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ANALYZING THE BARRIERS IN IMPLEMENTING LEAN GREEN APPROACH-AN EMPIRICAL INVESTIGATION

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Abstract

The Lean Green approach stands as a beacon in the realm of environmental sustainability and waste reduction within production processes. In a concerted effort to delve into the dynamics of its implementation, a comprehensive study was undertaken within the manufacturing landscape of India. This study sought to elucidate the impediments hindering the seamless integration of the Lean Green paradigm. Employing a rigorous methodology, a widespread questionnaire survey was conducted across numerous companies to meticulously gauge and rank the assorted barriers encountered. The analytical framework of this investigation was structured around a three-tier hierarchy diagram, meticulously designed to accommodate the complexities inherent in the Analytical Hierarchy Process (AHP), a widely acclaimed Multi-Criteria Decision Making (MCDM) technique. Through this systematic approach, insights were gleaned to discern the pivotal barriers that impede the adoption of Lean Green practices. The findings underscored a paramount revelation: the imperative role of employee motivation in driving Lean Green initiatives forward. It emerged as the linchpin, with its absence signifying the most formidable barrier to effective implementation. Within the gamut of barriers delineated through the survey, lack of motivation surfaced as the most salient, exerting a disproportionately significant influence on performance interruptions. Indeed, the barriers identified through this exhaustive survey collectively accounted for a substantial 64.26% of performance interruption, indicative of their profound impact on operational efficacy. Thus, the study not only sheds light on the challenges besetting the Lean Green journey but also underscores the critical importance of addressing motivational factors to surmount these hurdles and propel sustainable manufacturing practices into fruition.

Keywords: *Lean Green Concept, Analytical Hierarchy Process (Multi Criteria Decision Making Technique), and Manufacturing*

1. Introduction

The inception of the Lean Green concept traces back to the 1990s, marking a significant milestone in the realm of sustainable manufacturing practices. This multifaceted approach, elucidated by Handfield et al. (1997), embodies a system-wide, economically driven methodology aimed at the integration of waste elimination throughout the entire lifecycle of material and product manufacture, design, and disposal processes. Central to the Lean Green framework are initiatives such as green production planning and the adoption of advanced production technologies. These facets, integral to modern manufacturing systems, emphasize resource efficiency and reduced energy consumption, thereby contributing to environmental sustainability while enhancing economic viability. Moreover, the implementation of Lean Green strategies effectively addresses safety concerns and mitigates health risks associated with industrial operations, as highlighted by Deif (2011). A cornerstone principle of Lean Green is the relentless pursuit of waste elimination, encompassing both environmental and process-related inefficiencies. By prioritizing continuous improvement initiatives, as expounded by Gadde and Hulthén (2008), Lean Green endeavors to optimize temporal and monetary indicators, thereby fostering a culture of efficiency and sustainability within manufacturing environments. The symbiotic relationship between lean principles and green practices underscores their shared objective of waste minimization and environmental stewardship. Carvalho et al. (2011) underscore the interconnectedness of lean and green methodologies in tackling production waste and curbing the deleterious effects of pollution on the environment, thereby fostering a more sustainable and ecologically balanced industrial landscape. In the context of production management, the integration of diverse paradigms, including lean and green principles, serves to enhance operational efficiency and bolster the overall quality assurance framework. Mazur and Golas (2011) advocate for the synergistic alignment of lean and green practices, positing that such convergence not only optimize production processes but also adds tangible value to the quality management system, thereby fostering a culture of excellence and sustainability. The intricate interplay between lean and green principles is visually depicted in Figure 1, providing a comprehensive illustration of the multifaceted Lean-Green concept and its implications for sustainable manufacturing practices.

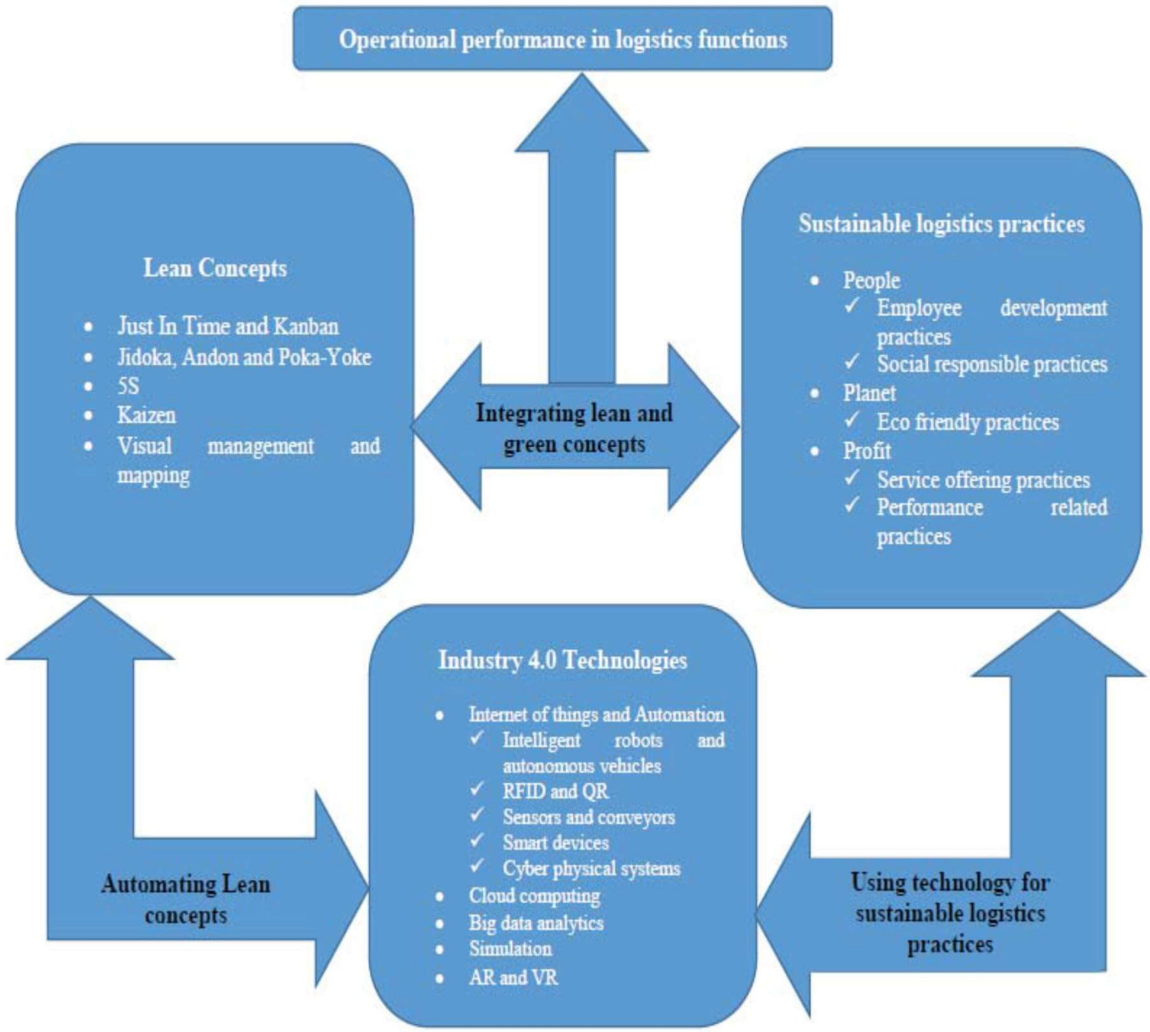

Figure 1: Lean- Green concept in detail

The implementation of a lean green approach plays a pivotal role in mitigating environmental effects and minimizing waste, thereby fostering a paradigm shift towards enhanced productivity. By adhering to the standards of green manufacturing, companies can harness the power of green innovation to not only reduce costs but also gain a competitive edge in the market (Badri et al., 1995). The ethos of the lean green approach extends beyond mere efficiency gains; it encompasses a holistic approach aimed at delivering superior value by elevating product quality and refining services. Moreover, it targets the reduction of both manufacturing and environmental wastes, thereby aligning with sustainable business practices (Shah and Ward, 2003). The multifaceted benefits of the lean green approach are underscored by its positive impact on various performance indicators, including the cost-effectiveness and quality of manufactured products. Through meticulous implementation, it facilitates the generation of tangible value while fortifying the operational prowess of manufacturing entities (Gupta and Jain, 2013). This study delves into the realm of manufacturing companies, meticulously scrutinizing the barriers impeding the seamless integration of the lean green approach. By evaluating the justification behind these barriers and identifying the pivotal obstacles hindering the systematic adoption of this concept, the research seeks to illuminate pathways towards sustained performance enhancement and environmental stewardship.

2. Literature Review

Zhou et al. (2008) posited an intricate framework delineating the six fundamental attributes pivotal to comprehensively assessing the green quotient of any product. These attributes encapsulate the entire lifecycle of a product, from its inception to its eventual disposal, encompassing aspects such as manufacturing processes, developmental endeavors, sales and distribution mechanisms, packaging considerations, recycling initiatives, and maintenance protocols. The crux of their argument lies in the assertion that a holistic evaluation of a product's environmental impact necessitates an exhaustive analysis across these six dimensions. Moreover, their research delved into the formulation of a robust green product evaluation index system, which serves as a foundational tool for assessing the eco-friendliness of various design projects. This evaluation system, meticulously crafted by Zhou et al., amalgamates 37 distinct performance indicators, each meticulously calibrated to capture nuanced aspects of environmental sustainability. By integrating this index system into the evaluative framework, stakeholders can effectively gauge the ecological footprint of their endeavors and strategize accordingly. Building upon this foundation, Taghaboni-Dutta et al. (2010) expanded upon the concept of green manufacturing, elucidating its multifaceted dimensions. Their conceptualization encompasses not only the production processes themselves but also extends to encompass usage patterns, product recovery mechanisms, packaging considerations, transportation logistics, and waste management strategies. By adopting a comprehensive outlook that encapsulates the entire value chain, Taghaboni-Dutta et al. underscore the importance of adopting a holistic approach towards green manufacturing. Furthermore, Madu et al. (2002) introduced a paradigm-shifting perspective by emphasizing the pivotal role of stakeholder engagement and designer integration in fostering environmentally conscious design practices. Their framework posits that by fostering synergy between stakeholders and designers, organizations can cultivate an ethos of environmental stewardship that permeates every facet of the design process. This integration engenders a hierarchical framework wherein environmental considerations are seamlessly interwoven into the fabric of product design, thereby facilitating the emergence of more sustainable solutions.

Additionally, Zailani et al. (2012) elucidated the concept of lean green manufacturing, advocating for the adoption of ecosystem-centric design methodologies. Central to their thesis is the notion that by embracing lean principles and incorporating environmental considerations into the very fabric of organizational strategy, firms can foster a symbiotic relationship with their ecological surroundings. By delineating internal environmental strategies and identifying key drivers within the external environment, Zailani et al. provide a roadmap for organizations seeking to navigate the complex terrain of sustainable manufacturing. Figure 2, as depicted in their work, serves as a visual taxonomy delineating the various dimensions of the green manufacturing approach. Through this illustrative representation, readers are provided with a comprehensive overview of the interconnected components comprising the green manufacturing paradigm. From production processes to logistical considerations, waste management strategies to stakeholder engagement initiatives, Figure 2 serves as a roadmap for organizations seeking to embark on the journey towards environmental sustainability.

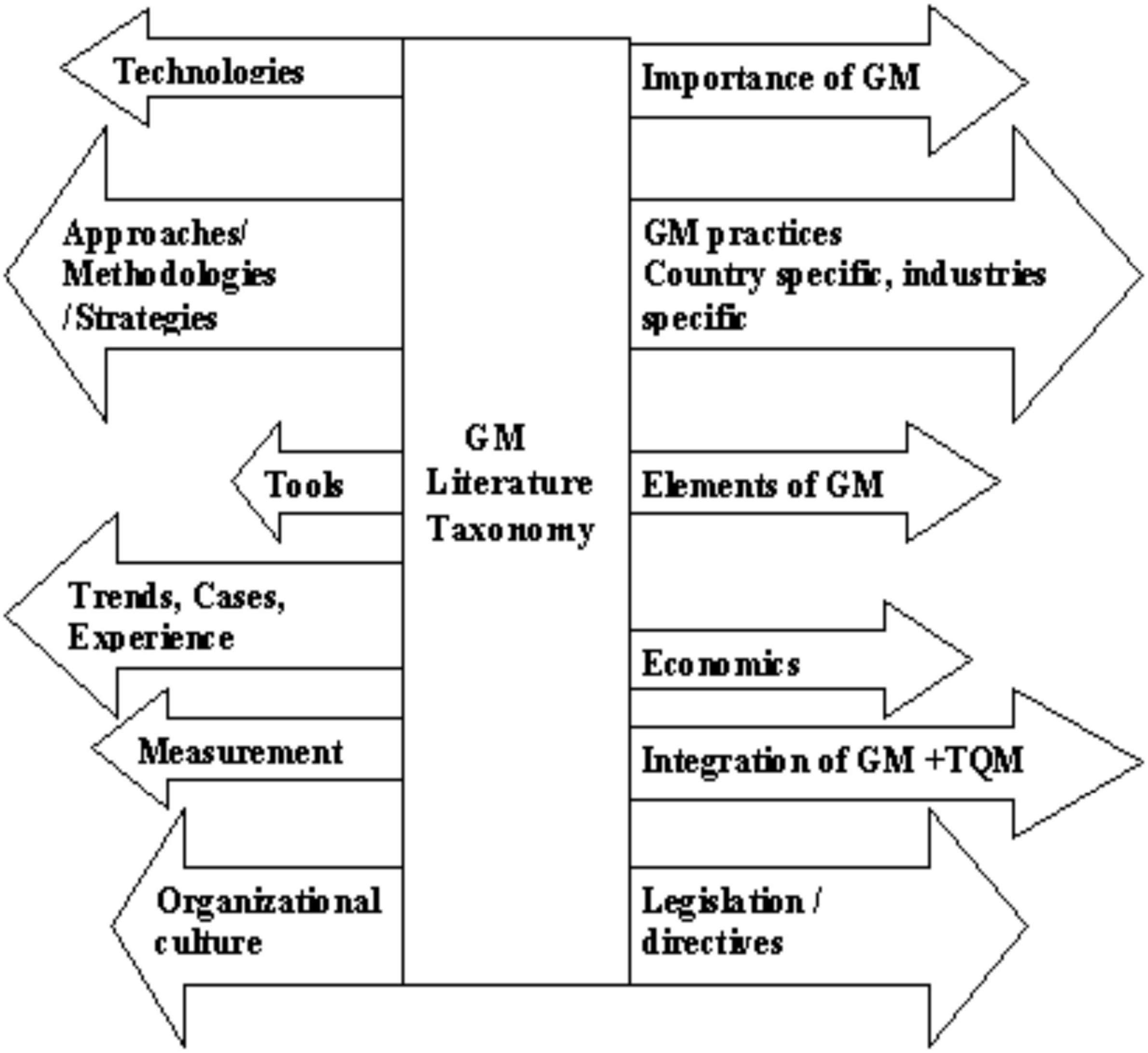

Figure 2: Taxonomy of Green Manufacturing Approach

Jovane et al. (2003) delve into the intricate dynamics of green manufacturing and sustainable development within the context of business models. Their comprehensive analysis underscores the pivotal role of environmental design, coupled with the integration of cutting-edge manufacturing technologies, in fostering sustainable business practices. By elucidating the symbiotic relationship between environmental consciousness and industrial advancement, Jovane et al. highlight the potential for synergistic growth wherein ecological concerns and economic imperatives converge. Building upon this foundation, Campos and Vazquez-Brust (2016) assert that the full realization of the lean and green concept hinges upon a profound understanding of the transformative journey required to recalibrate traditional supply chains. Central to this paradigm shift is the imperative to navigate and mitigate the myriad barriers inherent in the adoption of lean and green methodologies. Their argument underscores the need for a nuanced comprehension of the consequences and complexities involved, emphasizing the importance of fostering confidence in the face of organizational change. In a complementary vein, Rao and Holt (2005) posit the utility of environmental matrices constructed by experts as indispensable tools for monitoring and mitigating ecological footprints. Through the meticulous tracking of environmental waste across various domains including energy consumption, material utilization, waste generation, and water usage, these matrices serve as invaluable instruments for optimizing resource efficiency. By offering a systematic framework for assessing and addressing environmental impacts, Rao and Holt contribute to the arsenal of strategies aimed at promoting sustainability within industrial ecosystems.

Furthermore, Worley and Doolen (2006) shed light on the multifaceted benefits of lean and green initiatives beyond the realm of ecological conservation. Their research underscores the transformative potential of such endeavors in enhancing the work environment for organizational personnel. By streamlining operations, reducing hazardous exposures, and fostering safer workplace conditions, lean and green practices not only mitigate environmental risks but also bolster employee well-being and productivity. Worley and Doolen's findings underscore the holistic nature of sustainability initiatives, wherein ecological stewardship intertwines with socio-economic considerations to engender lasting organizational prosperity. Figure 3 serves as a visual encapsulation of the lean and green performance indicators elucidated throughout the discourse. Through graphical representation, it offers a succinct yet comprehensive overview of the key metrics and benchmarks essential for gauging the efficacy and impact of lean and green endeavors. By providing a visual roadmap for stakeholders, Figure 3 facilitates informed decision-making and strategic planning, underscoring the importance of data-driven approaches in fostering sustainable business practices.

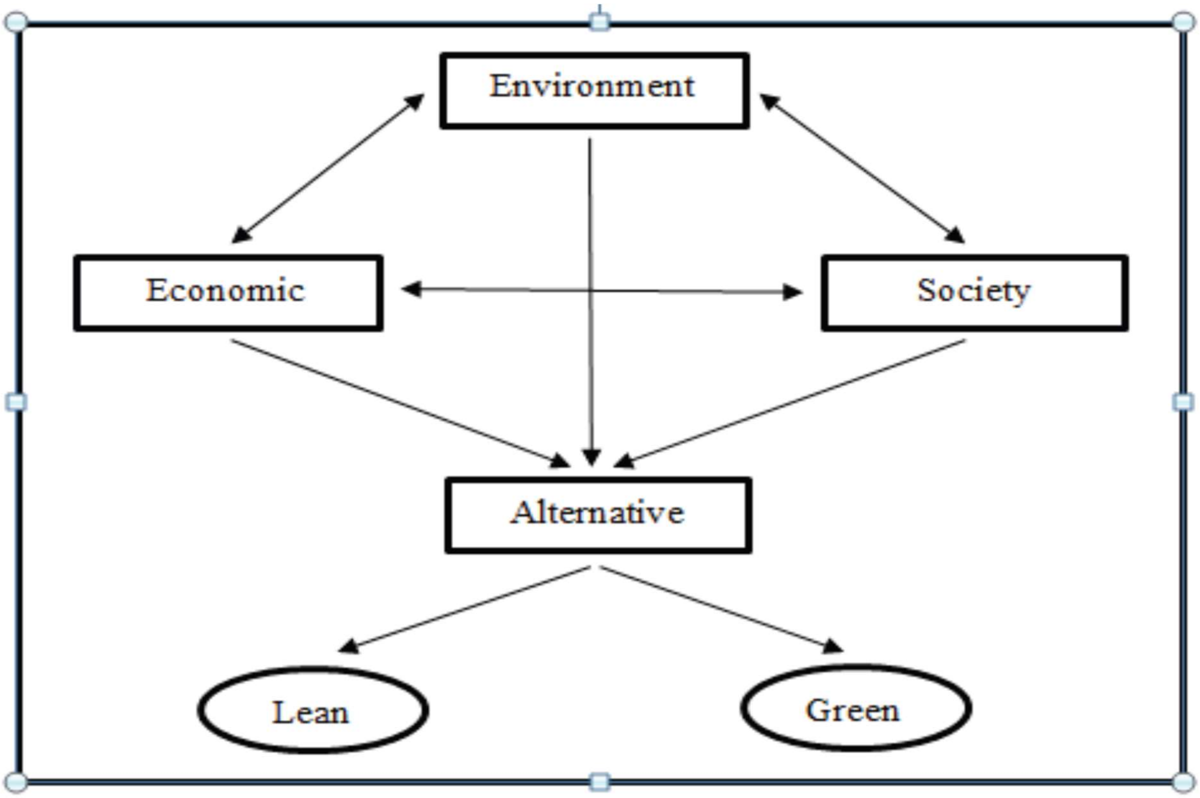

Figure 3: Lean Green Performance Indicators

Research Framework and Methodology

A comprehensive questionnaire survey was conducted, employing a convenient sampling approach due to its practicality and accessibility. The survey tapped into the extensive database compiled by the Directorate of Indian Industry and the Confederation of Industry, ensuring a robust representation of industrial sectors. Additionally, the Northern Indian Industrial Directory was leveraged to enrich the survey dataset with diverse inputs. Furthermore, a snowball sampling technique was implemented, where subsequent industries were identified through referrals from preceding ones, thereby broadening the scope and depth of the research. For a visual depiction of the methodology employed in this study, please refer to Figure 4. The questionnaire employed for this study comprises two distinct sections. The primary section encompasses crucial details pertaining to the company under investigation, the specific product line being manufactured, and the contact information of the respondents.

In the subsequent segment of the questionnaire, the evaluation of significant barriers associated with the adoption of lean green approaches is conducted utilizing a comprehensive five-point Likert scale. This scale is designed to capture the spectrum of respondents' perceptions, ranging from 1, indicating the absence of any perceived barrier, to 5, signifying an exceedingly substantial barrier. Specifically, the scale delineates responses as follows: 1) Not at all a barrier, 2) To a small extent a barrier, 3) To a moderate extent a barrier, 4) To a large extent a barrier, and 5) To an extremely large extent a barrier. The survey encompasses a diverse array of industries, with a total of 160 entities participating in the study. These industries span a wide spectrum, including those involved in the manufacturing of auto parts, multi-products, sheet metal components, billets and blooms, tractor parts, rods, bars, fasteners, and cycle parts. Such a comprehensive sampling approach ensures the representation of various sectors within the industrial landscape, thereby enhancing the robustness and generalizability of the study findings. Within these surveyed industries, respondents represent a cross-section of organizational hierarchies and functional roles. The inclusion of diverse respondent designations enriches the dataset by incorporating insights from individuals occupying varied positions within their respective organizations. Specifically, respondents encompass top-tier executives such as managing directors and partners, as well as middle management personnel including heads of departments, managers, assistant managers, and a cadre of technical professionals such as senior engineers and engineers spanning different departments.

By encompassing a wide array of industries and incorporating insights from individuals across various organizational roles, the questionnaire aims to provide a comprehensive understanding of the barriers encountered in the adoption of lean green approaches within the industrial landscape. This holistic approach ensures that the findings derived from the study are not only robust but also reflective of the multifaceted challenges faced by organizations striving to embrace sustainable and efficient operational practices.

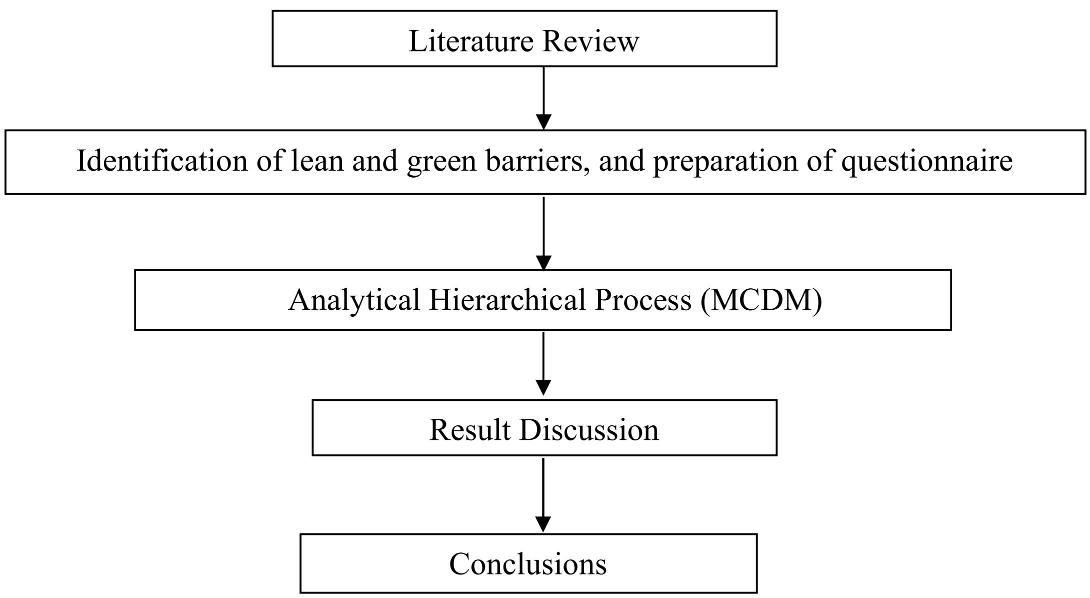

Figure 4: Research Methodology

Results and Discussion

4.1 Analytical Hierarchy Process (MCDM technique)

- Step 1:Preparation of Model for AHP application

To substantiate the significance of various lean green (LG) barriers in influencing performance interruptions, it becomes imperative to evaluate and rank these barriers while also quantifying their respective contributions. In this pursuit, Analytic Hierarchy Process (AHP) methodology emerges as a valuable tool. At the first level of hierarchy, the focus lies on elucidating the roles played by LG barriers. This involves understanding their individual impacts and how they collectively shape performance outcomes within manufacturing systems. Moving to the second level, the emphasis shifts towards delineating the practical application of these barriers within the intricate processes of current manufacturing systems. Here, the nuanced ways in which these barriers manifest and interact with operational workflows come into play, impacting the occurrence and mitigation of performance interruptions.

Finally, at the third level, the discourse expands to encompass the diverse performance outcomes engendered by the interplay of LG barriers. These outcomes span a spectrum from interrupted performance to the absence of improvement, shedding light on the multifaceted nature of performance dynamics within manufacturing contexts. Through this comprehensive hierarchical approach, AHP enables a nuanced understanding of how LG barriers influence performance, thereby informing targeted strategies for improvement and optimization.

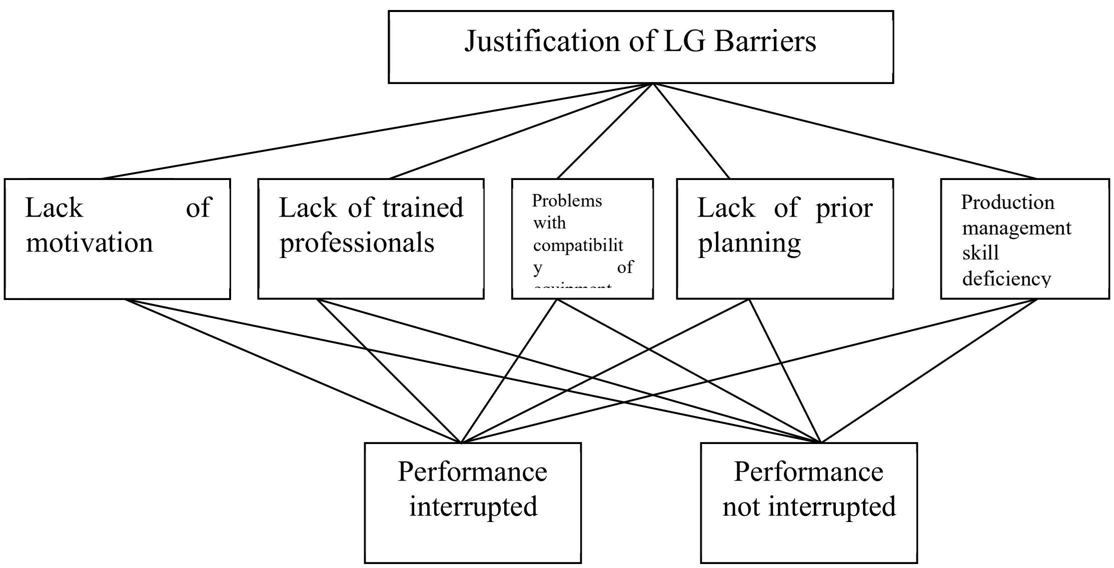

Figure 5: Model for Justification of LG practices

- Step 2: Degree of preference

The assessment of the significance of different barriers has been conducted utilizing a comprehensive 9-point scale, ranging from low to high. When the barrier on the right side exhibits a greater contribution compared to the left, its importance is retained as is. However, if the barrier on the left side is deemed more significant than the right, it is represented through the reciprocal of the scale. Each barrier has been evaluated according to respondent perceptions, employing a multi-criteria decision-making framework. Specifically, the Analytical Hierarchy Process (AHP) has been employed on a substantial sample size to validate and rank these barriers systematically. This methodological approach ensures a thorough and justified assessment of the barriers' relative importance.

- Step 3: Pair-wise comparison of different sub objectives

The importance of i^{th} sub-objective is compared with j^{th} sub-objectives is calculated. The Pair-wise comparison matrix for the sub-objectives is shown in Table 1.

Table 1: Pair Wise comparison of different sub-objectives

Barriers	**1**	**2**	**3**	**4**	**5**
Lack of motivation**(1)**	1	10.25	9	8	6.66
Lack of trained professionals**(2)**	10.25	1	4.83	3.25	7.5
Problems with compatibility of equipment**(3)**	9	4.83	1	3.91	10
Lack of prior planning**(4)**	8	3.25	3.91	1	2
Production management skill deficiency**(5)**	6.66	7.5	10	2	1
Total	34.91	26.83	16.77	18.16	27.16

Thus, the approximate priority weight (W_1, W_2, W_j) for each attribute is obtained as shown in Table 2.

$$W_j = 1/n \times \sum_{i=1}^{n} a_{ij} \quad (1)$$

Table 2: Normalized matrix of sub-objectives

	1	**2**	**3**	**4**	**5**	**Weight**
1	0.029	0.382	0.537	0.441	0.245	**0.327**
2	0.294	0.037	0.288	0.179	0.276	**0.215**
3	0.258	0.18	0.059	0.215	0.368	**0.216**
4	0.229	0.121	0.233	0.055	0.074	**0.142**
5	0.191	0.279	0.596	0.11	0.037	**0.243**

- Step 4: Consistency Check

In consistency check, Eigen values are verified

$$A \times W_i = \lambda_{max} \times W_i \qquad i = 1; 2; \ldots ; n \quad (2)$$

Where A represents the pair-wise comparison decision matrix and λ_{max} gives the highest Eigen value. Then consistency index (CI), which measures the inconsistencies of pair-wise comparisons is calculated as:

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \quad (3)$$

The last ratio that has to be calculated is CR. Generally, if CR is less than 0.1, the judgments are consistent and acceptable. The formulation of CR is:

$$CR = \frac{CI}{RI} \quad (4)$$

Where random index (RI) denotes the average RI with the value obtained by different orders of the pair-wise comparison matrices. The values of consistency test are given in Table 3.

Table 3: Consistency test

Maximum Eigen Value	C.I	R.I	C.R
9.808	0.1335	1.53	0.087

- Step 5: Priority weights for alternatives with respect to attribute

The analysis of how LG barriers affect performance interruption delves into the evaluation of various alternatives based on specific attributes. Table 4 provides a comprehensive overview of the decision-making process, illustrating the percentage contribution of these attributes towards the final determination. Through this methodical examination, the significance of LG barriers in influencing performance interruptions becomes clearer, shedding light on their role in shaping outcomes.

Table 4: Decision index table

		Justification	**Not Justification**	**Priority Weight**
1	Performance interrupted	1	3.56	0.768
	Performance not interrupted	0.324	1	0.232
2	Performance interrupted	1	3.78	0.782
	Performance not interrupted	0.295	1	0.218
3	Performance interrupted	1	2.49	0.677
	Performance not interrupted	0.56	1	0.323
4	Performance interrupted	1	2.426	0.725
	Performance not interrupted	0.35	1	0.275

5	Performance interrupted	1	1.327	0.591
	Performance not interrupted	0.637	1	0.409

The Justification index is calculated by multiplying priority weight by attribute weight and taking summation of all attributes.

Justification Index of Performance Interrupted = 1- 0.232 *0.327+ 0.218*0.215+ 0.323*0.216 + 0.275*0.142+ 0.409*0.243 = 0.6426 (5)

Conclusions and Limitations

The findings of this study underscore the pivotal role of motivation, or rather the lack thereof, as the foremost impediment hindering engagement in lean green initiatives. This observation is substantiated by a cascade of challenges, wherein deficiencies in production management skills, equipment compatibility issues, scarcity of trained professionals, and a dearth of prior planning all contribute significantly to obstructing the seamless adoption of lean green practices. Surprisingly, the significance of meticulous pre-planning in orchestrating production activities appears less pronounced in the context of implementing lean green methodologies, suggesting a potential reevaluation of traditional managerial approaches within this domain.

Furthermore, the provision of comprehensive training programs tailored to industry professionals emerges as a linchpin in steering organizations towards embracing the lean green paradigm. It is evident that an empowered and motivated workforce, equipped with the requisite skills and knowledge, serves as a catalyst for the successful integration of environmentally conscious practices into operational frameworks. Indeed, the motivational dynamics among employees, particularly their commitment to mitigating environmental and production waste, emerge as pivotal determinants in the systematic implementation of lean green strategies, underscoring the intrinsic link between human factors and organizational sustainability initiatives.

Quantitatively, the cumulative impact of these barriers on overall performance disruption is staggering, accounting for a substantial 64.26% of the variance observed. However, it is imperative to acknowledge potential methodological limitations inherent in the study design, particularly the reliance on a single respondent per company. Addressing this limitation, future research endeavors could employ robust case study methodologies to gauge the efficacy of identified barriers across diverse organizational contexts, thereby enhancing the generalizability of findings.

Moreover, the deliberate selection of a limited number of barriers warrants scrutiny, ostensibly aimed at mitigating sample fluctuations and reducing variability attributable to interdependencies among identified impediments. Nonetheless, the intricate interplay between these barriers presents an opportune avenue for further exploration, with the potential to delineate distinct categories such as autonomous, dependent, and independent barriers through the application of interpretive structural equation modeling. By elucidating the nuanced relationships between these impediments, organizations can devise more targeted interventions aimed at fortifying their resilience against impediments to lean green adoption, thereby fostering sustainable operational paradigms conducive to long-term ecological stewardship and competitive advantage.

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