Journal of Cleaner Production

A new way of environmentally sustainable manufacturing with assessing transformation through the green deployment of Lean Six Sigma projects

--Manuscript Draft--

Manuscript Number:	JCLEPRO-D-21-16500R2
Article Type:	Original article
Keywords:	- Green manufacturing; Lean Six Sigma; Project management; Environmental sustainability; principal component analysis
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Abstract:	Green deployment of Continuous Improvement (CI) projects such as Lean Six Sigma (LSS) is unknown among scholars and practitioners in contrast with green outcomes of LSS. Therefore, the aim of this study is to identify top factors to transform towards the green deployment of LSS projects as an untapped phenomenon for scholars and practitioners. A survey questionnaire was distributed globally to collect the data from LSS practitioners and consultants followed by the Principal Component Analysis (PCA) as a statistical dimension reduction method via Statistical Package for Social sciences (SPSS) software. New dimensions for critical success factors (CSFs), critical failure factors (CFFs) and barriers, and motivators were revealed to recommend top factors for green LSS project deployment. In addition to some factors similar to green LSS integration for green outcomes, we found some new factors suggested for green deployment of LSS projects. However, scarcity was also found in green LSS deployment for practitioners and scholars. Further in-depth studies including case studies could be conducted to assess the negative environmental impact of LSS projects. This study serves as an initial call for managers, consultants and research scholars to favour the sustainable deployment of LSS projects in manufacturing alongside the use of traditional approaches with a focus on costs, quality and delivery. This is the first study exposing the possibility of a paradigm shift in environmental sustainability integration with LSS project deployment in manufacturing operations. Keywords – Green manufacturing, Lean Six Sigma, project management, environmental sustainability, Principal Component Analysis

Highlights

- This study is an initial call for paradigm shift in operational excellence theory
- It promotes a new perspective of sustainability assessment and development
- It initiates precious insights for managers and practitioners acting sustainably
- A new perspective of Green LSS integration theory was introduced to scholars
- This study assists managers to use a cultural framework pursuing sustainability

Alireza Shokri: Conceptualisation, Software, Methodology, Validation, Formal Analysis, Investigation, Data Curation, Writing – Original Draft, Project Administration, Funding Acquisition **Jiju Antony:** Validation, Resources, Writing – Review and Editing, Project Administration **Joe Arturo Garza Reyes:** Validation, Resources, Writing – Review and Editing

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ABSTRACT

Green deployment of Continuous Improvement (CI) projects such as Lean Six Sigma (LSS) is unknown among scholars and practitioners in contrast with green outcomes of LSS. Therefore, the aim of this study is to identify top factors to transform towards the green deployment of LSS projects as an untapped phenomenon for scholars and practitioners. A survey questionnaire was distributed globally to collect the data from LSS practitioners and consultants followed by the Principal Component Analysis (PCA) as a statistical dimension reduction method via Statistical Package for Social sciences (SPSS) software. New dimensions for critical success factors (CSFs), critical failure factors (CFFs) and barriers, and motivators were revealed to recommend top factors for green LSS project deployment. In addition to some factors similar to green LSS integration for green outcomes, we found some new factors suggested for green deployment of LSS projects. However, scarcity was also found in green LSS deployment for practitioners and scholars. Further in-depth studies including case studies could be conducted to assess the negative environmental impact of LSS projects. This study serves as an initial call for managers, consultants and research scholars to favour the sustainable deployment of LSS projects in manufacturing alongside the use of traditional approaches with a focus on costs, quality and delivery. This is the first study exposing the possibility of a paradigm shift in environmental sustainability integration with LSS project deployment in manufacturing operations.

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1. Introduction

The perceived changes of manufacturing efficiency and competitive advantage to a more hybrid model of quality, efficiency and environmental sustainability have brought significant changes to the manufacturing era globally. In these circumstances, addressing a balanced approach to both positive economic and environmental development is a big challenge for manufacturers (Ye *et al*., 2020; Mishra, 2019; Abdul-Rashid *et al*., 2017). Therefore, the integration of environmental sustainability into continuous improvement (CI) methodologies such as Lean Six Sigma (LSS) is becoming a necessity in manufacturing activities (Farrukh *et al*., 2020; Parmar and Desai, 2020; Kaswan, 2019; Erdil *et al*., 2018). LSS is expected to help manufacturers to manage quality and process improvement while meeting environmental regulations (Kaswan et al., 2021; Chugani, *et al*., 2017; Sagnak and Kazancoglu, 2016). Moreover, the necessity of viewing LSS sustainability with maximum benefit and limited effort in a broader context has been previously highlighted as an emerging area (Parmar and Desai, 2020; Mkaimer, *et al*., 2017). However, LSS is usually considered as an outcome-oriented methodology with its positive role for economic sustainability through reducing waste generation in the scenario of green product development (Yazdi et al., 2021; Gaikward and Sunnapwar, 2021; Farrukh *et al*., 2020; De Freitas *et al*., 2017). This is more evident in the event of variation and defect reduction with both economic and environmental positive impact with significant and sometimes unnecessary effort (Yazdi et al., 2021; Gaikward and Sunnapwar, 2021; Ruben *et al*., 2017). As a result, new procedures have been proposed to incorporate environmental variables into existing LSS methodologies and generate integrated green LSS frameworks (Gaikward and Sunnapwar, 2021; Parmar and Desai, 2020; Mishra, 2019; Cherrafi *et al*., 2016). This triggered the green LSS integration with the motivation of green outcomes with less product waste (Farrukh *et al*., 2020; Belhadi *et al*., 2020; Ruben *et al*., 2018).

As part of a broader green LSS integration analysis, Cherrafi *et al*., (2016) stressed the importance of exploring possible conflicting measures as the result of green LSS integration. Nevertheless, the green deployment of actual LSS projects with lower environmental impact in their life cycle has been neglected by scholars and practitioners due to a profound focus on economic and quality-centred objectives of LSS (Gaikward and Sunnapwar, 2021; Farrukh *et al*., 2020; Parmar and Desai, 2020; De Freitas and Costa, 2017). Therefore, identifying the critical factors to transform and embrace the green deployment of LSS projects in the manufacturing remains untapped as a research gap. This research gap has already been highlighted by a recently published systematic literature review (Shokri *et al*., 2021). It highlights a need for manufacturing organisations that embark on LSS to be ready to shift from its currently used narrow, outcome-oriented approach to the use of an environmental and outcome-oriented LSS project deployment. Therefore, the present study contributes to the limited body of knowledge of sustainability integration into LSS by assessing a transformational move towards a new perspective of green LSS. Any transformational assessment needs to study the critical factors for success and failure, alongside organisational readiness (Sreedharan *et al*., 2019). Organisational readiness is defined as a key dimension for any change engagement initiative including LSS before an organisation invests its resources heavily in the initiative (Sreedharan *et al*., 2019; Douglas *et al*., 2017; Antony, 2014). This dimension encompasses motivators and barriers (Sreedharan, *et al*., 2019; Douglas *et al*., 2017). Therefore, this paper aims, through conducting a global empirical study, to identify top critical success factors (CSFs), critical failure factors (CFFs) and readiness factors for the green deployment of LSS projects. The idea of green deployment of LSS projects is a new concept extracted from the definition of green project management as a model designed to think green through the entire lifecycle of projects to merge environmental practices with routine project management methods (Shah and Naghi Ganji, 2019). As part of this assessment, the paper addresses the research question (RQ) "what is the set of top CSFs, CFFs, motivators and barriers for green deployment of LSS projects in a manufacturing setting?"

Accordingly, the objectives of this study are outlined below:

1) *conduct a critical review of the existing knowledge about green manufacturing, green LSS and their success and readiness factors*
2) *develop a conceptual model to inform data analysis*
3) *collect quantifiable data through a survey questionnaire*
4) *identify and recommend top CSFs, CFFs, drivers and barriers for the transformation towards green deployment of LSS projects*

The rest of this paper is organised as follow: Section 2 critically reviews the relevant current literature concerning green LSS integration and its CSFs, CFFs, motivators and barriers to justify the presented gap and generate a conceptual model. Section 3 describes the research methodology and analysis followed as part of the present research. Section 4 presents the survey results and findings, and Section 5 discusses such findings in relation to previous studies to draw robust theoretical and managerial implications. Finally, Section 6 concludes the research and suggests directions for future studies.

2. Conceptualisation and development of the theoretical constructs

The theoretical underpinning of the present research focuses on sustainable manufacturing and LSS as it aims to develop an integrated conceptual model covering these theories to address the RQ. Green manufacturing (GM) is based on sustainable manufacturing systems that integrate product and process design and manufacturing planning & control issues with and environmental considerations to maximise resource efficiency and a positive corporate responsibility image (Gaikward and Sunnapwar, 2021; Aboelmaged, 2018; Seth *et al*., 2018; and Govindan *et al*., 2015). GM is also defined as a philosophy of proactive adoption of more environmentally friendly resources, processes and practices that add value to firms and stakeholders, such as LSS (Ye *et al*., 2020; Abdul-Rashid *et al*., 2017). GM is an emerging area in manufacturing that needs more attention for knowledge and capability development (Seth *et al*., 2018). The integration of environmental management systems with LSS has been suggested to develop measurement system analyses essential for effective GM (Kaswan et al., 2021; Sagnak and Kazancoglu, 2016). Those with green credentials strive to conserve material and energy use during LSS projects (Farrukh *et al*., 2020). This highlights the importance of the integration of green LSS in the manufacturing sector in broader terms that consider the green deployment of LSS projects.

LSS is a leading initiative for maximising production efficiency and maintaining control over each step of the managerial process (George *et al*., 2005). Laureani and Antony (2018) defined LSS as a business improvement methodology that aims to maximise shareholder value by improving quality, speed, customer satisfaction and cost-efficiency. LSS aims to help organisations through business process improvement and adding value by unifying the strength and key features of both Lean and Six Sigma into a single approach (Yazdi et al., 2021; Costa, 2021; Hill *et al*., 2018; Sreedharan *et al*., 2018a). In addition to strategic benefits, LSS aims to clarify the manufacturing process of identifying opportunities for problem-solving, waste reduction, environmental sustainability, learning environment, facilitating innovative minds, as well as reducing variability in processes resulting in defects and improving the quality of manufacturing processes (Costa *et al*., 2021; Gupta *et al*., 2019; Sunder *et al*., 2018; Cherrafi *et al*., 2017; De Freitas *et al*., 2017). The transformation from a customer-centric to a more stakeholder-centric LSS seems to be a challenging and puzzling reality to maximise benefits, including the green deployment of LSS, which requires readiness assessment (Kaswan et al., 2021; Aboelmaged, 2018; Yadav *et al*., 2018). In order to maximise the environmental benefits of LSS, strategic thinking with a more holistic view on organisational improvement needs to be integrated with sustainability tools (Ruben *et al*., 2018; De Freitas *et al*., 2017; Antony *et al*., 2017). Furthermore, the strategic adaptation of a sustainability vision through a holistic evaluation of real data about the positive and negative impact of LSS projects on the environmental dimension of sustainability has been highlighted as a potential future research direction (Belhadi *et al*., 2020; De Freitas *et al*., 2017).

The deployment of LSS has significant inter-dependence with production and project planning and control (Singh et al., 2021b). This tends to be through planning, resource allocation, development and implementation. Green LSS enables LSS projects to be conducted based on healthy and sustainable business practices through environmental performance measurement

(Ruben *et al.*, 2017). Respectively, a paradigm shift into green and resource-efficient LSS deployment in manufacturing settings seems to be apparent, but un-tapped.

Change in the present study is articulated as transforming to a more resource-efficient, green and output-oriented LSS project deployment. Previously, various studies have reviewed LSS CSFs, CFFs alongside readiness in different industrial contexts through motivators and barriers (Sreedharan *et al.*, 2019; Douglas *et al.*, 2017; Shokri *et al.*, 2016). Therefore, it is required to investigate the top success and failure factors and readiness of manufacturers that embarked on LSS through four different constructs (CSFs, CFFs, motivators, barriers) in order to identify whether new sets of capabilities are required for the green deployment of LSS projects (Sreedharan *et al.*, 2019). A list of critical success and failure factors as well as the barriers and motivators of LSS and green LSS integration is presented in table I.

Table I –critical success and failure factors, motivators and barriers of LSS and green LSS

Readiness construct	Relevant factors/variables	References
CSFs	-Transactional leadership, Project management, Financial accountability -Top management commitment, Rewarding, Training, Capital investment Organisational change, resources -Engaging managers and employees, core values, strategic project selection, project manager selection, organisational infrastructure, customer focus, project tracking, supply chain management -Structured multi-attitude decision-making approach, integrated green LSS framework, committed cross-functional project team -Understanding LSS tools and techniques	Rathi et al., (2021); Laureani and Antony (2018) Rathi et al., (2021); Parmar and Desai (2020) Ng and Hempel (2017) Formigoni Carvalho Walter et al., (2021); Sreedharan et al., (2019); Ruben et al., 2018; and Cherrafi et al., (2017) Ben Mabrouk et al., (2021)
CFFs	-Lack of top management commitment, insufficient required training, poor project selection, insufficient resources, lack of knowledge, unavailability of data, and lack of strategic alignment in project selection, lack of resources -Difficulty in cultural change, Project deficiency, inadequate quality maturity deficiency -Lack of environmental knowledge, lack of strategic alignment between green and LSS, complications in implementation -Unwillingness by managers, resistance to change	Swarnakar et al., (2021); Swarnakar et al., (2020); De Freitas and Costa, (2017) Ruben et al., (2018) Marolla et al., (2021); Hudnurkar et al. (2019) Swarnakar et al., (2020) Habidin and Yusof, (2013)
Motivators	-Long term energy strategy, need for energy efficiency and competitiveness, legislative demand, international standards, enthusiasm, green innovation, stakeholder demand, satisfying customer demand, knowledge and publicity -Cost reduction, financial incentives, profit margin protection and changing competitive positions -Collaborative empirical research-based framework	Garza-Reyes et al., (2018); Subramanian and Abdulrahman, (2017) Prasad el al., (2021); Subramanian and Abdulrahman, (2017) Sreedharan et al., (2018)
Barriers	-Inadequate understanding and knowledge, insufficient organisational culture -Inadequate top management and employee's commitment, resistance to change, fear factor, insufficient resources and knowledge, wide-spread organisational cultural change, lack of environmental policy, capital investment, narrow target orientation, poor organisational infrastructure, lack of information and data	Garza Reyes et al., (2018) Sinha and Yadav (2021); Thomas and Khanduja (2021); Farrukh et al., (2020); Sreedharan et al., (2018); De Freitas et al., (2017)

	clarity and availability, insufficient environmental drive and competence, weak legislation, competition and uncertainty -Trade-off between economic and environmental performance indicators	De Freitas et al., 2017

2.1. CSFs of LSS and green LSS

CSFs are the required factors that have to be achieved in order to succeed in accomplishing objectives (Raval et al., 2021; Laureani and Antony, 2018). According to Kuvvetli *et al.* (2016), CSFs and their importance level are not universal due to various factors such as the socio-cultural structure of a country, but they are constant over time. The CSFs adopted in this study include personal and corporate competencies such as knowledge, skills and charisma. These were derived from the existing global literature on LSS and green LSS (Raval, et al., 2021; Alnadi and McLaughlin, 2021; and Abu Bakar *et al.*, 2015).

Any sustainable LSS initiative needs transactional leadership for relentless communication and reinforcement and transformational leadership to convey a sense of urgency for change (Laureani and Antony, 2018). Results from various empirical studies have highlighted top management commitment, rewarding, training, engaging managers and employees in LSS awareness programmes, core values, strategic project selection, right Black Belt (BB) and Green Belt (GB) selection as project managers, organisational infrastructure, customer focus, project tracking, supply chain management and training as top CSFs of any LSS initiative (Raval, et al., 2021; Alnadi and McLaughlin, 2021; Singh et al., 2021b; Sreedharan *et al.*, 2019). However, it was highlighted that a supportive environment for organisational change towards cultural maturity for continuous improvement, employee engagement and empowerment and coaching were recommended as necessary factors before any financial and human investment (Alnadi and McLaughlin, 2021; and Ng and Hempel, 2017). This enhances a better self-awareness amongst employees for more effective training (Jayaraman et al., 2012). The technical perspective of CSFs such as understanding LSS tools and techniques has also been highlighted by some scholars (Ben Mabrouk et al., 2021) that would also be critical for green and resource efficient implementation of LSS.

Nevertheless, a systematic integration of green and LSS to achieve the desired objectives is a complex procedure that needs dedicated top management commitment, cultural change, strategic project selection and financial resources (Rathi et al., 2021; Singh et al., 2021a; Mishra, 2019). A structured multi-attribute decision-making approach aligned with an integrated green LSS framework is essential in LSS project selection (Singh et al., 2021b;

Ruben *et al.*, 2018). Furthermore, Cherrafi *et al*. (2016) highlighted that the negative implications of LSS on the environment still have to be explored with consideration of top management commitment, supply chain management, training and cultural change. Therefore, in a later study, Ruben *et al*. (2017) highlighted that a committed cross-functional project team with sound knowledge of the benefits of green LSS and having reached a certain LSS maturity are required for successful green LSS integration. Interestingly, many of these CSFs are similar to core green manufacturing ideas such as training, top management commitment, resources, infrastructure, and supply chain management (Sangwan *et al*. 2018; Digalwar *et al*., 2017). Whilst management commitment was recommended as the top factor, training and education was highlighted as the most prominent challenging factor for manufacturers for any sustainable LSS implementation including green LSS (Formigoni Carvalho Walter et al., 2021). It is crucial to note that all of these studies about CSFs of green LSS have focused on green LSS outputs, for which a study identifying the CSFs of green deployment of LSS has not been conducted. Therefore, we developed the first RQ to investigate whether there is any new set of factors associated with this integration compared to existing CSFs:

RQ1) What are the CSFs for a green LSS project deployment in a manufacturing setting?

2.2. CFF of LSS and green LSS

CFFs are key elements that can make things go wrong in the implementation of LSS or green LSS. A high rate of LSS project failure with significant impacts is a key limitation for any LSS project (Swarnakar et al., 2021; De Freitas and Costa, 2017). If any LSS project does not meet the potential organisational, financial, technical, human or political benefits and bottom line sufficiently due to the absence or insufficiency of any CSF, it will be classified as a failure (Marolla et al., 2021; Ruben et al., 2018; Albliwi et al., 2014).

Some previous studies have revealed an extensive list of CFFs of LSS (Swarnakar et al., 2021; Swarnakar *et al*., 2020; Sreedharan *et al*., 2018a; Albliwi *et al*., 2014). Lack of top management commitment, resistance to change, inappropriate rewarding, insufficient required training, poor project selection, insufficient resources, lack of knowledge, unavailability of data, and lack of strategic alignment in project selection have been recommended as top CFFs of any LSS project (Marolla et al., 2021; Yazdi et al., 2021; Singh et al., 2021b; Swarnakar *et al*., 2020; De Freitas and Costa, 2017). However, there is no universality in highlighting these CFFs as lack of resources was recommended as a top CFF for developed countries, in contrast to lack of knowledge in developing countries (Albliwi *et al*., 2014). Furthermore, lack of top management commitment and lack of continuous monitoring were identified as key CFFs driving other CFFs (Swarnakar et al., 2021). Notwithstanding, difficulty in cultural change was highlighted as a key CFF concerning LSS integration with other management concepts such as environmental sustainability (Mishra, 2019; Ruben *et al*., 2018). Further study manifests the crucial role of new knowledge and resource development to avoid LSS project deficiency as a top failure (Hudnurkar et al., 2019).

Lack or insufficiency of any critical success factor for green LSS integration will be recognised as a potential for failure (Swarnakar *et al*., 2020; Mishra, 2019; and Ruben, *et al*., 2017). In fact, lack of environmental knowledge with a narrow result and customer-orientation with insufficient established environmental practices, lack of strategic alignment between green and LSS and complications in implementation were recommended as CFFs in green LSS integration (Swarnakar *et al*., 2020; Mishra, 2019; Ruben *et al*., 2018). This led to an unwillingness by managers, BBs or GBs and resistance to change as part of CFF (Habidin and Yusof, 2013). Despite longitudinal studies in CFFs of LSS and green LSS integration, studies identifying the CFFs of green deployment of LSS projects seem to be scarce. Therefore, a second RQ was developed to investigate whether there is any new set of factors associated with this integration compared to the existing CFFs:

RQ2) What are the CFFs for a green LSS project deployment in a manufacturing setting?

2.3. Motivators for LSS and green LSS

The implementation of green deployment of LSS is a new topic to LSS practitioners and scholars (Shokri *et al.*, 2021). Therefore, as part of a readiness assessment, critical motivators need to be identified to enhance the perceived value of green credentials and transform the currently used narrow, outcome-oriented approach of LSS to the environmental and outcome-oriented LSS project deployment. Motivators are prerequisites that provide stimulus to organisations to apply a new approach (Prasad el al., 2021; Kaswan, 2019).

Organisational readiness for green LSS measures is the most prominent motivator for green LSS (Kaswan, 2019). However, this needs further in-depth analysis to identify factors embedded in organisational readiness. Through a longitudinal study, a long list of motivators or drivers for energy efficiency in the manufacturing sector emerged, namely, long term energy strategy, need for energy efficiency and competitiveness, legislative demand, international standards, enthusiasm, green innovation, stakeholder demand, satisfying customer demand, knowledge and publicity (Farrukh, et al., 2021; Garza-Reyes *et al*., 2018; Seth *et al*., 2018; Subramanian and Abdulrahman, 2017; Cagno *et al*., 2015; Govindan *et al*., 2015). Economic drivers such as cost reduction, financial incentives, profit margin protection and changing competitive positions seem to be by far the most critical motivators for both green practices and LSS in the manufacturing sector (Prasad el al., 2021; Farrukh, et al., 2021; Subramanian and Abdulrahman, 2017; Trianni *et al*., 2016; Albliwi *et al*., 2015). Furthermore, Farrukh *et al*., (2020) and Cherrafi *et al*., (2016) highlighted intertwined internal and external drivers that include all of the above measures for the preliminary phase of transformation towards green LSS integration.

A recent study revealed that motivators for green LSS integration vary between developed and developing countries where the former is more regulatory and brand image-oriented in contrast to developing countries with more energy use reduction and customer satisfaction focus (Farrukh et al., 2021). Nevertheless, Sreedharan *et al*. (2018b) and Cherrafi *et al*., (2016) investigated this from a different perspective and recommended a collaborative empirical research-based framework as a motivator for scholars and practitioners to minimise green LSS integration gaps such as Green LSS project deployment. This reflects the scarcity of empirical studies to identify the top motivators for transformation towards green LSS project deployment. Therefore, the third RQ was developed to investigate whether there is any new set of factors associated with this integration compared to existing motivators:

RQ3) What are the motivators for a green LSS project deployment in a manufacturing setting?

2.4.Barriers to LSS and green LSS

Barriers are restrictions or insufficiency of motivators that impede organisational change towards new approaches such as green LSS integration (Orji, 2019; Sreedharan *et al*., 2018b). Barriers identification and their relative importance should be considered as a precautionary measure to reduce future failure of more efficient and effective green LSS integration (Shokri *et al*., 2021; Kaswan et al., 2021; Yadav *et al*., 2018).

Inadequate top management and employee commitment, resistance to change, fear factor, insufficient resources and knowledge, widespread organisational cultural change, lack of environmental policy, capital investment, narrow target orientation, poor organisational infrastructure, lack of information and data clarity and availability, insufficient environmental drive and competence, weak legislation, competition and uncertainty were recommended as top major obstacles for green LSS integration (Marolla et al., 2021; Kaswan et al., 2021; Belhadi *et al*., 2020; Farrukh *et al*., 2020; Orji, 2019; Garza-Reyes et al., 2018; Erdil *et al*., 2018). However, the extent of their minimisation or removal depends on the LSS maturity in manufacturing firms as many of these barriers are in common with initial LSS conceptualisation and hence are easier to handle in the transformation stage (Shokri *et al*., 2016; Albliwi *et al*., 2015). Nevertheless, organisational size was also identified as a key indicator with economic barriers recommended as a top priority for smaller manufacturers, unlike larger organisations with organisational barriers as a priority (Trianni *et al*., 20016; Cogno *et al*., 2015).

De Freitas *et al*., (2017) had a more analytical view and identified a trade-off between economic and environmental performance indicators as a key barrier for green LSS integration. Through a similar study, Cherrafi *et al*., (2016) highlighted a conflict between customer and quality-orientated LSS with environmental credentials as a key barrier to the integration. Cagno *et al*., (2015) did not identify cultural barriers in their study despite considering market, technological and economic barriers for any energy efficiency practice in the manufacturing sector. Furthermore, and through their hierarchical structured modelling, an extensive list of top barriers to green LSS product development was identified (Sinha and Yadav 2021; Kaswan et al., 2021 and Kumar et al., 2016). However, they found inter-dependency among these barriers and recommended lack of top management commitment, fund constraints (Thomas and Khanduja, 2021), supplier unwillingness, inadequate training and unsupportive culture as driving blocks for other barriers such as inadequate knowledge of energy efficiency, insufficient competence, lack of green LSS framework and uncertainty. A causal relationship was found amongst barriers in which environmental-related, management-related and organisational-related barriers got priority to be focused due to their causal interaction with other barriers (Kaswan et al., 2021). Cherrafi *et al*. (2016) stressed the removal of barriers of the green LSS integration as the top management responsibility.

There is a noticeable research scarcity with various studies identifying the barriers of energy efficiency and LSS or green LSS integration without a systematic comprehensive approach to identify solutions (Yadav *et al*., 2018). Therefore, the development of a comprehensive integrated readiness framework to include barriers and drivers of green LSS integration such as Green LSS project deployment has been recommended by previous scholars (Sreedharan *et al*., 2018b; and Cherrafi *et al*., 2016). This highlights the importance of finding the top barriers for transformation towards green LSS project deployment. Therefore, the fourth sub-set of RQ was developed to investigate whether there is any new set of factors associated with this integration compared to existing barriers:

RQ4) What are the barriers to a green LSS project deployment in a manufacturing setting?

The extensive and critical literature review conducted contributed to the development of a conceptual model of the readiness assessment for the green deployment of LSS projects within the manufacturing context (Figure 1). The upper side of the model is derived from energy and the resource-efficient use of tools, infrastructure, machinery and time (Trianni *et al*., 2016; Cogno *et al*., 2015), whilst the bottom side of the model includes four constructs of the readiness assessment (Sreedharan *et al*., 2019).

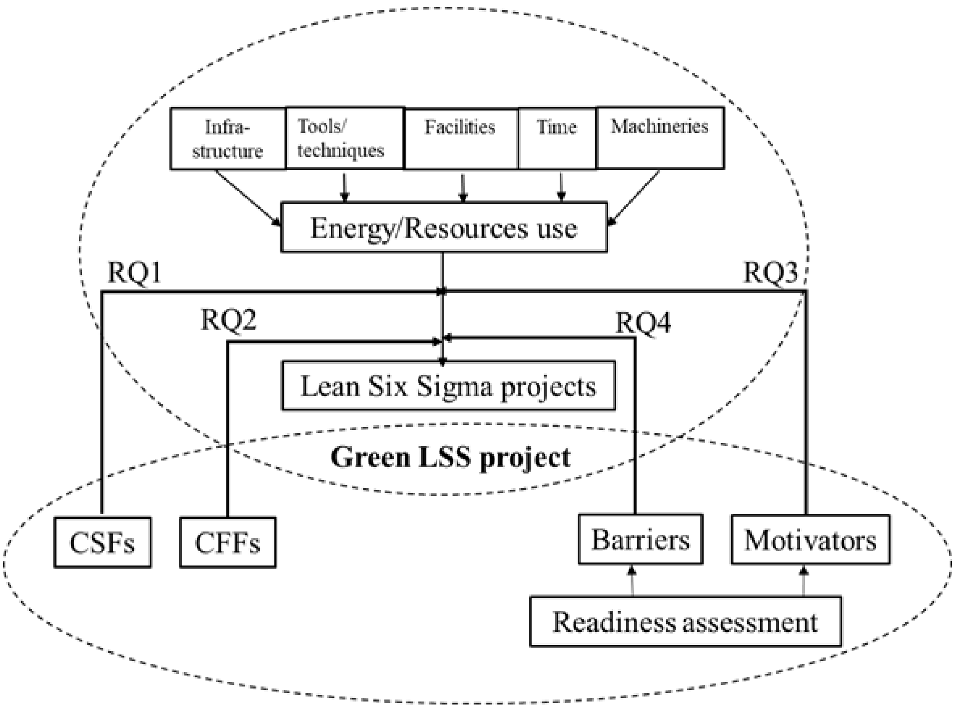

Figure 1 – Conceptual model for a readiness assessment for green LSS project deployment

3.Research methodology

3.1. Research framework and design

Having developed the conceptual model through a critical literature review, top critical factors and different readiness constructs were identified through a cross-sectional survey questionnaire (Appendix A) as part of a global study. This informed the research framework, which was based on a deductive approach focusing on identifying top critical success, failure and readiness factors for the green deployment of LSS projects (Laureani and Antony, 2018). The survey questionnaire was developed as a suitable instrument (Abdul-Rashid *et al*., 2017) to target CI and Operational Excellence experts in various sectors of manufacturing and academics with LSS knowledge/skills and research background around the world through purposive sampling. These experts were identified and approached through our networks such as social media, previous works/research activities, consultancy works and conferences. The descriptive analysis of respondents revealed a random balanced approach to different demographic categories in relation to role, sector, organisational size, LSS belt qualification and LSS experience (table II). The list of established environmental management practices in manufacturers is also presented in this table.

Table II – Demographics of respondents to the survey questionnaire

Role		**Size**	
Academic	8%	Not specified	27%
Consultant	15%	Large (>250)	51%
CI manager	29%	Medium (50-249)	11%
Lean practitioner	2%	Small (10-49)	7%
LSS practitioner	6%	Micro (<10)	5%
Managing director	6%	**LSS experience**	
Operative	3%	Not specified	27%
Other	9%	Never used	23%
Production manager	5%	< 5 years	29%
Quality manager	10%	5-10 years	11%
Supervisor	7%	11-20 years	7%
Sector		>20 years	3%
Consultancy	13%	**Environmental management practice**	
Education/Training	12%	Electricity power use measurement	17%
Manufacturing	55%	ISO14001	23%
Not for profit	1%	None	5%
Others	2%	Product Life Cycle Assessment	8%
Service	13%	Product Recycling	13%
Not specified	3%	Re-Manufacturing	11%
LSS Belt		Re-Using	7%
Not specified	3%	Waste Management	1%
None	23%	Waste Reduction	1%
White Belt	4%	Water Recycling	14%
Yellow Belt	8%		
Green belt	13%		
Black Belt	22%		
Master Black Belt	29%		

The questionnaire consisted of different sections, including general questions about LSS and green manufacturing experience, and questions concerning each of the four constructs, i.e. CSFs, CFFs, motivators and barriers (Sreedharan *et al*., 2019). The questions under each construct emerged from the critical literature review, reviewed carefully and validated by the research team with seven-point scaling representing a range of perceptions from “Not Important” to “Significantly Important”. The seven-point scaling was recommended as the most suitable scaling in terms of validity for exploratory studies and dimension reductions

(Kuvvetli *et al*., 2016; Habidin and Yusof, 2013). The first construct included 28 critical factors for LSS and green LSS, whilst the second construct included 23 failure factors. The third construct consisted of 21 motivators of LSS and green LSS, whilst the fourth construct consisted of 28 barriers.

No dependent variable was assumed in the study and all variables were treated equally with some assumed linear correlation (Kuvvetli *et al*., 2016). The seven-point scaling data collection combined with exploratory Principal Component Analysis (PCA) has been employed in previous similar studies to identify top factors (Laureani and Antony, 2018; Kuvvetli *et al*., 2016; Field, 2013; Habidin and Yusof, 2013; Jayaraman *et al*., 2012). Therefore, PCA was identified as the most suitable analysis technique to understand the data structure and identify fewer dimensions of top factors of green LSS deployment relevant to each construct. After a careful review of the questionnaire by the research team that included academics and LSS practitioners, the questionnaire was piloted with 10 LSS practitioners, CI consultants and academics with LSS knowledge as experts. Having received the comments and recommendations in relation to further clarity of questions and adding or removing some factors, it was enhanced and distributed online.

3.2. Data analysis

The questionnaire was distributed to 450 experts known through personal networks, from which 151 usable responses were received (34% response rate). This was deemed satisfactory, as according to the maximum likelihood estimation, in order for the sample to be effectual the number of respondents should be between10 and 100, and any sample size more than 150 seems to be suitable for PCA (Laureani and Antony, 2018; Habidin and Yusof, 2013). PCA was applied as a suitable data reduction analysis technique for this type of scaling analysis using IBM SPSS 26 software. The internal reliability for all four constructs was acceptable with a Cronbach's α for all constructs and their variables > 0.7 (Laureani and Antony, 2018; Kuvvetli *et al*., 2016; Brkic and Tomic, 2016). Table III presents the Cronbach's α of each construct.

Table III – Internal reliability test

Readiness construct	Cronbach's Alpha Based on Standardised Items	Cronbach's Alpha	No of Items
CSF	0.914	0.914	28
CFF	0.899	0.901	23
Motivators	0.924	0.924	21
Barriers	0.937	0.936	28

The data collection and follow-up distribution took four months. The responses were split into two categories (waves) as early (64 responses in the first two months) and late (87 responses in the second two months). To assess the potential of non-response bias, the study tested the difference of the available variables between early and late respondents (Zu *et al*., 2010) through Leven's Homogeneity of Variance for non-responsive sample test. No statistically significant difference (at a 95% significance level) between early and late responses was found. The same test yielded no statistically significant difference (at 95% significance level) among demographic variables such as role, organisational size, sector, experience, LSS skill/qualification, LSS experience and country of respondents.

The sample validity for the four constructs was tested through Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity as part of Confirmatory Factor Analysis (CFA). The KMO loading for each item within all four constructs was higher than 0.5 with sig < 0.001 of the Barlett's test (Table IV). This indicated that the sample size was valid with a sufficient correlation between items and at the outset, the PCA fitted well for this data set (Kuvvetli *et al*., 2016; Habidin and Yusof, 2013; Jayaraman *et al*., 2012).

The PCA using varimax rotation was performed to look at all variances and form uncorrelated linear combinations of observed variables in each construct (Laureani and Antony, 2018; Jyaraman *et al*., 2012). The varimax rotation method enabled capturing the greatest amount of information based on the least number of factors with the highest loads (Subramanian and Abdulrahman, 2017).

Each formed principal component (PC) was ordered in terms of exploratory power or Eigenvalue to explain the proportion of variance created by each component. The components with Eigenvalue >1 were retained as PC that explained the largest portion of the variance in the original data set. Therefore, the components with Eigenvalue <1 were excluded in order to reduce the chance of multicollinearity. Finally, after the varimax rotation, the loading explained how significantly each PC correlated with original variables and how they were influenced by them. We have excluded any variable with loading less than 0.5 to be part of each PC (Subramanian and Abdulrahman, 2017). However, the interpretation of each PC to label them was a challenging process that needed some brainstorming by the research team. The data set was grouped into four constructs and the variables were analysed individually for each construct.

Table IV – KMO and Bartlett's test of Sphericity for four constructs

CSF	Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.803
	Bartlett's Test of Sphericity	Approx. Chi-Square	2510.987
		df	378
		Sig.	0.000
CFF	Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.708
	Bartlett's Test of Sphericity	Approx. Chi-Square	1936.985
		df	253
		Sig.	0.000
Motivators	Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.852
	Bartlett's Test of Sphericity	Approx. Chi-Square	1791.490
		df	210
		Sig.	0.000
Barriers	Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.855
	Bartlett's Test of Sphericity	Approx. Chi-Square	2316.411
		df	378
		Sig.	0.000

3.2.1. Data analysis for CSF

As a starting point, the correlation structure indicated that there was some level of modest correlations, from which many of them were significant ($sig < 0.001$). This further suggested that there was scope for the reduction of data of the CSFs construct through PCA. The std. deviation among the variables remained almost constant, with very little variance (>0.97 and <1.62) among them, which indicated no requirement for data standardisation. The communality (R^2) of each variable in this construct remained high (>0.6 and <0.85). This reflected the proportion of its variance explained by each PC. The total variance explained by Eigenvalue reported that there were seven retained components in this construct with Eigenvalue >1, which explained 70.5% of the total variance accumulatively. The rotated component matrix was developed (table V) through component score coefficiency to present a new set of PC for this construct. This table contains the coefficients for the linear combination of factors. This means this rotated component matrix implies the link between each rotated principal component with its original contained factors.

Table V- Rotated component matrix for the CSF construct to develop a new set of PCs

New developed and labelled PC	**CSF Variables**	**Component**						
		1	2	3	4	5	6	7
Integrated Environmental Sustainability framework	Collaboration between researchers and practitioners	0.753						
	Alignment of green efficiency	0.700						
	Green technology integration into LSS	0.694						
	Integrated economic and environmental decision making	0.684						
	Leveraging LSS concept with environmental benefits	0.677						
	Green and LSS integration framework	0.643						
	Supply chain management	0.595						
	Resource management	0.524						
Project management	Project tracking		0.813					
	Project planning		0.805					
	Project sustainment		0.804					
	Strategic project selection		0.770					
	Stakeholder engagement		0.760					
	Transactional leadership		0.604					
Human and financial resources	Finance and capital investment			0.740				
	Rewarding			0.738				
	Training			0.601				
Collaborative road map	Collaboration				0.718			
	Methodology				0.620			
	Infra-structure team building				0.538			
Project managers' support	Master Black belt support					0.856		
	Black Belt support					0.828		
Leadership	Transformational leadership						0.803	
	Organisational culture						0.696	
	Cultural change						0.593	

Commitment	Employee engagement							0.780
	Top management commitment							0.775

3.2.2. Data analysis for CFF

Similar to the CSF construct, the correlation structure supported modest correlations, from which many of them were significant (*sig*< *0.001*). This also explained the sufficient scope for data reduction for the CFFs construct through PCA. The std. deviation among variables remained almost constant, with very little variance among them (>1.27 and <1.69) that indicated no requirement for data standardisation. The communality (R^2) of each variable in this construct remained high (>0.63 and <0.85), reflecting the proportion of its variance explained by each PC. The total variance explained by Eigenvalue reported there were seven retained components in this construct with Eigenvalue >1 that explained 72.6% of total variance accumulatively. The rotated component matrix was developed (table VI) through the component score coefficiency to present a new set of PC for this construct.

Table VI- Rotated component matrix for the CFF construct to develop a new set of PCs

New developed and labelled PC	**CFF Variables**	**Component**						
		1	2	3	4	5	6	7
Resistance to change	Middle management resistance	0.844						
	Organisational resistance	0.827						
	Employee resistance	0.723						
	Insufficient dedicated leadership	0.559						
Poor communication	Lack of collaboration		0.768					
	Poor communication		0.716					
	Poor project management		0.647					
	Lack of environmental knowledge		0.562					
Poor project management	Poor project selection			0.868				
	Poor project tracking			0.810				
	Insufficient established environmental practice			0.589				
	Management unwillingness			0.585				
Insufficient support and resources	Insufficient support by Master Black Belts				0.869			
	Insufficient support by Black belts				0.859			
	Insufficient resources				0.588			
Lack of dynamism	Poor team dynamics					0.723		
	Lack of training					0.623		

Lack of integrated green LSS framework	Lack of integrated green and LSS framework						0.781	
	Lack of strategic alignment between green and LSS						0.712	
Complications	Six Sigma narrow result-orientation							0.765
	Excessive customer orientation							0.567

3.2.3. Data analysis for motivators

The correlation structure for this construct also supported modest correlations, from which the vast majority of them were significant (*sig< 0.001*). Sufficient scope for data reduction for the construct of motivators through PCA was again supported. The std. deviation among the variables remained almost constant, with very little variance among them (>1.2 and <1.68), indicating no requirement for data standardisation. The communality (R^2) of each variable in this construct remained high (>0.6 and <0.82). This reflected the proportion of its variance explained by each PC. The total variance explained by Eigenvalue reported that there were five retained components in this construct with Eigenvalue >1 that explained 67% of total variance accumulatively, which was not as high as the other two constructs. The rotated component matrix was developed (table VII) through component score coefficiency to present a new set of PC for this construct.

Table VII- Rotated component matrix for the motivators construct to develop a new set of PCs

New developed and labelled PC	**Motivating variables**	**Component**				
		1	2	3	4	5
Stakeholders' value	Industrial sector initiative	0.708				
	Internal pressure	0.696				
	Asset recovery	0.693				
	International pressure	0.675				
	Stakeholder's pressure	0.644				
	Environmental knowledge	0.538				
	Maximum value for the stakeholders	0.532				
Legal and social demand	Legislative demand		0.714			
	Customer demand		0.712			
	Requirements by ISO14001		0.665			
	Publicity		0.543			
	Risk minimisation		0.543			
Environmental initiatives	Green technology			0.715		
	Life style change			0.680		
	Shift to environmental-centric performance			0.577		
	Reduced environmental and occupational safety expenses			0.563		
Managerial initiatives	Improved productivity				0.779	
	Enthusiasm				0.695	
	Financial incentives				0.519	
Energy efficiency initiatives	Long term energy efficiency objectives					0.782
	Need for energy cost efficiency					0.761

3.2.4. Data analysis for barriers

Similarly, the correlation structure for this construct supported modest correlations, from which the vast majority of them were significant (*sig*< *0.001*). Likewise, sufficient scope for data reduction for the construct of barriers through PCA was supported. The std. deviation among the variables remained almost constant, with very little variance among them (>1.1 and <1.64) that indicated no requirement for data standardisation. The communality (R^2) of each variable in this construct remained high (>0.6 and <0.81), reflecting the proportion of its variance explained by each PC. The total variance explained by Eigenvalue reported that there were seven retained components in this construct with Eigenvalue >1 that explained 68% of total variance accumulatively, which, similar to the construct of motivators, was not as high as the other two constructs. The rotated component matrix was developed (table VIII) through component score coefficiency to present a new set of PC for this construct.

Table VIII- Rotated component matrix for the motivators construct to develop a new set of PCs

New developed and labelled PC	**Barrier variables**	**Component**						
		1	2	3	4	5	6	7
Strategy and innovation deficiency	Fear factor	0.831						
	Challenging cooperation within supply chain	0.634						
	Absence of the sustainability framework	0.581						
	Inadequate research and development	0.528						
	Lack of technology	0.500						
Social and policy deficiency	Misunderstanding of the desired outcome		0.703					
	Weak legislation enforcement		0.669					
	Lack of information clarity		0.538					
	Poor organisational infra-structure		0.527					
	Inadequate knowledge		0.527					
	Inadequate social and environmental drive		0.508					
Knowledge and resource deficiency	Insufficient financial resources			0.763				
	Inadequate resources			0.716				
	Lack of data availability			0.562				
Green initiative deficiency	Lack of internal environmental policy				0.786			
	Difficulty to find environmental impact information				0.682			
	High set-up cost				0.625			
	Inadequate willingness and knowledge amongst suppliers				0.582			
Culture and leadership deficiency	Inadequate top management commitment					0.822		

	Inadequate commitment by staff					0.691		
	Lack of direction					0.562		
LSS obsession and over-burdening	Cost of training						0.636	
	Resistance to change						0.597	
	Narrow target-orientation of LSS projects						0.585	
Market challenges	Competition							0.823
	Uncertainty							0.574

4. Result of data analysis

Having run the PCA for all four constructs, rotated components that represent the new set of top readiness factors for each construct were identified. Through a challenging brainstorming process with consensus and cross-checking, each new PC as a new top factor for the green deployment of LSS projects was labelled.

4.1.RQ1 – The newly labelled set of CSFs for the green deployment of LSS projects from the rotated component matrix (table V) is depicted in Figure 2. It suggests that manufacturers need extensive focus on leadership, commitment at various organisational levels, support from LSS project managers, resources and a collaborative roadmap integrated with an environmental sustainability framework to succeed in the deployment of a green LSS project.

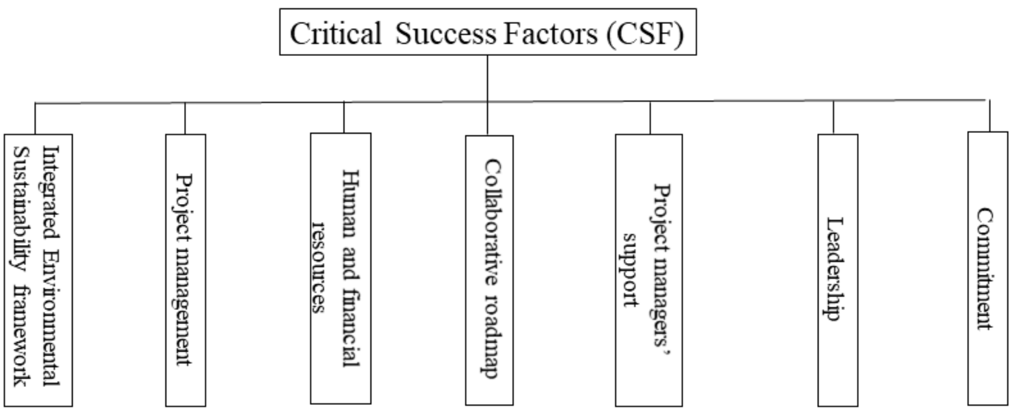

Figure 2 – New set of top CSF for the green deployment of LSS projects

4.2.RQ2 – The newly labelled set of CFFs for the green deployment of LSS projects from the rotated component matrix (table VI) is presented in figure 3. It was revealed that poor communication and project management, resistance to change, insufficient support and resources, lack of integrated green LSS framework and dynamic training, and complications are listed as top CFFs for any green LSS project deployment.

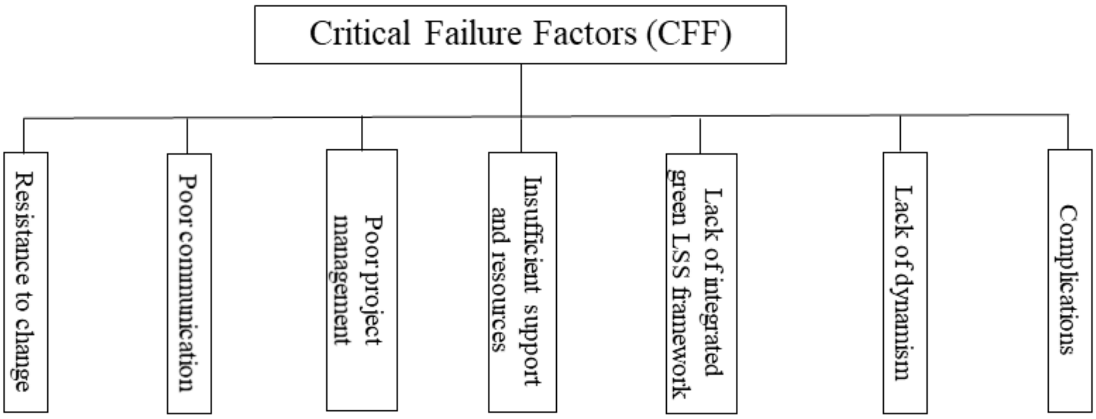

Figure 3 – New set of top CFF for the green deployment of LSS projects

4.3. RQ3 – The newly labelled set of motivators for the green deployment of LSS projects from the rotated component matrix (table VII) is depicted in Figure 4. It was found that energy efficiency objectives such as cost, stakeholder value, and legal and social demand are key motivators. Furthermore, managerial and environmental initiatives are required to drive managers and employees for any transformation towards the effective deployment of green LSS projects.

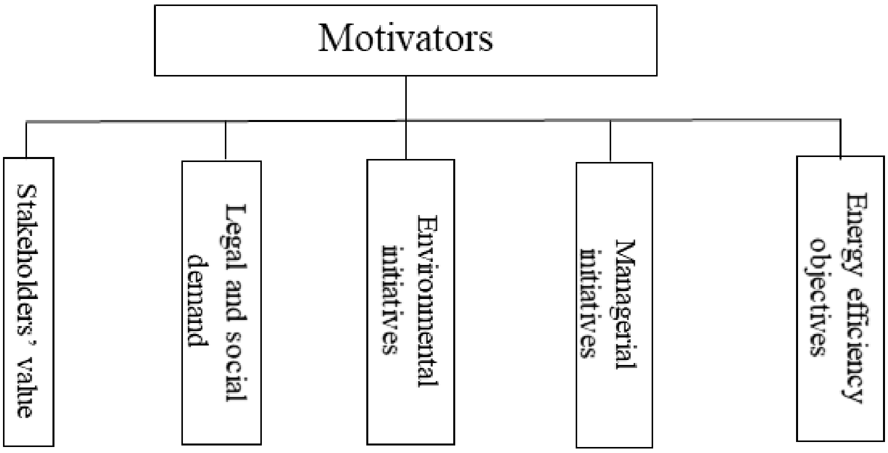

Figure 4 – New set of top motivators for the green deployment of LSS projects

4.4. RQ 4 - Finally, the newly labelled set of barriers for the green deployment of LSS projects from the rotated component matrix (table VIII) is depicted in Figure 5. It was found that market challenges and LSS obsession and over-burdening are key top barriers. Additionally, social and policy deficiency, strategy and innovation deficiency, cultural and leadership deficiency and deficiency in knowledge, resources and green initiatives were identified as further top barriers.

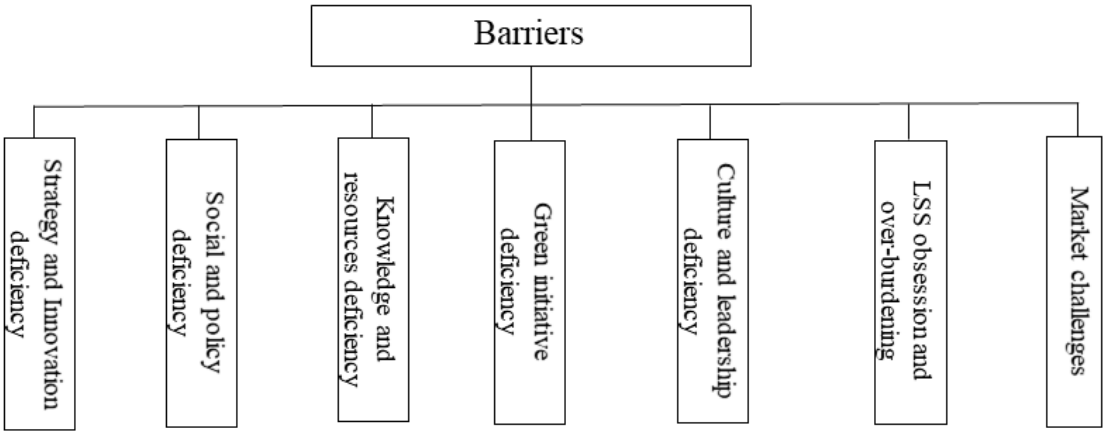

Figure 5 – New set of top barriers for the green deployment of LSS projects

5. Discussion

We intend to present theoretical and literature contribution of our study in this section by presenting our findings against underpinning theories and existing literature in the discipline.

5.1. Theoretical contribution

Our study makes a strong contribution to CI and sustainability theories to triggering the theoretical paradigm shift in relation to environmental sustainability and LSS integration. Our study contributes to the current GM theories and resource-efficient and stakeholder-oriented practices and systems in manufacturing (Gaikward and Sunnapwar, 2021; Ye *et al*., 2020; Aboelmaged, 2018; Sun *et al*., 2018) and green LSS integration (Singh et al., 2021a; Parmar and Desai, 2020; Farrukh *et al*., 2020; and Cherrafi *et al*., 2017).

This study fits well as a cross-bridge between these two research disciplines to tackle the research and managerial gap by looking at the transformation to green LSS project deployment with a resource-efficient life cycle. Moreover, the study is particularly in line with previous studies that highlighted the challenging and puzzling reality of this transformation and the need for a more holistic view on LSS integration with environmental sustainability such as readiness assessment to broaden the maximisation of benefits (Singh et al., 2021a; Aboelmaged, 2018; Yadav *et al*., 2018; and Ruben *et al*., 2018). The presented new set of CSFs, CFFs, motivators of and barriers to deploying green LSS projects somehow highlights the social dimension of sustainability (e.g. stakeholders' value and social and policy deficiency) when considering environmental sustainability. The complications presented as a key failure PC reflects the trade-off between economic and environmental sustainability. These new findings highlight reality behind three-dimensional (3BL) sustainability theory in this integration. However, the focus of this study was only on the environmental dimension of this integration.

5.2. Contribution to the literature

The existing literature suggested the importance and scarcity of exploring transformation from a purely quality outcome-oriented LSS to an environmental and quality outcome-oriented LSS project deployment in manufacturing environments (Shokri et al., 2021; Farrukh et al., 2020; De Freitas et al., 2017; and Cherrafi et al., 2016). This acted as a motivation to assess CSFs, CFFs and organisational readiness factors such as motivators and barriers and identify a new set of reduced dimensions of dynamic capability for this transformation as part of a preliminary study.

Our study is a preliminary study in the discipline. It empirically validates and assesses the new reduced set of CSFs, CFFs and readiness factors for the green deployment of LSS projects. We have developed an effective and efficient list of CSFs, CFFs, barriers to and motivators of transformation to and the implementation of green LSS project deployment. We found these new sets of CSFs and CFFs embedded in social values such as human resources, communication, cultural change and leadership and infrastructure such as environmental framework, project management and financial resources. This reality was almost similar to the previously provided CSFs but from a different angle that was the green deployment of LSS projects (Parmar and Desai, 2020; Swarnakar et al., 2020). Our finding also suggested motivators for the green deployment of LSS projects embedded in social values such as demand and built-in initiatives that were not clearly addressed by previous studies (Subramanian and Abdulrahman, 2017). Moreover, we found that barriers to the green deployment of LSS projects were rooted in strategic, political, social, legal and cultural issues, of which some of them were highlighted by previous studies (Farrukh et al., 2020). The present study makes a strong contribution to existing literature (Yadav *et al.*, 2018; Sreedharan *et al.*, 2018b; and Cherrafi *et al.*, 2016) that highlighted the importance of a systematic integrated readiness assessment framework for any green LSS integration, including green LSS deployment of LSS projects.

6. Conclusions, managerial implications and future studies

This empirical study focused on a research gap highlighting a need for the readiness for change in manufacturers that embark on LSS to shift from the currently used narrow, outcome-oriented approach to a hybrid model of environmental and outcome-oriented LSS project deployment. The aim of the study was to recommend lists of effective CSFs, CFFs and readiness factors systematically for the green deployment of LSS projects in manufacturing organisations. As part of this readiness assessment, the question "what are the CSFs, CFFs, motivators and barriers to green deployment of LSS projects in manufacturing environments?" was addressed.

Through this empirical global study, it is concluded that there is a series of new sets of CSFs, CFFs and readiness factors that are predominantly un-related to be addressed as barriers to and drivers of transformation for the implementation of green LSS projects. The vast majority of these factors identified were similar to other green LSS integration initiatives such as green outcomes. However, scarcity was also found in green LSS deployment for practitioners and scholars.

6.1. Managerial/practical implications

This study will provide precious insight for managers and LSS practitioners and champions to assist them to effectively and efficiently evaluate their organisational capability for transforming to an environmental and outcome-oriented LSS project deployment. In fact, our pioneering study changes the vision of manufacturing managers and LSS practitioners to transform to more sustainable stakeholder-oriented LSS project deployment rather than solely output-oriented projects. It means this study helps senior managers and LSS project managers broaden their view on LSS projects at early stages to identify hidden environmental issues and costs associated with already planned outcomes to promote more sustainable projects. Our finding demonstrates a clear path in the theoretical and practical paradigm shift in the field of Green LSS integration since there is research scarcity in this particular area and a significant knowledge and practical contribution of this study was manifested from its findings. Scholars and managers can exploit insights from this study to reinforce their knowledge base on the readiness assessment of a new perspective of the theory of green LSS integration.

6.2. Limitations and suggested future studies

Despite the high degree of generalisability, validity and credibility of this global empirical study through quantitative analysis, we acknowledge there are some limitations. This empirical study was based on an objective approach to the literature and there is a possibility of common method biasness. Therefore, it is considered that there is a need for future studies with more in-depth and critical analysis of the readiness framework in practice. This includes a further investigation of the feasibility of green LSS project deployment, economic and social sustainability implications, and the vision of managers and LSS practitioners through an interpretive and realistic strand of research such as interviews and case studies. This highlights the limitation with the objectivity of the selected factors from literature and the importance of subjectivity perspective identifying any factors raised by practitioners rather than literature. Another future research opportunity is to conduct a qualitative analysis to capture the understanding and willingness of LSS practitioners and CI consultants towards this paradigm shift in more depth and also understand the inter-relationship between readiness factors in each construct.

Acknowledgement

The authors acknowledge that this research was conducted under British Academy funded project (SRG18R1_180254). They also like to thank Mrs Malahat Faghiri for helping us in data analysis.

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Appendix A

Survey questionnaire

1. <u>General questions:</u>

1.1.What is your current role (please select as many applicable)?
CI manager quality manager Lean practitioner LSS practitioner
Managing director consultant supervisor operative production manager
Academic Other (please, specify…..)

1.2.What is the sector of organisation that you are currently working for?
Manufacturing Education/Training Consultancy Service
Not for profit Other (please, specify….)

1.3.How many years of experience do you have in this sector?
0-5 years 6-10 years 11-15 years 16 – 25 years >25 years

1.4.What is your current LSS belt qualification?
Master Black Belt Black Belt Green Belt Yellow Belt White Belt None

1.5.How many years have you had this qualification for?
< 1year 1-5years 6-10 years 11-15 years > 15 years

If you do not work in the manufacturing sector, please answer questions 4 to 7. If you work in the manufacturing sector, please answer all below questions.

1.6.What type of manufacturing industrial sector you are currently working?
Automotive Aerospace Chemical Packaging Semiconductor
Construction Food/beverages Electronic/technology Other (please, specify)

1.7.What is the size of your organisation?
Micro (<10 people) Small (10-49 people) Medium (50-250 people) Large (>250 people)

1.8.How long the company has been using lean production system or lean manufacturing?
Never used <5 years 5-10 years 11-20 years >20 years

1.9.How long the company has been using Six Sigma?
Never used <5 years 5-10 years 11-20 years >20 years

1.10. Have you been using any green lean/ green LSS practices before?
Yes May be No

1.11. If yes, please specify the type of green lean/LSS practice.

2. What type of environmental management practices or policies your company is currently implementing (please select as many applicable)?
Water recycling Product recycling Re-manufacturing Re-using
ISO14001 Product Life cycle Assessment Electricity power use measurement None
Other (please, specify…..)

3.1. What is the most common type of staff development practice in your organisation?
Residential course training Consultation On the job training (in the workplace)
Written instructions Supervision None
Other (please, specify….)

3.2. Roughly what proportion of your employees has had training about green lean/green Six Sigma concept?
0% <25% 25-50% 51-75% >75%

4. How important are the following ***success factors*** for energy efficient and green implementation of Lean/LSS projects? From 1 (not important) to 7 (significantly important)?

		1	2	3	4	5	6	7
4.1	Transformational and spiritual leadership							
4.2	Transactional and directive leadership							
4.3	Mature organisational culture in LSS and sustainability							
4.4	Cultural change							
4.5	Top management commitment							
4.6	Employee engagement and empowerment							
4.7	Rewarding							
4.8	Cross-departmental training and education							
4.9	Strategic project selection							
4.10	Resource management							
4.11	Effective stakeholders' engagement and analysis							
4.12	Finance and capital investment							
4.13	Internal communication and infra-structure team building							
4.14	Supply chain management and partnership							
4.15	Project selection							
4.16	Project tracking and screening							
4.17	Project sustainment							
4.18	Development of a green and LSS integration framework							
4.19	Black Belt support and dedication							

4.20	Master Black Belt support and dedication							
4.21	Collaboration between departments							
4.22	Effective application of methodology							
4.23	Organisational infrastructure							
4.24	Alignment of energy efficiency with business strategy							
4.25	Green technology integration to LSS							
4.26	Collaboration between researchers and practitioners							
4.27	Leveraging LSS concepts with environmental benefits							
4.28	Integrated economic and environmental decision making							
4.29	Other (please, specify)							

5. How important are the following ***failure factors*** for energy efficient and green implementation of Lean/LSS projects? From 1 (not important) to 7 (significantly important)?

		1	2	3	4	5	6	7
5.1	Lack of environmental knowledge and understanding							
5.2	Narrow result and target-orientation							
5.3	Insufficient dedicated leadership							
5.4	Excessive customer-orientation							
5.5	Insufficient established environmental practices and skills							
5.6	Unwillingness by managers to consider energy efficiency							
5.7	Complications in implementation/practice							
5.8	Insufficient resources							
5.9	Insufficient support by Black Belt							
5.10	Insufficient support by Master Black Belt							
5.11	Poor project management and sustainability							
5.12	Poor project selection							
5.13	Poor project tracking and screening							
5.14	Poor communication and cross-functionality							
5.15	Lack of integrated green and LSS framework							
5.16	Lack of collaboration							
5.17	Middle-level management resistance							
5.18	Employee resistance							
5.19	Organisational resistance							
5.20	Lack of strategic alignment between green and LSS							
5.21	Lack of project champions							
5.22	Poor team dynamics							
5.23	Lack of training							
5.24	Other (please, specify)							

6. How important are these **motivators** of energy efficient and green implementation of Lean/LSS projects from 1 (not important) to 7 (significantly important)?

		1	2	3	4	5	6	7
6.1	Need for energy cost efficiency and competitiveness							
6.2	Long-term energy and eco-efficiency strategy and objectives							
6.3	Life style and societal change and influence							
6.4	Maximise value for stakeholders							
6.5	Legislative demand							
6.6	Customer demand							

6.7	Publicity and reputation							
6.8	Requirement by ISO14001 and ISO50001 standards							
6.9	Stakeholders’ pressure							
6.10	Risk minimisation							
6.11	Shift to environmental-centric performance							
6.12	Internal pressure							
6.13	Industrial sector initiative							
6.14	Financial incentives and bonuses							
6.15	Reduced environmental and occupational safety expenses							
6.16	Environmental knowledge							
6.17	Enthusiasm							
6.18	Improved productivity							
6.19	Asset recovery							
6.20	International pressure							
6.21	Green technology							
6.22	Other (please, specify)							

7. How important these **barriers** are to energy efficient and green implementation of Lean/LSS projects from 1 (not important) to 7 (significantly important)?

		1	2	3	4	5	6	7
7.1	Competition and constant fire-fighting							
7.2	Uncertainty							
7.3	Inadequate top management commitment and support							
7.4	High initial and set-up cost							
7.5	Inadequate commitment and engagement from operational staff							
7.6	Misunderstanding of the desired outcomes							
7.7	Inadequate knowledge and awareness of energy efficiency							
7.8	Insufficient financial resources							
7.9	Lack of information clarity							
7.10	Insufficient competence and expertise							
7.11	Absence of a sustainability framework							
7.12	Inadequate social and environmental drive							
7.13	Narrow target –orientation of LSS projects							
7.14	Inadequate resources							
7.15	Difficulty to find environmental impact information							
7.16	Resistance to change							
7.17	Wide-spread organisational cultural change							
7.18	Weak legislation and enforcement							
7.19	Poor organisational infrastructure							
7.20	Inadequate research and development							
7.21	Lack of data availability							
7.22	Cost of training							
7.23	Lack of internal environmental policy							
7.24	Lack of technology/system							
7.25	Fear factor							
7.26	Challenging cooperation within supply chain							
7.27	Lack of direction							
7.28	Inadequate willingness and knowledge amongst suppliers							
7.29	Other (please, specify)							

Thank you for participating in this survey!