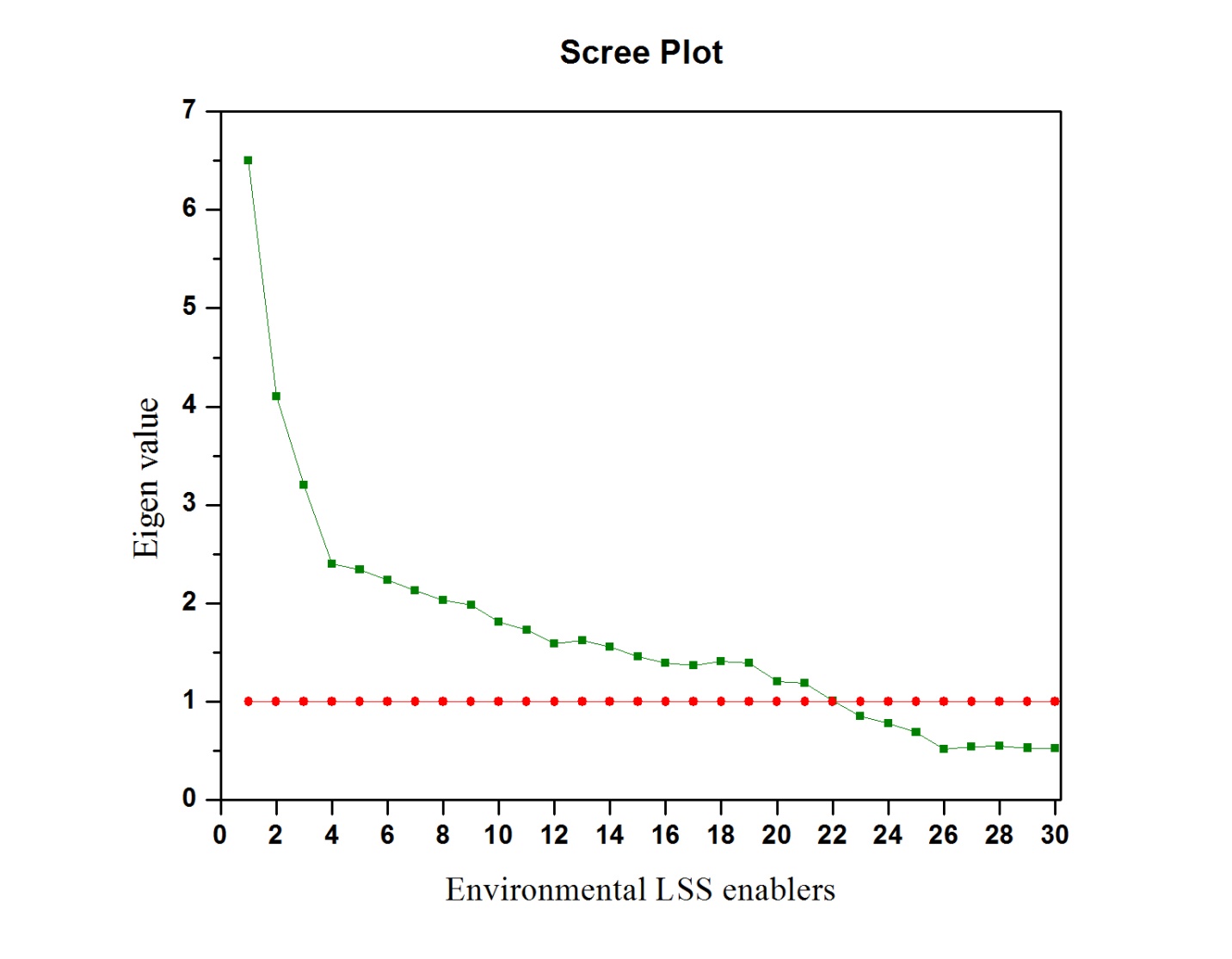
**Table 2: Detailed information of experts**

|  |  |  |  |
| --- | --- | --- | --- |
| **Experts** | **Academic/Industry/Consultant** | **Current Position** | **Professional Experience** |
| Expert 1 | Industry | Director of the Manufacturing Company | 20 Years |
| Expert 2 | Industry | General Manager | 17 Years |
| Expert 3 | Industry | Plant Head | 10 Years |
| Expert 4 | Industry | Production Manager | 12 Years |
| Expert 5 | Industry | Industrial Engineer | 10 Years |
| Expert 6 | Academic | Professor and Six Sigma Black Belt | 33 Years |
| Expert 7 | Academic | Associate Professor | 19 Years |
| Expert 8 | Academic | Assistant Professor and LSS Researcher | 8 years |
| Expert 9 | Academic | Research Scholar | 4 Years |

The enablers are categorized statistically through Exploratory Factor Analysis (EFA). Factor analysis is a data reduction technique which reduces the number of factors into significant numbers for modeling purpose (Hair et al., 2010). It is used to determine the minimum number of factors that represent the covariation among all elements. The factors with a variance greater than 1 are extracted for the analysis (Eigenvalue >1). The loading of 30 enablers in suitable factors is achieved using EFA with a sample size of 300 (n=300). In this analysis, the Kaiser-Meyer-Olkin (KMO) and Bartlett test of sphericity are estimated using Principal Component Analysis (PCA) with Varimax rotation (de Freitas et al., 2017). The Varimax rotation reduces the number of variables to strengthen the interpretability during loading on orthogonal factors (Rehman et al., 2016). The factor extraction is based on Eigenvalue; it might be more than 1 and the minimum three items should be loaded in individual factor with a factor loading value higher than 0.40 (Jain and Raj, 2016). The Cattell scree plot represents the environmental LSS enablers on X-axis and corresponding Eigenvalue on Y-axis (refer Figure 2). The eigenvalue of environmental LSS enablers is reduced as elbow curvature moves toward the right in the scree plot. The enablers having Eigenvalue more than 1, are selected for further analysis. The outcome of the scree plot reveals that 22 enablers are selected for measuring the performance of environmental LSS.

**Table 3: Grouping of environmental LSS enablers**

|  |  |  |  |
| --- | --- | --- | --- |
| **Main Criteria** | **Sub-criteria** | **Abbreviation** | **Author Support** |
| Environmental-based enablers (ELSSE) | Carbon reduction initiatives | E1 | (Dhingra et al., 2014; Verrier et al., 2016; Baysan et al., 2019; Gupta and Barua, 2016 Gupta, & Barua, 2017; Redmond et al., 2016; Oliveira et al., 2018; Garza-Reyes et al., 2018; Deif 2011; Rathi et al., 2015; Rathi et al., 2015b; Cluzel et al., 2010; Leme et al., 2018; Tanwer et al., 2015; Júnior et al., 2018) |
| Environmental friendly packing of products | E2 |
| Incentive to produce green products | E3 |
| Practices of Green design | E4 |
| Environmental friendly transportation | E5 |
| Green operational practices | E6 |
| Market demands for green products | E7 |
| Strategic based enablers (SLSSE) | Effective project leadership | S1 | (Antony et al., 2017; Yadav and Desai, 2017; Sreedharan et al., 2018; Chiarini, 2014; Yadav et al., 2018; Johansson and Sundin, 2014; Rathi et al., 2015; Arumugam et al., 2012; Jayaraman et al., 2012; Burritt et al., 2019) |
| Rewards and incentives for employee | S2 |
| Top-management commitment, Involvement, and support | S3 |
| Environmental LSS supportive organizational Infrastructure | S4 |
| Performance measurement system | S5 |
| Consistent and accurate data collection | S6 |
| Culture-based enablers (CLSSE) | Selection and retention of employee | C1 | (Alhuraish et al., 2017; Antony et al., 2017; Gnanaraj et al., 2012; Rathi et al., 2017; Chaurasia et al., 2019; Hill et al., 2018; Chugani et al., 2017; Garza-Reyes et al., 2016; Sartal et al., 2018) |
| Teamwork | C2 |
| Effective communication among departments | C3 |
| Sufficient time to solve problems | C4 |
| Employee empowerment | C5 |
| Share project success stories | C6 |
| Organizational culture and ethics | C7 |
| Resources based enablers (RLSSE) | Understanding of Environmental LSS methodology | R1 | (Henriques and Catarino, 2016; Das et al., 2016; Vinodh et al., 2014; Rana and Sharma, 2019; Sreedharan et al., 2019; Sunder and Antony, 2018; Garza-Reyes, 2015; Stankalla et al., 2018; Kamble et al., 2019) |
| Project selection and prioritization | R2 |
| LSS awareness program and training | R3 |
| Financial benefits sharing among employees due to Environmental  LSS | R4 |
| Fund for operational expenditure | R5 |
| Linkage based  enablers (LLSSE) | Supplier relationship management | L1 | (Noori, 2015; Psomas, 2016; Chan et al., 2014; Deif, 2011; Rehman et al., 2016; Bhattacharya et al., 2019; Silva et al., 2019; Stankalla et al., 2019; Vinodh et al., 2016) |
| Customer satisfaction and delight | L2 |
| Understanding customer demand | L3 |
| Linking Environmental LSS to buyer-suppliers | L4 |
| Linking Environmental LSS to core business processes | L5 |

**Figure 2: Scree plot of environmental LSS enablers**

Further, extracted enablers are loaded into five factors, which authenticates the expert’s input as well as the reason for the categorization of enablers into five factors. In Table 4, 1,2,3,4, and 5 represent the main categorized enablers as ELSSE, SLSSE, CLSSE, RLSSE, and LLSSE respectively.

**Table 4: Grouping of environmental LSS enablers using EFA**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Rotated Component Matrixa** | | | | |
|  | **Component** | | | | |
| 1 | 2 | 3 | 4 | 5 |
| E1  E2  E3  E4  E5  E6  E7 | .971  .934  .904  .911  .857  .645  .542 | .987  .857  .942  .947  .579  .651 | .977  .840  .887  .909  .663  .504  .589 | .966  .905  .824  .915  .635 | .941  .876  .913  .877  .943 |
| S1  S2  S3  S4  S5  S6 |
| C1  C2  C3  C4  C5  C6  C7 |
| R1  R2  R3  R4  R5 |
| L1  L2  L3  L4  L5 |

|  |
| --- |
| Extraction Method: Principal Component Analysis.  Rotation Method: Varimax with Kaiser Normalization.a |
| a. Rotation converged in 5 iterations. |

*3.3 Analysis of Extracted Enablers*

To get significant environmental LSS enablers from the extracted ones, CIMTC and Importance-index analysis are employed. CIMTC is the Pearson correlation coefficient between individual items and the total score excluding that item (Eniola and Entebang, 2015). The items having a correlation value less than 0.3, are eliminated before further analysis. Table 5 demonstrates the detailed statistics and CIMTC analysis for environmental LSS enablers. The statistical analysis reveals that CIMTC values of eight environmental LSS enablers (i.e., enabler code E6, E7, S5, S6, C5, C6, C7, and R5) are lower than 0.3 (cut off value); hence these enablers are not considered for further study. The remaining twenty-two environmental LSS enablers contain CIMTC value in the range of 0.5421 to 0.8920, which ensures that selected enablers are important. Also, the finalized enablers achieve a mean value above 3.8545 and a maximum standard deviation of 1.0987, which indicates the importance of environmental LSS enablers in MSMEs. Further, Importance-index analysis is employed to strengthen the expert’s opinion gathered through the questionnaire survey. The numerical scores are consequently altered into the relative Importance-index by using equation 1.

Importance Index () = (1)

Here represents the weight given to *i (i* = 1, 2, 3, 4, 5*)* and represents the frequency of response for *i.*

The importance index range lies within the range from 0 to 1. The importance index is classified into five clusters as shown in equation 2.

(2)

The importance-index analysis of environmental LSS enablers is computed using equation 1, and the outcomes are exhibited in Table 5.

**Table 5: Importance-index analysis, enablers statistics, and CIMTC**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sr. No.** | **Enablers Code** | **Environmental LSS Enablers** | **Mean** | **Standard Deviation** | **Importance Index** | **CIMTC** |
| **Environmental-based enablers (ELSSE)** | | | | | | |
| 1 | E1 | Carbon reduction initiatives | 4.3745 | 0.9841 | 0.897 | 0.8102 |
| 2 | E2 | Environmental friendly packing of products | 3.9074 | 0.7243 | 0.795 | 0.6650 |
| 3 | E3 | Incentive to produce green products | 4.2753 | 1.0120 | 0.805 | 0.7952 |
| 4 | E4 | Practices of Green design | 3.8566 | 0.8915 | 0.687 | 0.7458 |
| 5 | E5 | Environmental friendly transportation | 4.9053 | 1.0072 | 0.907 | 0.8920 |
| 6 | E6 | Green operational practices | 2.9121 | 0.5472 | 0.194 | 0.2738 |
| 7 | E7 | Market demands for green products | 2.8124 | 0.4739 | 0.173 | 0.2943 |
| **Strategic based enablers (SLSSE)** | | | | | | |
| 1 | S1 | Effective project leadership | 4.1013 | 0.9725 | 0.745 | 0.6542 |
| 2 | S2 | Rewards and incentives for employee | 4.2123 | 0.9365 | 0.798 | 0.7102 |
| 3 | S3 | Top-management commitment, Involvement and support | 4.0341 | 0.8754 | 0.699 | 0.7584 |
| 4 | S4 | Environmental LSS supportive organizational Infrastructure | 4.8923 | 0.9214 | 0.892 | 0.7258 |
| 5 | S5 | Performance measurement system | 3.0017 | 0.4578 | 0.172 | 0.2981 |
| 6 | S6 | Consistent and accurate data collection | 2.7842 | 0.5782 | 0.189 | 0.2784 |
| **Culture-based enablers (CLSSE)** | | | | | | |
| 1 | C1 | Selection and retention of employee | 4.2745 | 0.9012 | 0.798 | 0.7254 |
| 2 | C2 | Teamwork | 3.8545 | 1.0214 | 0.657 | 0.5421 |
| 3 | C3 | Effective communication among departments | 4.1589 | 0.9325 | 0.697 | 0.5821 |
| 4 | C4 | Sufficient time to solve problems | 4.3510 | 1.0891 | 0.759 | 0.6248 |
| 5 | C5 | Employee empowerment | 3.0121 | 0.8742 | 0.124 | 0.1981 |
| 6 | C6 | Share project success stories | 2.8794 | 0.4748 | 0.184 | 0.2244 |
| 7 | C7 | Organizational culture and ethics | 2.9578 | 0.3842 | 0.147 | 0.2421 |
| **Resources based enablers (RLSSE)** | | | | | | |
| 1 | R1 | Understanding of Environmental LSS methodology | 4.4755 | 1.0741 | 0.785 | 0.6987 |
| 2 | R2 | Project selection and prioritization | 4.2529 | 0.9421 | 0.824 | 0.7559 |
| 3 | R3 | Environmental LSS awareness program and training | 4.6725 | 0.9129 | 0.764 | 0.8721 |
| 4 | R4 | Financial benefits sharing among employees due to Environmental LSS | 4.1572 | 0.9458 | 0.812 | 0.8102 |
| 5 | R5 | Fund for operational expenditure | 2.9872 | 0.4274 | 0.098 | 0.2824 |
| **Linkage based enablers (LLSSE)** | | | | | | |
| 1 | L1 | Supplier relationship management | 4.0542 | 0.9348 | 0.685 | 0.7452 |
| 2 | L2 | Customer satisfaction and delight | 4.0892 | 1.0254 | 0.773 | 0.6298 |
| 3 | L3 | Understanding customer demand | 4.2101 | 0.9548 | 0.649 | 0.7648 |
| 4 | L4 | Linking Environmental LSS to buyer-suppliers | 4.1924 | 1.0987 | 0.625 | 0.7235 |
| 5 | L5 | Linking Environmental LSS to core business processes | 4.0122 | 0.9654 | 0.694 | 0.6928 |

These outcomes are compared with cut off values as mentioned in equation 2 and finally concluded that out of thirty enablers, twenty-two environmental LSS enablers are found significant and selected for further study (refer to Table 6).

**Table 6: Finalized environmental LSS enablers in Indian MSMEs**

|  |  |  |
| --- | --- | --- |
| **Main Criteria** | **Sub-criteria** | **Abbreviation** |
| Environmental-based enablers (ELSSE) | Carbon reduction initiatives | E1 |
|  | Environmental friendly packing of products | E2 |
|  | Incentive to produce green products | E3 |
|  | Practices of Green design | E4 |
|  | Environmental friendly transportation | E5 |
| Strategy based enablers (ELSSE) | Effective project leadership | S1 |
|  | Rewards and incentives for employee | S2 |
|  | Top-management commitment, Involvement, and support | S3 |
|  | Environmental LSS supportive organizational  Infrastructure | S4 |
| Culture-based enablers (CLSSE) | Selection and retention of employee | C1 |
|  | Teamwork | C2 |
|  | Effective communication among departments | C3 |
|  | Sufficient time to solve problems | C4 |
| Resources based enablers (RLSSE) | Understanding of Environmental LSS methodology | R1 |
|  | Project selection and prioritization | R2 |
|  | Environmental LSS awareness program and training | R3 |
|  | Financial benefits sharing among employees due to Environmental LSS | R4 |
| Linkage based enablers (LSSLE) | Supplier relationship management | L1 |
|  | Customer satisfaction and delight | L2 |
|  | Understanding customer demand | L3 |
|  | Linking Environmental LSS to buyer-suppliers | L4 |
|  | Linking Environmental LSS to core business processes | L5 |

*3.4 Reliability Assessment of Finalized Enablers*

It becomes necessary to validate the sorted data before its further use; otherwise, results may be false (De Pelsmacker and Janssens, 2007). The reliability test is conducted to check the authentication of finalized enablers in SPSS software. In this test, Alpha is a significant parameter used for the assessment of considerable state in statistical and medical sciences (Streiner, 2003). It was developed by Lee Cronbach in 1951 which exhibits the internal consistency among items, and its value lies between 0 to 1 (Cortina, 1993). For better internal consistency, homogeneity, and length of the test, the value of alpha was recommended from 0.70 to 0.90 (Tavakol and Dennick, 2011). In the present case, the value of Cronbach's Alpha is computed as 0.890, which represents good internal consistency among finalized enablers (refer to Table 7).

**Table 7: Reliability Test Result**

|  |  |  |
| --- | --- | --- |
| **Cronbach's Alpha** | **Cronbach's Alpha Based on Standardized Items** | **No. of Items** |
| 0.890 | 0.903 | 22 |

**4. Method Adopted**

*4.1 Best Worst Method*

BWM is an MCDM approach developed by Rezaei to prioritize and select the best and the worst alternative among a set of alternatives (Rezaei, 2015). This method can be used by one decision-maker or a group of decision-makers (Salimi and Rezaei, 2018). It becomes popular due to its salient features, such as the least comparisons matrix data required, high consistency among alternatives, and only integer numbers are required to make a comparison matrix (Rezaei et al., 2015). Consider *n* criteria and make a pairwise comparison matrix *A* as shown in equation 3.

(3)

Here is considered as which represents the relative importance of criteria *i* to *j*. reveals that criteria *i* and *j* are having equal importance. represents that *i* is more significant than *j* and exhibits the extreme importance of *i* to *j*. It is possible to make a comparison among *i* to *j* into two categories, i.e., reference comparison and secondary comparison (Rezaei et al., 2015). The definition of said comparisons is explained as follows:

*Definition 1:* The comparison among is said to be a reference comparison if *i* is the best criteria and/or *j* is the worst criteria and vice-versa.

*Definition 2:* The comparison among is said to be secondary comparison if *i* or *j* is the best or the worst criteria and .

In equation 3, for n criteria, all conceivable comparisons are . It concludes that n comparisons are The rest is *n(n-1),* for half of which , while another half is reciprocal of the first half. From the first *n(n-1)/2* comparisons, (2n-3) are reference comparisons, and rest are secondary comparisons (Rezaei et al., 2016b).

**5. Application of BWM with Practical Case**

The present study is conducted in the Indian MSMEs engaged in the manufacturing of medical equipment. The prime intention of current research is to facilitate the environmental LSS implementation at the selected site through the analysis of vital enablers. BWM approach is adopted for the prioritization of the selected enablers by solving the practical case study. BWM steps used in the present practical case are as follows (Rezaei et al., 2015):

*Step 1: Determine a set of decision enablers*

A set of five main criteria and twenty-two sub-criteria of environmental LSS enablers are finalized statistically and fundamentally by expert’s input of the selected industry (refer Table 6).

*Step 2: Determine the best and worst enabler*

In this step, a brainstorming session is conducted among selected experts from industry and academia background (refer to Table 2). They have selected the most important enabler and the least important enabler among finalized twenty-two enablers.

*Step 3: Determine the preference of best enabler over all other enablers using a scale of 1 to 9.*

The experts provide the preference of best *enabler* over all other *enablers* and the best-to-other vector is shown in equation 4.

(4)

Here represents the preference of bestenabler *B* over the *j* enabler*.* In this case, the comparison matrix of main criteria enablers is shown in Table 8 that represents the preference of best enabler (SLSSE) over all other main enablers.

**Table 8: Best-to-others (BO) and others-to-worst (OW) pairwise comparison of main criteria**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **BO** |  | ELSSE | SLSSE | CLSSE | RLSSE | LLSSE |
| Best criteria: SLSSE |  | 2 | 1 | 4 | 3 | 8 |
| **OW** |  |  |  |  | Worst criteria: LLSSE |  |
| ELSSE |  |  |  |  | 4 |  |
| SLSSE |  |  |  |  | 8 |  |
| CLSSE |  |  |  |  | 2 |  |
| RLSSE |  |  |  |  | 3 |  |
| LLSSE |  |  |  |  | 1 |  |

*Step 4: Determine the preference of all other enablers over the worst enabler using a scale of 1 to 9.*

The top management and plant head suggested the preference of all enablers over the worst enabler and written in the form of a vector, as shown in equation 5.

(5)

Here, indicates the preference of enabler *j* over the worst enabler *W* which represents the value for *=1.* The vector represents the preference of all enablers over the worst enabler is shown in Table 9.

The pairwise comparisons of all sub-criteria of main criteria are formulated by considering the inter-dependency of environmental LSS enablers. The outcomes of best-to-others and other-to-worst sub-criteria are shown in Table 9-13. The pairwise comparisons of sub-criteria for environmental-based enablers are shown in Table 9. The pairwise comparisons of sub-criteria for strategy based enablers are shown in Table 10. The pairwise comparisons of sub-criteria for culture-based enablers are shown in Table 11. The pairwise comparisons of sub-criteria for resources based enablers are shown in Table 12. The pairwise comparisons of sub-criteria for linkage based enablers are shown in Table 13.

**Table 9: Best-to-others (BO) and others-to-worst (OW) pairwise comparisons for environmental-based enablers**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **BO** |  | E1 | E2 | E3 | E4 | E5 |
| Best criteria: E2 |  | 2 | 1 | 5 | 9 | 3 |
| **OW** |  |  |  |  |  | Worst criteria: E4 |
| E1 |  |  |  |  |  | 3 |
| E2 |  |  |  |  |  | 9 |
| E3 |  |  |  |  |  | 2 |
| E4 |  |  |  |  |  | 1 |
| E5 |  |  |  |  |  | 7 |

**Table 10: Best-to-others (BO) and others-to-worst (OW) pairwise comparisons for strategy based enablers**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **BO** |  | S1 | S2 | S3 | S4 |
| Best criteria: S4 |  | 5 | 3 | 2 | 1 |
| **OW** |  |  |  |  | Worst criteria: S1 |
| S1 |  |  |  |  | 1 |
| S2 |  |  |  |  | 2 |
| S3 |  |  |  |  | 3 |
| S4 |  |  |  |  | 5 |

**Table 11: Best-to-others (BO) and others-to-worst (OW) pairwise comparisons for culture-based enablers**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **BO** |  | C1 | C2 | C3 | C4 |
| Best criteria: C2 |  | 8 | 1 | 3 | 2 |
| **OW** |  |  |  |  | Worst criteria: C1 |
| C1 |  |  |  |  | 1 |
| C2 |  |  |  |  | 8 |
| C3 |  |  |  |  | 2 |
| C4 |  |  |  |  | 3 |

**Table 12: Best-to-others (BO) and others-to-worst (OW) pairwise comparisons for resources based enablers**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **BO** |  | R1 | R2 | R3 | R4 |
| Best criteria: R3 |  | 2 | 5 | 1 | 7 |
| **OW** |  |  |  |  | Worst criteria: R4 |
| R1 |  |  |  |  | 5 |
| R2 |  |  |  |  | 2 |
| R3 |  |  |  |  | 7 |
| R4 |  |  |  |  | 1 |

**Table 13: Best-to-others (BO) and others-to-worst (OW) pairwise comparisons for linkage based enablers**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **BO** |  | L1 | L2 | L3 | L4 | L5 |
| Best criteria: L2 |  | 2 | 1 | 4 | 2 | 8 |
| **OW** |  |  |  |  | Worst criteria: L5 |  |
| L1 |  |  |  |  | 4 |  |
| L2 |  |  |  |  | 8 |  |
| L3 |  |  |  |  | 2 |  |
| L4 |  |  |  |  | 4 |  |
| L5 |  |  |  |  | 1 |  |

*Step 5: Calculate the optimal weights*

The sum of optimal weights of all sub-criteria should be 1 which consists of all set of pair and equivalent to andrespectively. To estimate the optimal weights of sub-criteria, the maximum absolute difference of all set of j criteria should be minimized, as shown in equation 6.

Maximum Absolute Difference = (6)

where and are computed using equations 7 and 8, respectively.

(7)

(8)

Equation 6 can be represented in the form of min-max model 1, as shown in equation 9.

Model 1 (9)

where n represents the number of alternatives.

Model 1 can be transformed into the linear programming model, as shown in equation 10.

Model 2 (10)

By solving model 2, the value of optimal weights are estimated at the optimal value of (0.10534) as shown in Table 14. The maximum value of consistency index according to is considered from Table 15. With the help of consistency index and value, the consistency ratio is estimated as 0.04580 using equation 11.

(11)

, indicates that value close to 0 possesses more consistency and close to 1 possess less consistency.

Furthermore, the global weights of all sub-criteria are computed using equation 12 and ranking to sub-criteria is assigned as per their global weights (refer to Table 14)

(12)

**Table 14: Final ranking of environmental LSS enablers**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Main criteria** | **Weight of main criteria** | **Sub-criteria** | **Weight of sub-criteria** | **Global weight** | **Rank** |
| Environmental-based enablers (ELSSE) | 0.2945 | Carbon reduction initiatives (E1) | 0.2095 | 0.0617 | 6 |
| Environmental friendly packing of products (E2) | 0.1361 | 0.0400 | 8 |
| Initiative to produce green products (E3) | 0.4051 | 0.1193 | 3 |
| Practices of Green design (E4) | 0.1430 | 0.0421 | 7 |
| Environmental friendly transportation (E5) | 0.1063 | 0.0313 | 9 |
| Strategy based enablers (ELSSE) | 0.4461 | Effective project leadership (S1) | 0.1623 | 0.0724 | 5 |
| Rewards and incentives for the employee (S2) | 0.1846 | 0.0824 | 4 |
| Top-management commitment, Involvement and support (S3) | 0.2112 | 0.1242 | 2 |
| Environmental LSS supportive organizational  Infrastructure (S4) | 0.4419 | 0.1971 | 1 |
| Culture-based enablers (CLSSE) | 0.0983 | Selection and retention of employee (C1) | 0.2091 | 0.0205 | 18 |
| Teamwork (C2) | 0.3015 | 0.0296 | 12 |
| Effective communication among departments (C3) | 0.2578 | 0.0253 | 15 |
| Sufficient time to solve problems (C4) | 0.2316 | 0.0227 | 16 |
| Resources based enablers (RLSSE) | 0.1063 | Understanding of LSS methodology (R1) | 0.2912 | 0.0309 | 11 |
| Project selection and prioritization (R2) | 0.2592 | 0.0275 | 13 |
| Environmental LSS awareness program and training (R3) | 0.2950 | 0.0312 | 10 |
| Financial benefits sharing among employees due to LSS (R4) | 0.1546 | 0.0264 | 14 |
| Linkage based enablers (LLSSE) | 0.0548 | Linking Environmental LSS to core business processes (L1) | 0.2945 | 0.0161 | 19 |
| Customer satisfaction and delight (L2) | 0.1575 | 0.0086 | 20 |
| Understanding customer Demand (L3) | 0.1025 | 0.0056 | 21 |
| Linking Environmental LSS to buyer-suppliers (L4) | 0.4025 | 0.0220 | 17 |
| Supplier relationship management (L5) | 0.0430 | 0.0023 | 22 |

**Table 15: Consistency Index value (Rezaei, J. 2015a)**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Consistency Index | 0.00 | 0.44 | 1.00 | 1.63 | 2.30 | 3.00 | 3.73 | 4.47 | 5.23 |

To prove the effectiveness and consistency of BWM results, comparisons are made with other MCDM approaches i.e. AHP and ANP. The comparison of results among MCDM approaches provides vigorous and realistic outcomes for the professional and industrial personals (Seth et al., 2018a). The comparison of results is shown in Table 16.

**Table 16: Comparison of BWM, AHP and, ANP**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Main Criteria** | | **BWM weight** | **BWM Rank** | **AHP weight** | **AHP Rank** | **ANP weight** | **ANP Rank** | **BWM Consistency Ratio** | **AHP Consistency Index** | **ANP Consistency Index** |
| ELSSE | 0.2945 | | 2 | 0.2858 | 2 | 0.2093 | 2 | 0.0458 |  |  |
| SLSSE | 0.4461 | | 1 | 0.4412 | 1 | 0.4763 | 1 |  |  |
| CLSSE | 0.0983 | | 4 | 0.0998 | 4 | 0.1349 | 4 | 0.10925 | 0.07253 |
| RLSSE | 0.1063 | | 3 | 0.1394 | 3 | 0.1514 | 3 |  |  |
| LLSSE | 0.0548 | | 5 | 0.0338 | 5 | 0.0281 | 5 |  |  |

**6. Discussion on Findings**

The present research aims to make environmental LSS adaptable so that it can be readily adopted by Indian MSMEs for sustainable development. Initially, thirty environmental LSS enablers are extracted using an extensive literature review and expert’s opinions (refer to Table 3). The extracted enablers are further classified into five main groups, such as ELSSE, SLSSE, CLSSE, RLSSE, and LLSSE through EFA (refer to Table 4). The classification of enablers is based on their nature and area of implementation. The Eigenvalue and factor loading values should be more than 1 and 0.40 respectively, which ensures the validation of classified enablers.

Further, Importance-index analysis and CIMTC methods are adopted to identify highly significant enablers (refer to Table 5). Statistical analysis shows that eight enablers are not having a significant impact on environmental LSS implementation in MSMEs. It happens because of their CIMTC and Importance-Index values lesser than 0.3 and 0.2, respectively. Such enablers are eliminated from the study to improve consistency and reliability in results. Finally, twenty-two enablers are finalized for further prioritization (refer to Table 6). The consistency of finalized enablers is validated through the reliability test which ensures bias-free enablers. In the reliability test, Cronbach's Alpha value is 0.890, which represents that environmental LSS enablers are highly consistent (refer to Table 7). It is essential to know the ranking of finalized environmental LSS enablers based on their importance and effectiveness so that key impacted enablers can be targeted at the utmost priority. Therefore, the BWM approach is applied to prioritize the finalized enablers with a practical case at the selected site. BWM results are compared with AHP and ANP approaches for checking the robustness, consistency, and validation of results.

The BWM results depict that environmental LSS supportive organizational infrastructure (S4) (enabler belongs to main criteria SLSSE) got 1st rank in prioritization with a global weight 0.1971 (refer Table 14). In developing countries, the economic growth of the organization is primarily based on well-structured and extensive infrastructure (Habidin and Yusof, 2012). India has 87th rank in terms of infrastructure among 148 participating countries (Forum, 2018), which highlights the importance of essential infrastructure for enhancing competitiveness in Indian MSMEs.

The next emerged enabler is ‘top-management commitment, involvement, and support (S3)’ which gets 2nd rank with a global weight 0.1242. This enabler expedites the project managers and financial experts to ensure the availability of funds for sustainable development within the organization (de Freitas et al., 2017). Management involvement also plays a significant role in the organization for allocating adequate human, technical, and economic resources to implement a new strategy. Rewards and incentives to employees (S2) enabler boost up the morale of staff towards environmental LSS implementation to produce green products. Also, effective project leadership (S1) motivates the employees to work efficiently for the implementation of environmental LSS in a cooperative manner. The above-mentioned enablers come under the main-criteria SLSSE, which shows strategy based connection among enablers.

Initiative to produce green products (E3) (enabler of main criteria ELSSE) got 3rd rank with the global weight 0.1193. The production of green products will solve multiple environmental issues and develop a sustainable workplace (Kushwaha and Sharma, 2016). Such initiation motivates the employees to work towards the practice of green product design (E4) by integrating the concept of 3Rs (reduce, reuse, and recycling) of the available resources. Besides, carbon reduction initiatives (E1) also contributes to the transition from the customary process to an eco-friendly process (Malek and Desai, 2019). It is essential to focus on the packaging and transportation of products from manufacturing companies to end-users for carbon reduction initiatives (Dieste et al., 2019). For this, the organizations need to more emphasize the usages of eco-friendly and bio-degradable materials for packaging the products (E2) (Rydz et al., 2015). Environmental friendly transport (E5) enabler also addresses the carbon emission issues and achieves economic sustainability. By putting more intention on the enablers as mentioned above, environmental issues of manufacturing units can be addressed.

The enablers ‘environmental LSS awareness program and training (R3)’ (10th rank) and ‘understanding of environmental LSS methodology (R1)’ (11th rank) belongs to the main criteria RLSSE. A well-intended training program will help to pact with change and to enhance the skills of the staff about new technology (Stankalla et al., 2018). A good training program provides staff with the necessary expertise, abilities, and strategies to implement environmental LSS comprehensively. The training develops a culture of understanding environmental LSS and motivation to work vigorously towards its adoption for manufacturing sustainability.

‘Teamwork (C2)’ (Rank 12) and ‘Effective communication among departments (C3)’ (Rank 15) are found significant enablers under main criteria CLSSE. Effective teamwork provides a strong relationship among employees and buildup confidence to adopt a new approach in a business environment (Bailey et al., 2011). For an organization, it is essential to have a favorable culture and efficient communication among different departments for the execution of a sustainable program. Personal resources must be adaptive and fully involved with the evolving culture (Thakur and Mangla, 2019).

The main criteria LLSSE contain the significant enablers i.e. ‘Linking environmental LSS to buyer-suppliers (L4)’ (Rank 17), and ‘Linking environmental LSS to core business processes (L1)’ (Rank 19). Linking the environmental LSS approach to business tactics facilitates the organization for achieving sustainable development through waste reduction, reuse, and recycle of the available resources. The profit and competitiveness of industry should be linked with the features of environmental LSS and buyer-suppliers in the supply chain (Aboutorab et al., 2018). Such integration benefits the environment and society together with the organization in terms of reduced costs, eco-friendly processes, and increased market share.

Finally, the comparison of BWM results is made with AHP and ANP methods to check the robustness of obtained results. All three MCDM approaches provide a nearby, similar ranking to the main-criteria of environmental LSS enablers (refer to Table 16). This shows the robustness of results and depicts that the prioritization of environmental LSS enablers is accurate and consistent. The BWM consistency ratio reveals that it is less than 4% (0.04580) for the prioritization of environmental LSS enablers. Another side, the consistency index in AHP and ANP is found to be 10% (0.10925) and 7% (0.07034) respectively. It signifies that BWM provides more consistent results as compared to AHP and ANP.

*6.1 Managerial and Practical Implication*

In developed countries (U.S.A, European Union), strict policies and regulations promote the effective implementation of environmental LSS to achieve business excellence (Zargun and Al-Ashaab, 2014). But environmental LSS is still in its infancy stage in developing nations (Cherrafi et al., 2016; Ben Ruben et al., 2018). Literature reveals that the majority of Indian companies are not adequately aware of the environmental LSS approach due to deficiency of readiness measures and framework (Rehman et al., 2016; Thanki and Thakkar, 2018). In this perspective, the present research outcomes encourage to Indian MSMEs managers and practitioners to implement environmental LSS effectively by providing required readiness measures. It will be helpful for MSMEs managers to uplift their organization in the context of operational and environmental improvement. For environmental LSS initiation in any organization, key enablers must be required as per their need and priority.

In the Indian context, MSMEs produce products in terms of low and high margins (Seth and Pandey, 2009). Due to the availability of limited resources and resistance to culture change, MSMEs fail to adopt environmental LSS in both cases, i.e., low and high margin products (Khurana et al., 2019). In this context, the present research provides key environmental LSS enablers for MSMEs to achieve manufacturing sustainability. The consideration of such enablers provides the path for successful initiation of the environmental LSS program comprehensively. Environmental LSS supportive organizational infrastructure (S4) emerges as the most dominating enabler with prioritized rank ‘1’. As India possesses 87th rank in organizational infrastructure, S4 enabler provides awareness to engineering managers about the importance of infrastructure for being competitive in the global market. The next dominating enabler is the top-management commitment, involvement and support (S3). The extensive participation and engagement of top management are highly viable for the successful adoption of a new approach (de Freitas et al., 2017). The initiatives to produce green products (E3) emerged as a driver of environmental LSS adoption in MSMEs. The green product manufacturing and carbon reduction initiative provides liberty from air and water pollution and simultaneously saving energy resources (Kushwaha and Sharma, 2016). Moreover, environmental LSS awareness programs and training (R3) improves the skills of the employees and management required for the execution of the program. This enabler enhances the morale and confidence of staff, results they would be ready for change. This will also support plant managers for making sound strategies and tactical decisions relevant to controlling adverse effects on the environment during production.

From a societal perspective, the investigation of environmental LSS enablers will assist decision-makers in building a healthy working environment inside the firms as well as in society. The society would be benefited by reducing pollution levels in terms of minimizing carbon footprints through the successful execution of environmental LSS program in the industry. Through environmental LSS implementation, the industries can quickly develop green products at an optimal cost, further supports excellent living standards with a safer environment. The LSS experts and consultants can achieve cleaner production by resolving environmental issues through the adoption of present research insights.

**7.Conclusions**

The present study provides a path for effective implementation of environmental LSS in MSMEs to achieve the goal of various sustainable initiatives like Make in India, NAPCC-2018, NMP-2025, and Paris pact 2030. Industrial managers and practitioners need to understand the features and driving nature of environmental LSS enablers before its application. In this lieu, the present study explored thirty environmental LSS enablers from the extensive literature review and expert’s inputs. Twenty-two environmental LSS enablers are finalized and categorized by using CIMTC and EFA respectively. Further, BWM approach is adopted for the prioritization of finalized environmental LSS enablers. The BWM applied pragmatically to strengthen the findings and providing significant responses to set research questions in the current study. As per the first research question, the most dominating enablers i.e. environmental LSS supportive organizational infrastructure; top-management commitment and involvement; initiatives to producing green products; rewards and incentives for the employee; effective project leadership; carbon reduction initiatives, and environmental LSS awareness program and training respectively. In the response of the second research question, the BWM results reveal that the main criteria enabler ‘SLSSE’ emerged as the most dominating in nature followed by ‘ELSSE,’ ‘RLSSE,’ ‘CLSSE’ and ‘LLSSE’, respectively. At the initial stage of environmental LSS implementation, MSMEs managers pay more attention to strategy and environmental based enablers to get success. Under environmental regulations and customer requirements, present research can expedite practitioners and consultants to identify appropriate enablers for fluent implementation of the program.

From the perspective of the third research question, the researchers can restructure analogous results for the enablers and variables associated with their problem. The prioritization of enablers will also help managers and practitioners to classify their attention according to enabler’s position and importance to achieve sustainable gains. Besides, society would be benefited by reducing pollution levels in terms of minimizing carbon emission through the successful execution of environmental LSS programs in the industry. Finally, BWM results are compared with AHP and ANP approaches for checking the robustness and consistency of results. The outcome shows that the BWM results are in good agreement with AHP and ANP results (refer to Table 16).

*7.1 Limitation of present research work*

The present research is conducted only in MSMEs and the results may differ in various sectors like healthcare, finances, education, etc. Another major limitation is that the present case study is tested pragmatically within one industry. The current research mainly concerned with the Indian perspective and the results may vary from country to country due to their own culture, diversity, perceptions, government policies, and distinctive needs.

*7.2 Future research scope*

In the future, researchers and practitioners can solve multiple case studies of MSMEs to get more reliable and consistent results. The present concept can also be executed in different sectors like healthcare, financial, education, etc. for the maturity of environmental LSS. The current research can be extended in terms of prioritizing the environmental LSS enablers through Fuzzy BWM, Modified TOPSIS, Fuzzy DEMATEL, etc. Moreover, the inter-relationship model of finalized environmental LSS enablers can be formed using Structural Equation Modeling (SEM).

**Reference**

Aboutorab, H., Saberi, M., Asadabadi, M.R., Hussain, O., Chang, E., 2018. ZBWM: The Z-number extension of Best Worst Method and its application for supplier development. Expert Syst. Appl. 107, 115–125. https://doi.org/10.1016/j.eswa.2018.04.015

Alexander, P., Antony, J., Rodgers, B., 2019. Lean Six Sigma for small- and medium-sized manufacturing enterprises: a systematic review. Int. J. Qual. Reliab. Manag. https://doi.org/10.1108/IJQRM-03-2018-0074

Alhuraish, I., Robledo, C., Kobi, A., 2017. A comparative exploration of lean manufacturing and six sigma in terms of their critical success factors. J. Clean. Prod. 164, 325–337. https://doi.org/10.1016/j.jclepro.2017.06.146

Antony, J., Setijono, D., Dahlgaard, J.J., 2016. Lean Six Sigma and Innovation – an exploratory study among UK organisations. Total Qual. Manag. Bus. Excell. 27, 124–140. https://doi.org/10.1080/14783363.2014.959255

Antony, J., Snee, R., Hoerl, R., 2017. Lean Six Sigma: yesterday, today and tomorrow. Int. J. Qual. Reliab. Manag. 34, 1073–1093. https://doi.org/10.1108/IJQRM-03-2016-0035

Arumugam, V., Antony, J., Douglas, A., 2012. Observation: A Lean tool for improving the effectiveness of Lean Six Sigma. TQM J. 24, 275–287. https://doi.org/10.1108/17542731211226781

Badri Ahmadi, H., Kusi-Sarpong, S., Rezaei, J., 2017. Assessing the social sustainability of supply chains using Best Worst Method. Resour. Conserv. Recycl. 126, 99–106. https://doi.org/10.1016/j.resconrec.2017.07.020

Bailey, A.Y.A., Motwani, J., Smedley, E.M., 2011. When Lean and Six Sigma converge: a case study of a successful implementation of Lean Six Sigma at an aerospace company. Int. J. Technol. Manag. 57, 18. https://doi.org/10.1504/ijtm.2012.043949

Baysan, S., Kabadurmus, O., Cevikcan, E., Satoglu, S.I., Durmusoglu, M.B., 2019. A simulation-based methodology for the analysis of the effect of lean tools on energy efficiency: An application in power distribution industry. J. Clean. Prod. 211, 895–908. https://doi.org/10.1016/j.jclepro.2018.11.217

Belhadi, A., Kamble, S.S., Zkik, K., Cherrafi, A., Touriki, F.E., 2020. The integrated effect of Big Data Analytics, Lean Six Sigma and Green Manufacturing on the environmental performance of manufacturing companies: The case of North Africa. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2019.119903

Belhadi, A., Touriki, F.E., El Fezazi, S., 2018. Lean Implementation in Small and Medium-Sized Enterprises in Less Developed Countries: Some Empirical Evidences From North Africa. J. Small Bus. Manag. 56, 132–153. https://doi.org/10.1111/jsbm.12396

Ben Ruben, R., Vinodh, S., Asokan, P., 2018. ISM and Fuzzy MICMAC application for analysis of Lean Six Sigma barriers with environmental considerations. Int. J. Lean Six Sigma 9, 64–90. https://doi.org/10.1108/IJLSS-11-2016-0071

Ben Ruben, R., Vinodh, S., Asokan, P., 2017. Implementation of Lean Six Sigma framework with environmental considerations in an Indian automotive component manufacturing firm: a case study. Prod. Plan. Control 28, 1193–1211. https://doi.org/10.1080/09537287.2017.1357215

Bhattacharya, A., Nand, A., Castka, P., 2019. Lean-green integration and its impact on sustainability performance: A critical review. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2019.117697

Burritt, R.L., Herzig, C., Schaltegger, S., Viere, T., 2019. Diffusion of environmental management accounting for cleaner production: Evidence from some case studies. J. Clean. Prod. 224, 479–491. https://doi.org/10.1016/j.jclepro.2019.03.227

Cai, W., Lai, K. hung, Liu, C., Wei, F., Ma, M., Jia, S., Jiang, Z., Lv, L., 2019. Promoting sustainability of manufacturing industry through the lean energy-saving and emission-reduction strategy. Sci. Total Environ. 665, 23–32. https://doi.org/10.1016/j.scitotenv.2019.02.069

Caldera, H.T.S., Desha, C., Dawes, L., 2019. Evaluating the enablers and barriers for successful implementation of sustainable business practice in ‘lean’ SMEs. J. Clean. Prod. 218, 575–590. https://doi.org/10.1016/j.jclepro.2019.01.239

Chan, J., Jie, R., Kamaruddin, S., Azid, I.A., 2014. Implementing the Lean Six Sigma Framework in a Small Medium Enterprise ( SME ) – A Case Study in a Printing Company. Proc. 2014 Int. Conf. Ind. Eng. Oper. Manag. 387–396.

Chaurasia, B., Garg, D., Agarwal, A., 2019. Lean Six Sigma approach: A strategy to enhance performance of first through time and scrap reduction in an automotive industry. Int. J. Bus. Excell. 17, 42–57. https://doi.org/10.1504/IJBEX.2019.096903

Chen, Z., Ming, X., Zhou, T., Chang, Y., Sun, Z., 2020. A hybrid framework integrating rough-fuzzy best-worst method to identify and evaluate user activity-oriented service requirement for smart product service system. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2020.119954

Cherrafi, A., Elfezazi, S., Chiarini, A., Mokhlis, A., Benhida, K., 2016. 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, 828–846. https://doi.org/10.1016/j.jclepro.2016.08.101

Chiarini, A., 2014. Sustainable manufacturing-greening processes using specific Lean Production tools: An empirical observation from European motorcycle component manufacturers. J. Clean. Prod. 85, 226–233. https://doi.org/10.1016/j.jclepro.2014.07.080

Chugani, N., Kumar, V., Garza-Reyes, J.A., Rocha-Lona, L., Upadhyay, A., 2017. Investigating the green impact of Lean, Six Sigma and Lean Six Sigma. Int. J. Lean Six Sigma 8, 7–32. https://doi.org/10.1108/ijlss-11-2015-0043

Cluzel, F., Yannou, B., Afonso, D., Leroy, Y., Millet, D., Pareau, D., 2010. Managing the complexity of environmental assessments of complex industrial systems with a lean 6 Sigma approach, in: Proceedings of the 1st International Conference on Complex Systems Design and Management, CSDM 2010. pp. 279–294. https://doi.org/10.1007/978-3-642-15654-0\_20

Cortina, J.M., 1993. What Is Coefficient Alpha? An Examination of Theory and Applications. J. Appl. Psychol. 78, 98–104. https://doi.org/10.1037/0021-9010.78.1.98

Das, S., Bisen, J., Kumar, S., Gupta, H., 2016. Developing a model of critical success factors for TQM implementation in MSMEs in India and their effect on internal and external quality of organisation. Int. J. Bus. Excell. 10, 449. https://doi.org/10.1504/ijbex.2016.10000171

de Freitas, J.G., Costa, H.G., Ferraz, F.T., 2017. Impacts of Lean Six Sigma over organizational sustainability: A survey study. J. Clean. Prod. 156, 262–275. https://doi.org/10.1016/j.jclepro.2017.04.054

De Pelsmacker, P., Janssens, W., 2007. A model for fair trade buying behaviour: The role of perceived quantity and quality of information and of product-specific attitudes. J. Bus. Ethics 75, 361–380. https://doi.org/10.1007/s10551-006-9259-2

Deif, A.M., 2011. A system model for green manufacturing. J. Clean. Prod. 19, 1553–1559. https://doi.org/10.1016/j.jclepro.2011.05.022

Dhingra, R., Kress, R., Upreti, G., 2014. Does lean mean green? J. Clean. Prod. 85, 1–7. https://doi.org/10.1016/j.jclepro.2014.10.032

Dieste, M., Panizzolo, R., Garza-Reyes, J.A., Anosike, A., 2019. The relationship between lean and environmental performance: Practices and measures. J. Clean. Prod. 224, 120–131. https://doi.org/10.1016/j.jclepro.2019.03.243

Eniola, A.A., Entebang, H., 2015. Government Policy and Performance of Small and Medium Business Management. Int. J. Acad. Res. Bus. Soc. Sci. 5. https://doi.org/10.6007/ijarbss/v5-i2/1481

European Commission, 2018. 2050 long-term strategy | Climate Action [WWW Document]. 2050 long-term Strateg.

Fercoq, A., Lamouri, S., Carbone, V., 2016. Lean/Green integration focused on waste reduction techniques. J. Clean. Prod. 137, 567–578. https://doi.org/10.1016/j.jclepro.2016.07.107

Forum, W.E., 2018. The Future of Jobs Report 2018, World Economic Forum. https://doi.org/10.1177/1946756712473437

Gandhi, N.S., Thanki, S.J., Thakkar, J.J., 2018. Ranking of drivers for integrated lean-green manufacturing for Indian manufacturing SMEs. J. Clean. Prod. 171, 675–689. https://doi.org/10.1016/j.jclepro.2017.10.041

Garza-Reyes, J.A., 2015. Lean and green-a systematic review of the state of the art literature. J. Clean. Prod. 102, 18–29. https://doi.org/10.1016/j.jclepro.2015.04.064

Garza-Reyes, J.A., Al-Balushi, M., Antony, J., Kumar, V., 2016. A Lean Six Sigma framework for the reduction of ship loading commercial time in the iron ore pelletising industry. Prod. Plan. Control. https://doi.org/10.1080/09537287.2016.1185188

Garza-Reyes, J.A., Torres Romero, J., Govindan, K., Cherrafi, A., Ramanathan, U., 2018. A PDCA-based approach to Environmental Value Stream Mapping (E-VSM). J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2018.01.121

Gnanaraj, S.M., Devadasan, S.R., Murugesh, R., Sreenivasa, C.G., 2012. Sensitisation of SMEs towards the implementation of Lean Six Sigma-an initialisation in a cylinder frames manufacturing Indian SME. Prod. Plan. Control 23, 599–608. https://doi.org/10.1080/09537287.2011.572091

Gupta, H., Barua, M.K., 2017. Supplier selection among SMEs on the basis of their green innovation ability using BWM and fuzzy TOPSIS. J. Clean. Prod. 152, 242–258. https://doi.org/10.1016/j.jclepro.2017.03.125

Gupta, H., Barua, M.K., 2016. Identifying enablers of technological innovation for Indian MSMEs using best-worst multi criteria decision making method. Technol. Forecast. Soc. Change 107, 69–79. https://doi.org/10.1016/j.techfore.2016.03.028

Gupta, P., Anand, S., Gupta, H., 2017. Developing a roadmap to overcome barriers to energy efficiency in buildings using best worst method. Sustain. Cities Soc. 31, 244–259. https://doi.org/10.1016/j.scs.2017.02.005

Habidin, N.F., Yusof, S.M., 2012. Relationship between lean six sigma, environmental management systems, and organizational performance in the Malaysian automotive industry. Int. J. Automot. Technol. 13, 1119–1125. https://doi.org/10.1007/s12239-012-0114-4

Haeri, S.A.S., Rezaei, J., 2019. A grey-based green supplier selection model for uncertain environments. J. Clean. Prod. 221, 768–784. https://doi.org/10.1016/j.jclepro.2019.02.193

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E., 2010. Multivariate Data Analysis\_sumario. Analysis 816. https://doi.org/10.1016/j.ijpharm.2011.02.019

Henriques, J., Catarino, J., 2016. Motivating towards energy efficiency in small and medium enterprises. J. Clean. Prod. 139, 42–50. https://doi.org/10.1016/j.jclepro.2016.08.026

Hill, J., Thomas, A.J., Mason-Jones, R.K., El-Kateb, S., 2018. The implementation of a Lean Six Sigma framework to enhance operational performance in an MRO facility. Prod. Manuf. Res. 6, 26–48. https://doi.org/10.1080/21693277.2017.1417179

International Energy Agency, 2018. Global Energy & CO2 Status Report, Global Energy & CO2 Status Report.

Jain, V., Raj, T., 2016. Modeling and analysis of FMS performance variables by ISM, SEM and GTMA approach. Int. J. Prod. Econ. 171, 84–96. https://doi.org/10.1016/j.ijpe.2015.10.024

Jayaraman, K., Kee, T.L., Soh, K.L., 2012. The perceptions and perspectives of Lean Six Sigma (LSS) practitioners : An empirical study in Malaysia. TQM J. https://doi.org/10.1108/17542731211261584

Johansson, G., Sundin, E., 2014. Lean and green product development: Two sides of the same coin? J. Clean. Prod. 85, 104–121. https://doi.org/10.1016/j.jclepro.2014.04.005

Kamble, S., Gunasekaran, A., Dhone, N.C., 2019. Industry 4.0 and lean manufacturing practices for sustainable organisational performance in Indian manufacturing companies. Int. J. Prod. Res. https://doi.org/10.1080/00207543.2019.1630772

Kaswan, M.S., Rathi, R., 2019. Analysis and modeling the enablers of Green Lean Six Sigma implementation using Interpretive Structural Modeling. J. Clean. Prod. 231, 1182–1191. https://doi.org/10.1016/j.jclepro.2019.05.253

Khaba, S., Bhar, C., 2018. Analysing the barriers of lean in Indian coal mining industry using integrated ISM-MICMAC and SEM. Benchmarking 25, 2145–2168. https://doi.org/10.1108/BIJ-04-2017-0057

Khan, N.Z., Shihab, S.K., Attri, R., Siddiquee, A.N., Khan, Z.A., 2019. Prioritization of lower back pain risk factors among industrial workers using the best–worst method. Int. J. Occup. Saf. Ergon. https://doi.org/10.1080/10803548.2019.1600303

Khurana, S., Haleem, A., Mannan, B., 2019. Determinants for integration of sustainability with innovation for Indian manufacturing enterprises: Empirical evidence in MSMEs. J. Clean. Prod. 229, 374–386. https://doi.org/10.1016/j.jclepro.2019.04.022

Kumar, S., Kumar, N., Haleem, A., 2015. Conceptualisation of Sustainable Green Lean Six Sigma: An empirical analysis. Int. J. Bus. Excell. 8, 210–250. https://doi.org/10.1504/IJBEX.2015.068211

Kushwaha, G.S., Sharma, N.K., 2016. Green initiatives: A step towards sustainable development and firm’s performance in the automobile industry. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2015.07.072

Lande, M., Shrivastava, R.L., Seth, D., 2016. Critical success factors for Lean Six Sigma in SMEs (small and medium enterprises). TQM J. 28, 613–635. https://doi.org/10.1108/TQM-12-2014-0107

Leme, R.D., Nunes, A.O., Message Costa, L.B., Silva, D.A.L., 2018. Creating value with less impact: Lean, green and eco-efficiency in a metalworking industry towards a cleaner production. J. Clean. Prod. 196, 517–534. https://doi.org/10.1016/j.jclepro.2018.06.064

Luthra, S., Mangla, S.K., Yadav, G., 2019. An analysis of causal relationships among challenges impeding redistributed manufacturing in emerging economies. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2019.04.011

Malek, J., Desai, T.N., 2019. Prioritization of sustainable manufacturing barriers using Best Worst Method. J. Clean. Prod. 226, 589–600. https://doi.org/10.1016/j.jclepro.2019.04.056

Ministry of the Environment, 2019. Towards Climate-Smart Day-to-Day Living – Medium-term Climate Change Plan to 2030 [WWW Document]. Minist. Environ.

Nallusamy, S., Nivedha, R., Subash, E., Venkadesh, V., Vignesh, S., Vinoth Kumar, P., 2018. Minimization of rejection rate using lean six sigma tool in medium scale manufacturing industry. Int. J. Mech. Eng. Technol. 9, 1184–1194.

Noori, B., 2015. The critical success factors for successful lean implementation in hospitals. Int. J. Product. Qual. Manag. 15, 108–126. https://doi.org/10.1504/IJPQM.2015.065987

Oliveira, G.A., Tan, K.H., Guedes, B.T., 2018. Lean and green approach: An evaluation tool for new product development focused on small and medium enterprises. Int. J. Prod. Econ. 205, 62–73. https://doi.org/10.1016/j.ijpe.2018.08.026

Omrani, H., Alizadeh, A., Emrouznejad, A., 2018. Finding the optimal combination of power plants alternatives: A multi response Taguchi-neural network using TOPSIS and fuzzy best-worst method. J. Clean. Prod. 203, 210–223. https://doi.org/10.1016/j.jclepro.2018.08.238

Pandey, H., Garg, D., Luthra, S., 2018. Identification and ranking of enablers of green lean Six Sigma implementation using AHP. Int. J. Product. Qual. Manag. 23, 187–217. https://doi.org/10.1504/IJPQM.2018.089156

Psomas, E., 2016. The underlying factorial structure and significance of the Six Sigma difficulties and critical success factors: The Greek case. TQM J. 28, 530–546. https://doi.org/10.1108/TQM-04-2015-0049

Raja Sreedharan, V., Raju, R., Rajkanth, R., Nagaraj, M., 2018. An empirical assessment of Lean Six Sigma Awareness in manufacturing industries: construct development and validation. Total Qual. Manag. Bus. Excell. 29, 686–703. https://doi.org/10.1080/14783363.2016.1230470

Rana, R., Sharma, M., 2019. Dynamic causality testing for EKC hypothesis, pollution haven hypothesis and international trade in India. J. Int. Trade Econ. Dev. 28, 348–364. https://doi.org/10.1080/09638199.2018.1542451

Rathi, R., Khanduja, D., Sharma, S.K., 2017. A fuzzy-MADM based approach for prioritising Six Sigma projects in the Indian auto sector. Int. J. Manag. Sci. Eng. Manag. 12, 133–140. https://doi.org/10.1080/17509653.2016.1154486

Rathi, R., Khanduja, D., Sharma, S.K., 2015a. Synergy of fuzzy AHP and Six Sigma for capacity waste management in Indian automotive industry. Decis. Sci. Lett. 441–452. https://doi.org/10.5267/j.dsl.2015.1.005

Rathi, R., Khanduja, D., Sharma, S.K., 2015b. A fuzzy MADM approach for project selection: a six sigma case study. Decis. Sci. Lett. 255–268. https://doi.org/10.5267/j.dsl.2015.11.002

Rathi, R., Khanduja, D., Sharma, S.K., 2015c. Six Sigma Project Selection Using Fuzzy TOPSIS Decision Making Approach. Manag. Sci. Lett. 5, 447–456. https://doi.org/10.5267/j.msl.2015.3.009

Raval, S.J., Kant, R., Shankar, R., 2018. Lean Six Sigma implementation: modelling the interaction among the enablers. Prod. Plan. Control 29, 1010–1029. https://doi.org/10.1080/09537287.2018.1495773

Redmond, J., Wolfram Cox, J., Curtis, J., Kirk-Brown, A., Walker, B., 2016. Beyond business as usual: how (and why) the habit discontinuity hypothesis can inform SME engagement in environmental sustainability practices. Australas. J. Environ. Manag. 23, 426–442. https://doi.org/10.1080/14486563.2016.1188424

Rehman, M.A., Seth, D., Shrivastava, R.L., 2016. Impact of green manufacturing practices on organisational performance in Indian context: An empirical study. J. Clean. Prod. 137, 427–448. https://doi.org/10.1016/j.jclepro.2016.07.106

Rezaei, J., 2016. Best-worst multi-criteria decision-making method: Some properties and a linear model. Omega (United Kingdom) 64, 126–130. https://doi.org/10.1016/j.omega.2015.12.001

Rezaei, J., 2015. Best-worst multi-criteria decision-making method. Omega (United Kingdom) 53, 49–57. https://doi.org/10.1016/j.omega.2014.11.009

Rezaei, J., Nispeling, T., Sarkis, J., Tavasszy, L., 2016. A supplier selection life cycle approach integrating traditional and environmental criteria using the best worst method. J. Clean. Prod. 135, 577–588. https://doi.org/10.1016/j.jclepro.2016.06.125

Rezaei, J., Wang, J., Tavasszy, L., 2015. Linking supplier development to supplier segmentation using Best Worst Method. Expert Syst. Appl. 42, 9152–9164. https://doi.org/10.1016/j.eswa.2015.07.073

Ruben, R. Ben, Vinodh, S., Asokan, P., 2018. Lean Six Sigma with environmental focus: review and framework. Int. J. Adv. Manuf. Technol. 94, 4023–4037. https://doi.org/10.1007/s00170-017-1148-6

Ruiz-Benitez, R., López, C., Real, J.C., 2017. Environmental benefits of lean, green and resilient supply chain management: The case of the aerospace sector. J. Clean. Prod. 167, 850–862. https://doi.org/10.1016/j.jclepro.2017.07.201

Rydz, J., Sikorska, W., Kyulavska, M., Christova, D., 2015. Polyester-based (bio)degradable polymers as environmentally friendly materials for sustainable development. Int. J. Mol. Sci. https://doi.org/10.3390/ijms16010564

Sagnak, M., Kazancoglu, Y., 2016. Integration of green lean approach with six sigma: an application for flue gas emissions. J. Clean. Prod. 127, 112–118. https://doi.org/10.1016/j.jclepro.2016.04.016

Salimi, N., 2017. Quality assessment of scientific outputs using the BWM. Scientometrics 112, 195–213. https://doi.org/10.1007/s11192-017-2284-3

Salimi, N., Rezaei, J., 2018. Evaluating firms’ R&D performance using best worst method. Eval. Program Plann. 66, 147–155. https://doi.org/10.1016/j.evalprogplan.2017.10.002

Sartal, A., Martinez-Senra, A.I., Cruz-Machado, V., 2018. Are all lean principles equally eco-friendly? A panel data study. J. Clean. Prod. 177, 362–370. https://doi.org/10.1016/j.jclepro.2017.12.190

Seth, D., Nemani, V.K., Pokharel, S., Al Sayed, A.Y., 2018a. Impact of competitive conditions on supplier evaluation: a construction supply chain case study. Prod. Plan. Control 29, 217–235. https://doi.org/10.1080/09537287.2017.1407971

Seth, D., Pandey, M.K., 2009. A multiple-item inventory model for a non-stationary demand. Prod. Plan. Control 20, 242–253. https://doi.org/10.1080/09537280902843607

Seth, D., Rastogi, S., 2019. Application of vendor rationalization strategy for manufacturing cycle time reduction in engineer to order (ETO) environment: A case study. J. Manuf. Technol. Manag. 30, 261–290. https://doi.org/10.1108/JMTM-03-2018-0095

Seth, D., Rehman, M.A.A., Shrivastava, R.L., 2018b. Green manufacturing drivers and their relationships for small and medium(SME) and large industries. J. Clean. Prod. 198, 1381–1405. https://doi.org/10.1016/j.jclepro.2018.07.106

Shashi, Cerchione, R., Centobelli, P., Shabani, A., 2018. Sustainability orientation, supply chain integration, and SMEs performance: a causal analysis. Benchmarking 25, 3679–3701. https://doi.org/10.1108/BIJ-08-2017-0236

Siegel, R., Antony, J., Garza-Reyes, J.A., Cherrafi, A., Lameijer, B., 2019. Integrated green lean approach and sustainability for SMEs: From literature review to a conceptual framework. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2019.118205

Silva, B.B., Mergulhão, R.C., Favoretto, C., Mendes, G.H.S., 2019. Critical success factors of Six Sigma implementations in companies in Brazil. Int. J. Lean Six Sigma 10, 143–160. https://doi.org/10.1108/IJLSS-01-2018-0008

Singh, M., Kumar, P., Rathi, R., 2019. Modelling the barriers of Lean Six Sigma for Indian micro-small medium enterprises: An ISM and MICMAC approach. TQM J. https://doi.org/10.1108/TQM-12-2018-0205

Singh, M., Rathi, R., 2019. A structured review of Lean Six Sigma in various industrial sectors. Int. J. Lean Six Sigma. https://doi.org/10.1108/IJLSS-03-2018-0018

Soti, A., Shankar, R., Kaushal, O.P., 2010. Modeling the enablers of Six Sigma using interpreting structural modeling. J. Model. Manag. 5, 124–141. https://doi.org/10.1108/17465661011060989

Sreedharan, V.R., Gopikumar, G. V., Nair, S., Chakraborty, A., Antony, J., 2018. Assessment of critical failure factors (CFFs) of Lean Six Sigma in real life scenario: Evidence from manufacturing and service industries. Benchmarking 25, 3320–3336. https://doi.org/10.1108/BIJ-10-2017-0281

Sreedharan, V.R., Raju, R., Vijaya, V., Antony, J., 2019. Assessment of Lean Six Sigma Readiness (LESIRE) for manufacturing industries using fuzzy logic. Int. J. Qual. Reliab. Manag. https://doi.org/10.1108/IJQRM-09-2017-0181

Sreedharan V, R., Sunder M, V., 2018. A novel approach to lean six sigma project management: a conceptual framework and empirical application. Prod. Plan. Control 29, 895–907. https://doi.org/10.1080/09537287.2018.1492042

Stankalla, R., Chromjakova, F., Koval, O., 2019. A review of the Six Sigma belt system for manufacturing small and medium-sized enterprises. Qual. Manag. J. https://doi.org/10.1080/10686967.2019.1580119

Stankalla, R., Koval, O., Chromjakova, F., 2018. A review of critical success factors for the successful implementation of Lean Six Sigma and Six Sigma in manufacturing small and medium sized enterprises. Qual. Eng. 30, 453–468. https://doi.org/10.1080/08982112.2018.1448933

Streiner, D.L., 2003. Starting at the beginning: An introduction to coefficient alpha and internal consistency. J. Pers. Assess. 80, 99–103. https://doi.org/10.1207/S15327752JPA8001\_18

Sunder M, V., Antony, J., 2018. A conceptual Lean Six Sigma framework for quality excellence in higher education institutions. Int. J. Qual. Reliab. Manag. 35, 857–874. https://doi.org/10.1108/IJQRM-01-2017-0002

T., R., K.P., S., 2018. Identification and modeling of process barriers. Int. J. Lean Six Sigma. https://doi.org/10.1108/ijlss-09-2016-0044

Tanwer, A.K., Prajapati, D.R., Singh, P.J., 2015. Effect of various factors for achieving environmental performance in manufacturing industry: A review. Int. J. Product. Qual. Manag. https://doi.org/10.1504/IJPQM.2015.065986

Tavakol, M., Dennick, R., 2011. Making sense of Cronbach’s alpha. Int. J. Med. Educ. 2, 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd

Thakur, V., Mangla, S.K., 2019. Change management for sustainability: Evaluating the role of human, operational and technological factors in leading Indian firms in home appliances sector. J. Clean. Prod. 213, 847–862. https://doi.org/10.1016/j.jclepro.2018.12.201

Thanki, S., Govindan, K., Thakkar, J., 2016. An investigation on lean-green implementation practices in Indian SMEs using analytical hierarchy process (AHP) approach. J. Clean. Prod. 135, 284–298. https://doi.org/10.1016/j.jclepro.2016.06.105

Thanki, S.J., Thakkar, J., 2018. Interdependence analysis of lean-green implementation challenges: A case of Indian SMEs. J. Manuf. Technol. Manag. 29, 295–328. https://doi.org/10.1108/JMTM-04-2017-0067

van de Kaa, G., Kamp, L., Rezaei, J., 2017. Selection of biomass thermochemical conversion technology in the Netherlands: A best worst method approach. J. Clean. Prod. 166, 32–39. https://doi.org/10.1016/j.jclepro.2017.07.052

Verrier, B., Rose, B., Caillaud, E., 2016. Lean and Green strategy: The Lean and Green House and maturity deployment model. J. Clean. Prod. 116, 150–156. https://doi.org/10.1016/j.jclepro.2015.12.022

Vinodh, S., Ben Ruben, R., Asokan, P., 2016. Life cycle assessment integrated value stream mapping framework to ensure sustainable manufacturing: A case study. Clean Technol. Environ. Policy 18, 279–295. https://doi.org/10.1007/s10098-015-1016-8

Vinodh, S., Kumar, S.V., Vimal, K.E.K., 2014. Implementing lean sigma in an Indian rotary switches manufacturing organisation. Prod. Plan. Control 25, 288–302. https://doi.org/10.1080/09537287.2012.684726

Wan Ahmad, W.N.K., Rezaei, J., Sadaghiani, S., Tavasszy, L.A., 2017. Evaluation of the external forces affecting the sustainability of oil and gas supply chain using Best Worst Method. J. Clean. Prod. 153, 242–252. https://doi.org/10.1016/j.jclepro.2017.03.166

Yadav, G., Desai, T.N., 2017a. Analyzing Lean Six Sigma enablers: A hybrid ISM-fuzzy MICMAC approach. TQM J. 29, 488–510. https://doi.org/10.1108/TQM-04-2016-0041

Yadav, G., Desai, T.N., 2017b. A fuzzy AHP approach to prioritize the barriers of integrated Lean Six Sigma. Int. J. Qual. Reliab. Manag. 34, 1167–1185. https://doi.org/10.1108/IJQRM-01-2016-0010

Yadav, G., Luthra, S., Huisingh, D., Mangla, S.K., Narkhede, B.E., Liu, Y., 2020. Development of a lean manufacturing framework to enhance its adoption within manufacturing companies in developing economies. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2019.118726

Yadav, G., Seth, D., Desai, T.N., 2018. Prioritising solutions for Lean Six Sigma adoption barriers through fuzzy AHP-modified TOPSIS framework. Int. J. Lean Six Sigma 9, 270–300. https://doi.org/10.1108/IJLSS-06-2016-0023

Yazdi, M., Nedjati, A., Zarei, E., Abbassi, R., 2020. A reliable risk analysis approach using an extension of best-worst method based on democratic-autocratic decision-making style. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2020.120418

Zargun, S., Al-Ashaab, A., 2014. Critical success factors for lean manufacturing: A systematic literature review an international comparison between developing and developed countries, in: Advanced Materials Research. pp. 668–681. https://doi.org/10.4028/www.scientific.net/AMR.845.668

Zhu, Q., Johnson, S., Sarkis, J., 2018. Lean six sigma and environmental sustainability: A hospital perspective. Supply Chain Forum 19, 25–41. https://doi.org/10.1080/16258312.2018.1426339